

Feb. 27, 1973

H. SCHOENGOLD

3,718,779

LOUDSPEAKER DIAPHRAGM HAVING MARGINAL AIR RELEASE
PASSAGES AND CENTER HIGH FREQUENCY PROPAGATOR

Original Filed July 22, 1967

2 Sheets-Sheet 1

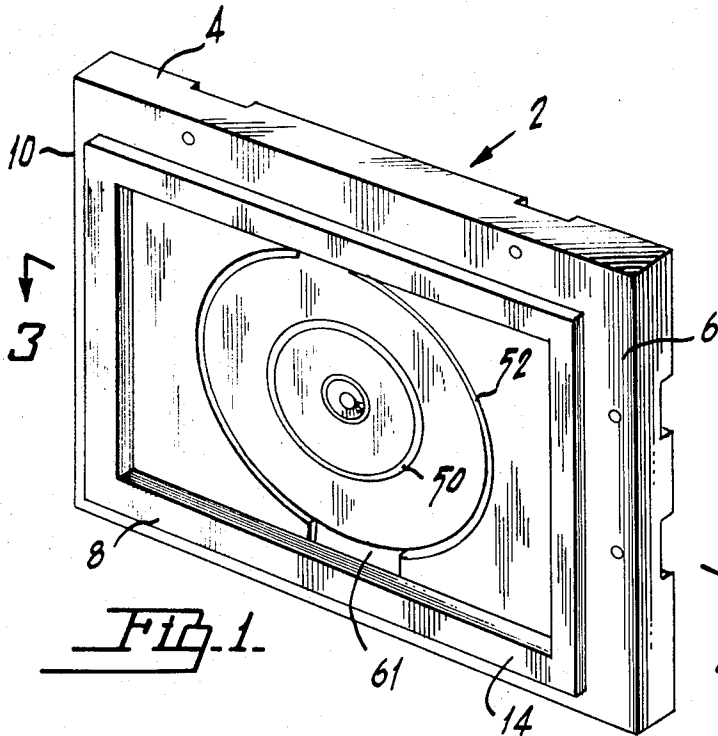


FIG. 1.

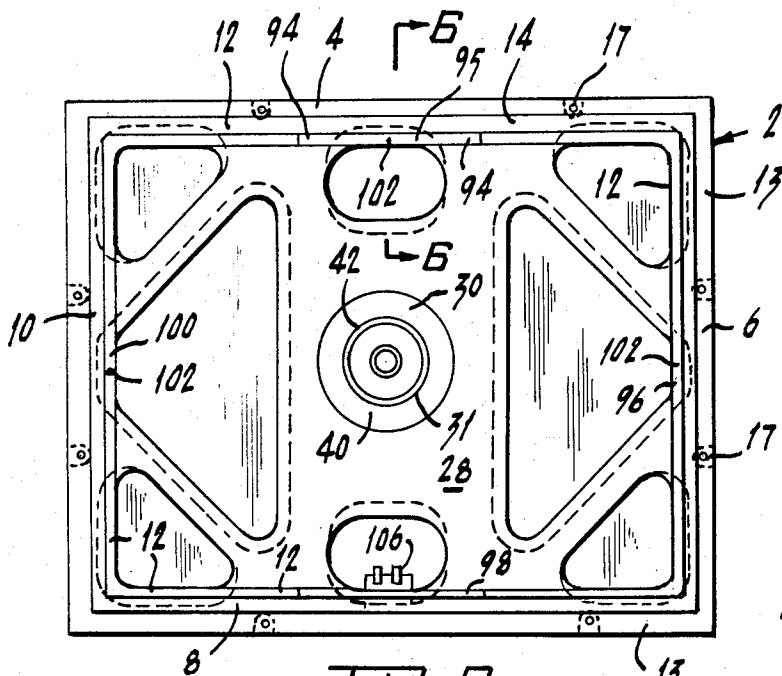


FIG. 2.

