

Oct. 23, 1962

E. MATSUOKA

3,059,720

HIGH FREQUENCY LOUDSPEAKERS

Filed July 27, 1959

5 Sheets-Sheet 1

Fig. 1.

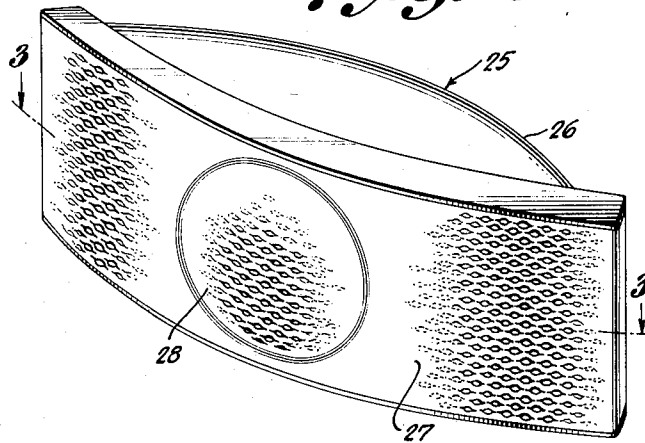


Fig. 3.

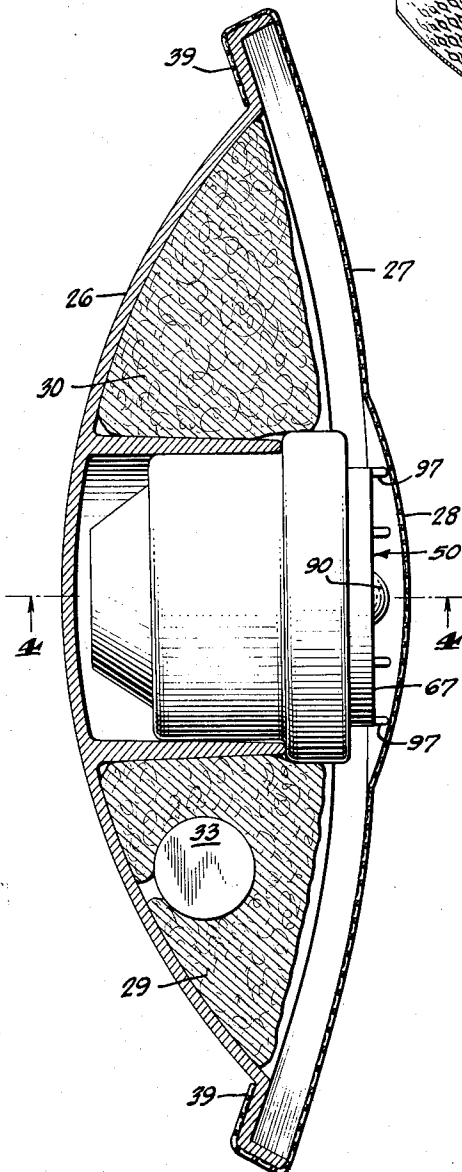
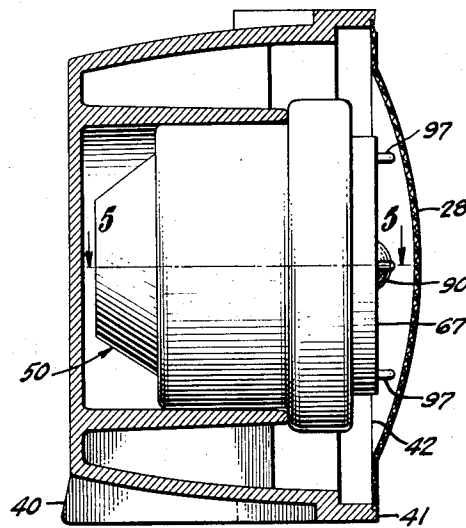


Fig. 4.