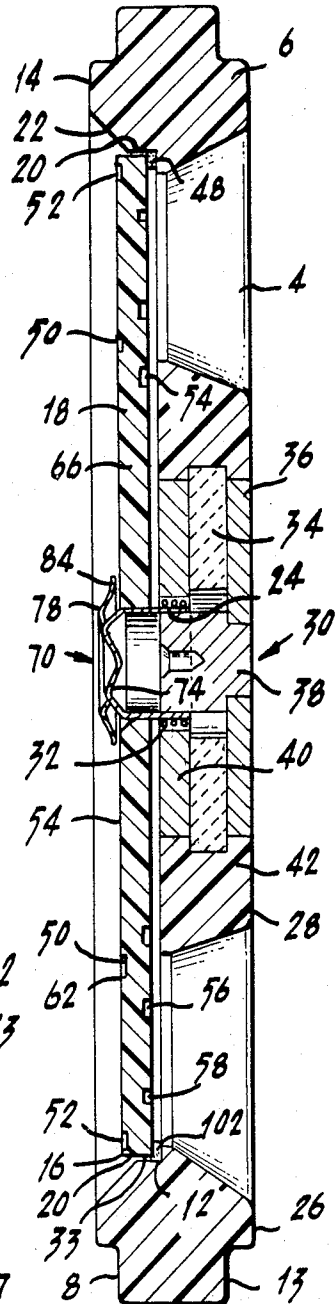


FIG. 3.

INVENTOR

HERBERT SCHOENGOLD

BY *Sperry and Zode*

Attorneys

Feb. 27, 1973

H. SCHOENGOLD

3,718,779

LOUDSPEAKER DIAPHRAGM HAVING MARGINAL AIR RELEASE

PASSAGES AND CENTER HIGH FREQUENCY PROPAGATOR

Original Filed July 22, 1967

2 Sheets-Sheet 2

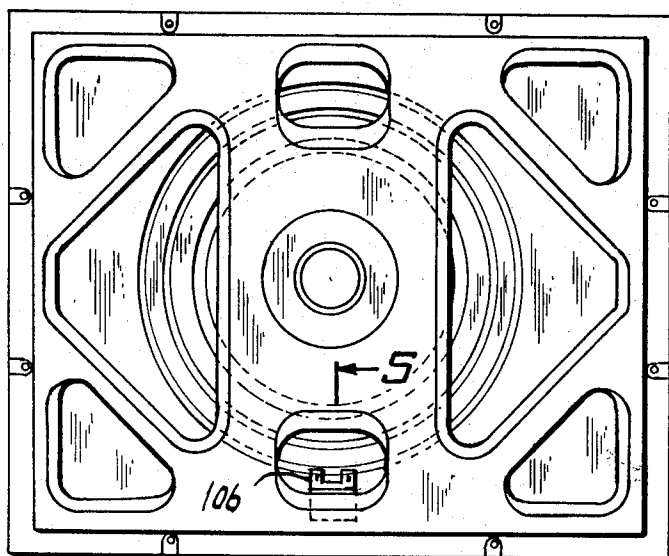


Fig. 4.

S

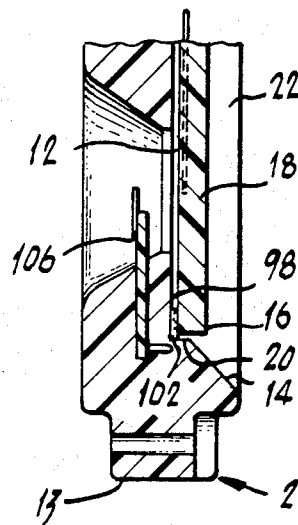


Fig. 5.

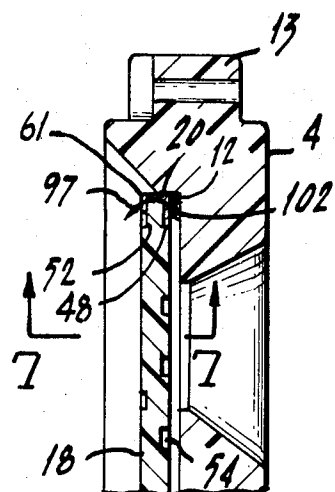


Fig. 6.

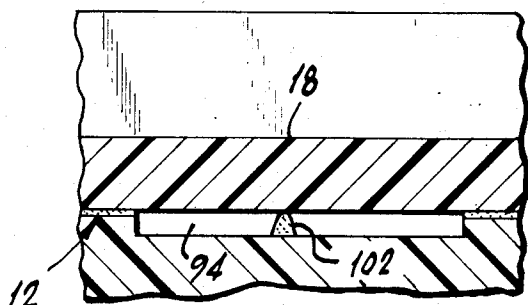


Fig. 7.

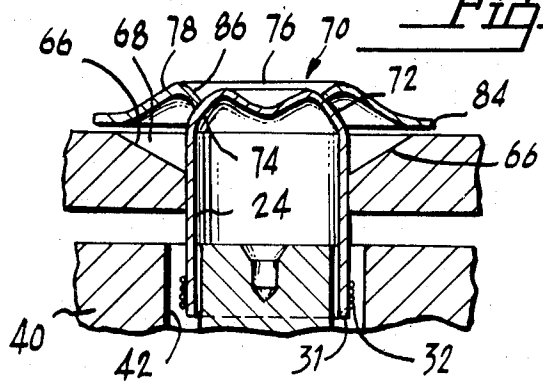


Fig. 8.

INVENTOR

HERBERT SCHOENGOLD

BY *Sperry and Zide*

Attorneys

1

3,718,779

LOUDSPEAKER DIAPHRAGM HAVING MARGINAL AIR RELEASE PASSAGES AND CENTER HIGH FREQUENCY PROPAGATOR

Herbert Schoengold, Mount Vernon, N.Y., assignor to Electronic Research Associates, Inc., Cedar Grove, N.J.

Original application July 22, 1967, Ser. No. 648,089.

Divided and this application Oct. 29, 1970, Ser.

No. 85,140

Int. Cl. H04r 1/24, 7/04, 9/06

U.S. Cl. 179—115.5 R

10 Claims

ABSTRACT OF THE DISCLOSURE

Sound reproducing equipment comprising a frame having a diaphragm supported at its peripheral edges by said frame. The diaphragm is preferably mounted on the frame in a manner to permit movement of the diaphragm as a complete entity at low frequencies. At the same time the diaphragm is provided with a high frequency propagator which cooperates with the voice coil and diaphragm to increase the range of the vibrations produced by the equipment without introducing feed-back or distortional characteristics during operation. As a result the combination serves to extend the frequency response of the equipment and increase the fidelity of the sound reproduction.

RELATED PATENT APPLICATIONS

This application is a division of applicant's copending application Ser. No. 648,089 filed July 22, 1967, now Pat. No. 3,569,638.

BACKGROUND OF INVENTION

The present invention is directed to improved loudspeakers and other sound reproducing equipment which are of thin construction and light in weight and which are capable of use under widely varying temperature and humidity conditions, and in equipment and locations presenting unusual requirements in these respects. At the same time the construction of the diaphragm and its mounting are such as to permit the faithful reproduction of sounds over a range of frequencies extending from, say 40 to 20,000 c.p.s. with a minimum of distortion.

The greatly increased use and application of loudspeaking and sound reproducing equipment, and the vast improvements in the fidelity of stereo and audio equipment has resulting in a demand for devices capable of meeting critical acoustical specifications while imposing limitations such as reduced size, weight and thickness, or unusual conditions of operation such as wide ranges in temperature and severe conditions of humidity.

While certain of these requirements can be met by the use of special and unusual compositions or constructions, the advantages produced in any one or more of these respects are generally attained at the expense of other important characteristics. Thus it has been suggested that sound reproducing equipment may be provided with a relatively thin flat diaphragm instead of the more usual cone type of loudspeaker. Typical patents calling for such constructions are Nos. 1,498,384; 1,746,289; 1,802,826; 2,047,367; and 3,236,958. Such diaphragms have in general been formed of wood or other relatively heavy materials, and while they are of particular advantage in the faithful reproduction of low frequency sounds or as "woofers," their weight and inertia, and the power required to actuate the same generally precludes their use in light-weight equipment, and instruments designed for reproducing high frequency sounds and notes in the upper range of musical tones. It is therefore necessary in such equipment to provide a separately mounted and energized

2

high frequency device or "tweeter" in order to reproduce a relatively wide range of sound frequencies.