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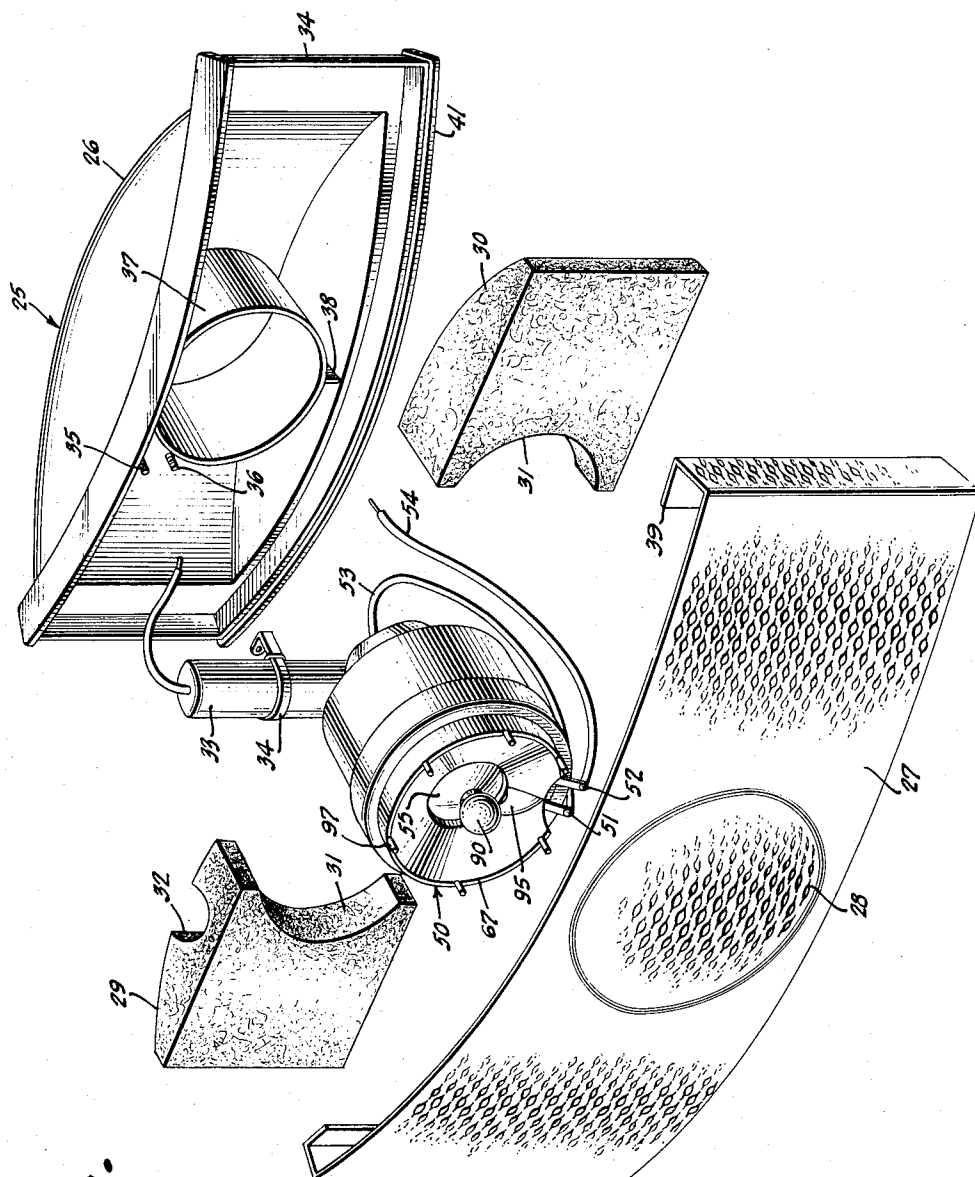


Fig. 2.

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Fig. 5.

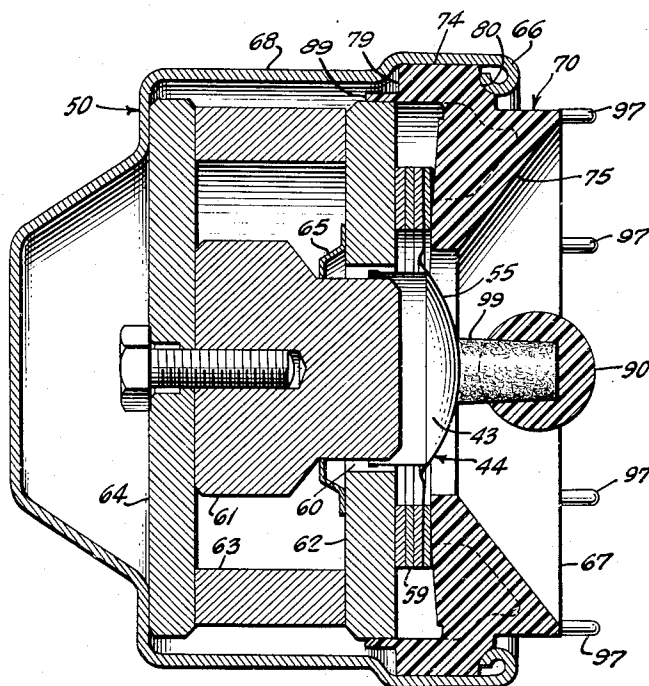
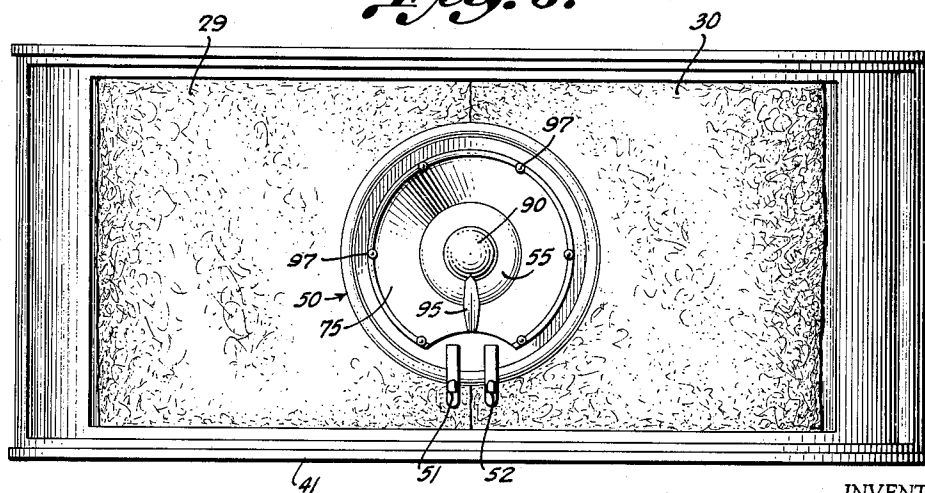