In the alternative, it has been suggested that loudspeakers may be provided with stiff, light weight, diaphragms formed of cellular plastic materials as exemplified by U.S. Pat. Nos. 1,824,664; 2,905,260 and 3,046,362 as well as British Pat. No. 510,707. However, when such stiff, light weight diaphragms are formed in a substantially flat shape, it is found that they have a marked tendency to undergo mid- and high-frequency "break-up" due to vibration of the central and peripheral portions of the diaphragm at different frequencies or out of phase with each other, creating intermediate nodal points and zones within the diaphragm which result in sound distortions.

Furthermore, in practically all sound reproducing equipment heretofore produced there has been a marked disparity between the characteristics and acoustical properties of the diaphragm on the one hand, and those of the frame and elements by which the diaphragm and magnetic elements associated with the voice coil are mounted on the other. As a result the latter elements may set up vibrations of their own independently of the diaphragm and voice coil when the equipment is actuated. Therefore, there is a tendency for interfering vibrations to be fed back to elements of the loud speaker equipment so as to create poor frequency response, distortion, buzzing, and parasitic noises which impair the quality of the sound produced.

SUMMARY OF THE INVENTION

In accordance with the present invention these objections or limitations of prior loudspeaker assemblies are reduced or eliminated and thin, light-weight, sound reproducing equipment is provided which is capable of use under widely varying and adverse conditions of operation. At the same time the quality of the tones or sounds produced is materially improved and rendered consistent over a range of frequencies which may extend from 40 to 20,000 c.p.s. or greater.

THE DRAWINGS

FIG. 1 is a perspective view illustrating a typical form of sound reproducing assembly embodying the present invention;

FIG. 2 is a front elevation view of the frame of the equipment illustrated in FIG. 1 with the diaphragm removed therefrom;

FIG. 3 is a transverse sectional view through the equipment illustrated in FIG. 1 taken on the line 3—3 thereof;

FIG. 4 is a rear view of the assembly illustrated in FIG. 1;

FIG. 5 is a sectional view through a portion of the frame and diaphragm taken on the line 5—5 of FIG. 4;

FIG. 6 is an enlarged sectional view of a portion of the frame and diaphragm illustrated in FIG. 1, taken on the line 6—6 thereof;

FIG. 7 is a sectional view of a portion of the frame and diaphragm shown in FIG. 6 taken on the line 7—7 thereof; and

FIG. 8 is a sectional view through the voice coil form and the diaphragm having a preferred type of high frequency propagator carried thereby.

PREFERRED EMBODIMENT OF THE INVENTION

In that form of the invention chosen for purposes of illustration in the figures of the drawings, the sound reproducing equipment embodies a flat marginal frame 2, which as shown, is rectangular in shape and provided with side members 4, 6, 8 and 10. The inner edges of the side members of the frame 2 are provided with inwardly projecting diaphragm supporting ledges 12 which, as shown in FIGS. 2 and 3, lie in a common plane facing the front 14

3

of the frame, as seen in FIG. 1. The marginal portions 16 of a thin, flat, stiff and light weight diaphragm 18 are supported on the ledges 12 and surrounded by shoulders 20 which are of a height approximately equalling the thickness of the diaphragm. Inclined surfaces 22 extend outwardly from the upper edges of the shoulders 20 to the front 14 of the frame so as to present an outwardly flaring horn-like surface about the edges of the diaphragm 18.

As shown in FIGS. 3, 5 and 6 the frame 2 has an outer edge or flange 13 which may be received within a channelled or other mounting support to enable the assembly to be secured in place in a suitable mounting means (not shown) and the assembly may be concealed by cloth or fabric covers or by any other suitable or decorative material through which the sounds produced may penetrate without distortion. In the alternative the unit may be utilized as an element or panel in a ceiling, wall, furniture or elsewhere as desired.

A tubular voice coil form 24 is secured to the flat diaphragm 18 adjacent the center thereof and projects toward the opposite or rear face 26 of the frame 2 as shown in FIG. 3.

A magnet supporting rib 28 has the opposite ends thereof secured to opposite sides of the frame 2, such as the sides 4 and 8, and has a magnetic assembly 30 carried thereby and presenting an air gap 31 surrounding the voice coil form 24 and the voice coil 32 which is mounted on the form 24.

The frame and magnet supporting rib 28 may be formed of any suitable material. However, for many purposes it is preferred to utilize a frame and diaphragm formed of material which is the same or similar in its acoustical or physical properties. Thus, the frame 2, diaphragm 18 and magnet supporting rib 28 may all be formed of expanded cellular plastic material or other acoustically compatible plastic material such as a solidified foam or expanded beads of polystyrene. An alternative construction utilizing such acoustically compatible materials embodies a frame 2 and supporting rib 28 in the form of a single, integral and unitary molded assembly, which may be substantially rigid and, for example, may be produced by injection molding or otherwise and composed of unexpanded plastic material having a density ranging from about 0.8 to 10.0 pounds per cubic foot. On the other hand, the diaphragm 18 may be formed of stiff, light weight plastic material of a similar nature but having an expanded or cellular form. A typical composition adopted for use in forming the diaphragm is expanded polystyrene, preferably having a density ranging from about 0.8 to 1.8 pounds per cubic foot.

While the density of the material used in forming the frame and magnet supporting rib may be somewhat higher than that used in forming the diaphragm, and in some instances may, as indicated above, be formed of unexpanded, non-cellular or other substantially rigid material, it is most desirable to employ materials in forming the frame and magnet support which are sufficiently similar or compatible with the material used in forming the diaphragm so that the major elements of the entire assembly will have matching acoustical and physical characteristics presenting a minimum tendency to set up their own or independent and interfering vibrations or to undergo substantially different changes when subjected to widely differing conditions of temperature, humidity and the like.

The magnet supporting rib 28 is secured to the frame 2 adjacent the rear or opposite face 26 of the frame 2 and is spaced from and extends parallel to the diaphragm 18 as shown in FIG. 3. The magnetic assembly 30 is fixedly secured to the magnet supporting rib 28 and held in fixed position thereby. Further, as shown in FIG. 3, the magnetic assembly 30 is preferably molded in place within the supporting rib 28 in position to surround the voice coil 32 carried by the voice coil form 24 on diaphragm 18. The assembly 30 includes a permanent magnet 34 which may be formed of a magnetic alloy such as

4

"Alnico" or a ceramic material such as "Indox" or the like. The magnet 34 is provided with a rear plate 36 and a central pole piece 38 both of which are formed of ferro-magnetic material. A front plate or pole piece 40 is also formed of ferro-magnetic material and contacts the permanent magnet 34. A central opening 42 in the pole piece 40 surrounds the voice coil 32 on the voice coil form 24. The sides of the central opening 42 in pole piece 40 are spaced from the central pole piece 38 so as to provide the air gap 31 of limited cross section in which the voice coil 32 of the diaphragm is located, as indicated in FIG. 8.

In accordance with the present invention, the diaphragm 18, as indicated above is preferably formed of stiff, light weight, expanded polystyrene, or other cellular plastic material, and in most instances has a thickness of about $\frac{1}{16}$ to $\frac{1}{2}$ inch depending upon the size and type of the sound reproducing equipment embodying the present invention. Further, in order to permit the equipment to produce a wide range of sounds, varying in frequency from say 40 to 20,000 c.p.s., it is desirable to construct and mount the diaphragm in a novel manner which serves to reduce or eliminate the tendency to produce undesired "break-up" or nodal lines, zones or points within the diaphragm during vibration thereof.

For this purpose the diaphragm 18 is preferably provided with compliance rings, lines or corrugations which are located between the centrally located voice coil form 32 and the periphery or marginal edges 16 of the diaphragm. Furthermore, it is desirable to secure the marginal edges 16 of the diaphragm to the supporting ledges 12 of the frame 2 in a manner to enable the entire diaphragm to serve as a sound generating piston capable of reproducing tones or vibrations in the lowest audible or sub-audible range.

As illustrated in the drawings these advantages are attained by providing sufficient clearance 33 between the outer edges of the marginal portions 16 of the diaphragm and the surrounding shoulders 20 of the frame to allow the diaphragm to flex without restraint being imposed on the edges of the diaphragm by said shoulders. Moreover, the means or material employed for securing the marginal portions 16 of the diaphragm to the ledges 12 of the frame are preferably of a yieldable or flexible nature. For this purpose an adhesive such as silicone rubber or other strong but yieldable cement 48 has been found to be particularly suitable.

The compliance rings, lines or corrugations formed in the diaphragm 18 may be variously spaced and arranged. As shown in the drawings it has been found desirable in some constructions to provide compliance means in the form of concentric grooves 50 and 52 in the front or outer face of the diaphragm 18 and to provide the rear face of the diaphragm with a plurality of grooves which differ in diameter from the grooves 50 and 52 so as to be spaced radially therefrom. As shown in FIG. 3, the grooves 54 and 56 on the rear face of the diaphragm 18 are positioned adjacent and on opposite sides of the inner or smaller diameter groove 50 in the front face of the diaphragm whereas the grooves 58 and 60 in the rear face of the diaphragm are similarly located adjacent and on opposite sides of the outer or larger diameter groove 52 in the front face of the diaphragm. In practice the inner groove 50 and the associated grooves 54 and 56 on the opposite side of the diaphragm 18 are somewhat greater in width than the outer groove 52 and its companion grooves 58 and 60. The depth of the grooves 50 and 52 in the front of the diaphragm may also be slightly less than the depth of the grooves in the rear face of the diaphragm. However, these dimensional characteristics of the grooves and the diameter thereof may be varied if desired. Nevertheless, it is generally preferred to employ an inner groove 50 which is so spaced radially from the voice coil form 24 as to enclose an area equal to about 50% or more of the total area of the diaphragm 18.

5

The provision of such compliance grooves serves to allow the diaphragm to respond to, and faithfully reproduce, tones and sound which vary materially in frequency, whereby the tendency for nodal points or interfering or out-of-phase vibrations to develop in different portions of the diaphragm is materially reduced. However, there is a tendency for such a fully compliant diaphragm to lose its integrity or unitary character so as to present substantially uncoupled zones whereby low frequency vibrations may not be faithfully reproduced or may be distorted. In accordance with the present invention it is therefore desirable to insert a yieldable elastic composition, such as a silicone rubber material, into the grooves 50 and 52 in the front face of the diaphragm as indicated at 62. This material serves to impose a limited restraint between the zones of the diaphragm at opposite sides of the compliance means. If desired similar yieldable or elastic material may be inserted in the rear grooves of the diaphragm also. Such elastic or yieldable material accordingly serves as a filter or functions as a limited coupling means between the adjacent zones of the diaphragm which precludes undesirable or excessive break-up, and independent or completely isolated vibration of the zones or elements of the diaphragm. As a result more uniform and accurate response of the complete diaphragm during vibration at low frequencies is attainable. By way of illustration, it is found in practice that a loss in response may develop in the range of about 600 c.p.s. if the yieldable restraining insert 62 in the compliance grooves 50 and 52 in the front of the diaphragm is omitted, whereas more uniform response is attained by reason of the limited coupling provided in accordance with the present invention.

It has further been found that the piston action of the full diaphragm is improved, and distortion may be reduced by providing relief means or zones of freedom adjacent portions of the marginal edges 16 of the diaphragm. For this purpose, as shown in FIGS. 1, 2 and 7, the diaphragm supporting ledges 12 of the side numbers 4, 6, 8 and 10 of the frame 2 are cut away or molded so as to be of lesser height than the remainder of said ledges 12 as shown at 94 in FIG. 7 and at 94, 96, 98 and 100 in FIG. 2. Nevertheless limited points or "dabs" of less yieldable bonding material may be located at the central portions of the zones of freedom 94, 96, 98 and 100 as indicated at 102. In this way the marginal portions 16 adjacent the mid portions of the edges of the diaphragm 18 are characterized by limited but restrained freedom of movement which serves to prevent distortion or the possibility of any rubbing of the edges of the diaphragm against the adjacent shoulder 20 of the frame. In addition, these bonds serve to stabilize the positioning of the whole diaphragm with respect to the frame by minimizing the effects of cold flow of the bonding cements 48. As shown in FIGS. 6 and 7 the relief means or zones of freedom 94, 96, 98 and 100 also afford air release passages about the edges of the diaphragm as indicated at 95 in FIG. 2 and at opposite sides of the "dab" of material 102 as represented by the arrow 97 in FIG. 6. These air release passages serve to diminish the damping action of the air adjacent the edges of the diaphragm during vibration thereof so as to increase the freedom of movement and improve the piston effect of the entire diaphragm in response to low frequency vibrations.

In order further to extend the range and fidelity of sound reproducing equipment embodying the present invention the diaphragm 18 and voice coil 24 are provided with high frequency propagating means. For this purpose the voice coil form 24, which is tubular in shape, may be formed of plastic coated paper, light metal such as aluminum, or other suitable material, and is secured to the diaphragm 18 by molding, cementing or otherwise attaching it fixedly and accurately in place adjacent the center of the diaphragm. The portion of the diaphragm surrounding the voice coil form is tapered inwardly and

6

downwardly as shown at 66 so as to present an outwardly facing horn effect and at the same time allow the forward extremity 68 of the voice coil form to project in front of the adjacent portions of the diaphragm.

The high frequency propagator is indicated generally at 70 and, as shown, includes an element 72 which presents a convex marginal edge 74 which is cemented or otherwise secured to the projecting extremity 68 of the voice coil form 24. The center of the element 72 is provided with a depression 76 surrounded by the vibratory element 78. The vibratory element is in the form of a separate thin metal ring having an inwardly and downwardly inclined attaching rim 86 cemented or otherwise fixed at its inner edge to the convex surface of the element 72. The outer free marginal edge 84 of the vibratory element 78 is inclined toward the surface of the diaphragm 18 and extends over the adjacent horn-like surface 66 so as to be spaced therefrom. In this way the high frequency propagator is actuated directly and positively by the voice coil form in response to undamped vibrations induced by the voice coil and magnet assembly whereby the frequency response in the reproduction of tones of high pitch is materially improved. At the same time high frequency propagator moves with, and to some extent partakes of, the low frequency vibrations of the central portion or zone of the diaphragm. In this way the action of the high frequency propagator and the diaphragm 18 are combined and correlated without introducing distortion or setting up interference therebetween. Furthermore, the coned surface 66 of the diaphragm directly adjacent the vibrating free edge 84 of the propagator aids in directing such vibrations forwardly with the lower frequency vibrations created by the piston action of the diaphragm as a whole.

As a result, the entire spectrum of frequencies, from the lowest tones to the highest pitch sounds, are faithfully reproduced by the various elements of the combination whereas only the minimum amplitude of piston motion is required. Accordingly both electrical and mechanical distortion are substantially reduced and increased electromagnetic efficiency is attained despite the unusually wide range of frequencies and response resulting upon operation of the equipment.

While the constructions shown and described are typical of sound reproducing equipment embodying the present invention, it will be apparent that the frame and diaphragm may be circular or elliptical in shape and may be constructed in various other ways in order to adapt the invention to thin, light weight equipment having other or special applications. In view thereof it should be understood that the particular devices shown in the drawings and described above are intended to be illustrative only and are not intended to limit the scope of the invention.

I claim:

1. Sound reproducing equipment comprising a substantially flat frame presenting a ledge projecting inwardly about the sides of the frame, a substantially flat diaphragm formed of stiff, non-porous light weight material, said diaphragm having the marginal edges thereof yieldably secured at spaced points about its edges to said ledge on the frame by flexible adhesive material, said ledge being of lesser height than the remainder of said ledge in portions thereof between said spaced points so as to present air release passages about the marginal edges of the diaphragm to diminish the damping action of said air adjacent the edges of the diaphragm during vibration of the diaphragm, a voice coil form secured to said diaphragm near the central portion thereof, and having a voice coil thereon, a support for a magnetic assembly mounted in a fixed position with respect to said frame and extending parallel to said diaphragm, a magnetic assembly mounted on said support and presenting an air gap in which said voice coil is located, and electrical con-

7

ductors connected to said voice coil for actuating said diaphragm.

2. Sound reproducing equipment as defined in claim 1 wherein said frame is formed of non-cellular material and said diaphragm is formed of cellular material.

3. Sound reproducing material as defined in claim 2 wherein said frame is formed of non-cellular molded plastic material.

4. Sound reproducing material as defined in claim 1 wherein the frame is generally rectangular in shape and the portions of the frame which are of lesser height are located in the mid portion of the sides of the frame.

5. Sound reproducing equipment comprising: a substantially flat frame, presenting a ledge projecting inwardly about the sides of the frame; a substantially flat diaphragm formed of stiff, light weight material; said diaphragm having the marginal edges thereof yieldably secured, at spaced points about the edges thereof, to said ledge by flexible adhesive material; a voice coil form secured to said diaphragm near the central portion thereof, and having a voice coil disposed thereon, adjacent a first axial end thereof; a support for a magnetic assembly mounted in a fixed position with respect to said frame and extending parallel to said diaphragm; a magnetic assembly mounted on said support and presenting an air gap in which said voice coil is located, electrical conductors connected to said voice coil for actuating said diaphragm; high frequency propagating means attached to said voice coil form at a second axial end thereof; said flat diaphragm being formed to define a hornlike recess disposed immediately adjacent and surrounding said voice coil form; whereby the surfaces defining said recess and a surface of said propagating means combine to form an annular chamber disposed about the second end of said voice coil form; and said annular chamber being opened about, and tapering in axial thickness toward, the circumferential periphery thereof.

6. Sound reproducing equipment, according to claim 5, wherein: said high frequency propagating means includes a central element attached to said second axial

8

end of said voice coil form and an outer ring-like element attached to said central element; said outer ring-like element being spaced from said flat diaphragm.

7. Sound reproducing equipment, according to claim 6, wherein: said ring-like element is formed to curve away from said flat diaphragm and then to slope generally toward said flat diaphragm along the radially outward extension of said ring-like element.

8. Sound reproducing equipment, according to claim 6, wherein: said ring-like element extends radially outwardly to substantially cover said recess, with the exception of said opening extending about the circumferential periphery of said annular chamber.

9. Sound reproducing equipment, according to claim 5, wherein: said high frequency propagating means comprises a metallic substance and said flat diaphragm comprises a cellular material.

10. Sound reproducing equipment, according to claim 6, wherein: said central element is formed with a concave depression formed in a surface thereof, facing away from said flat diaphragm.

References Cited

UNITED STATES PATENTS

3,403,235	9/1968	Bishop	179—115.5 R
3,268,672	8/1966	Roesel et al.	179—115.5 R
3,213,209	10/1965	Doelitzsch	179—115.5 R
2,922,849	1/1960	Uchida	179—115.5 DV
2,014,621	9/1935	Jensen	179—115.5 R
2,852,089	7/1958	Cohen et al.	179—115.5 R
2,905,260	9/1959	Williams	179—181 R
2,974,204	3/1961	Supitilov	179—115.5 R

KATHLEEN H. CLAFFY, Primary Examiner

T. L. KUNDERT, Assistant Examiner

U.S. Cl. X.R.

179—181 R, 181 F; 181—32 R