Fig. 6.



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Fig. 9.

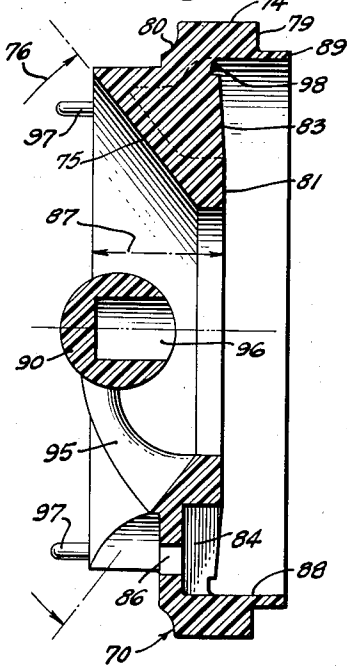


Fig. 7.

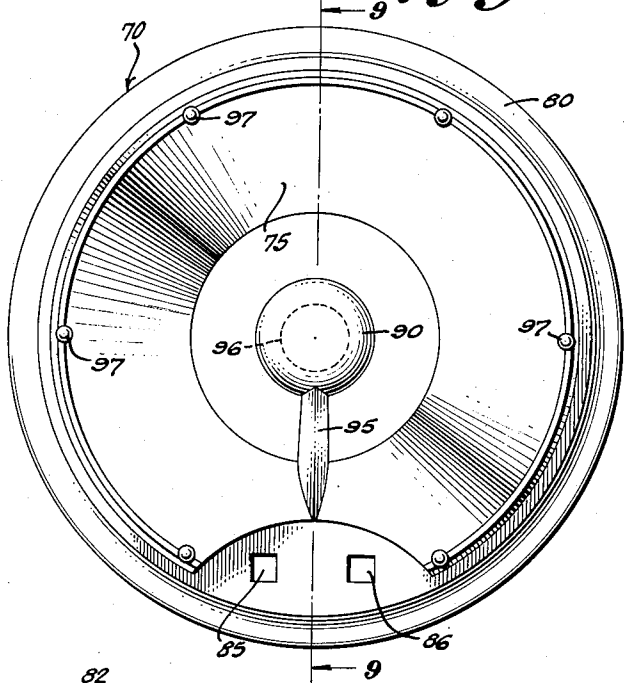
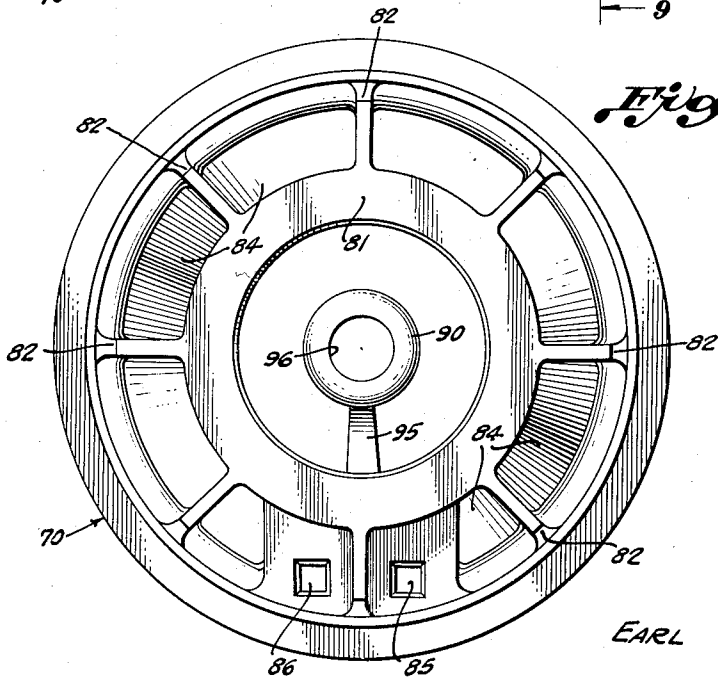


Fig. 8.



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Fig. 11.

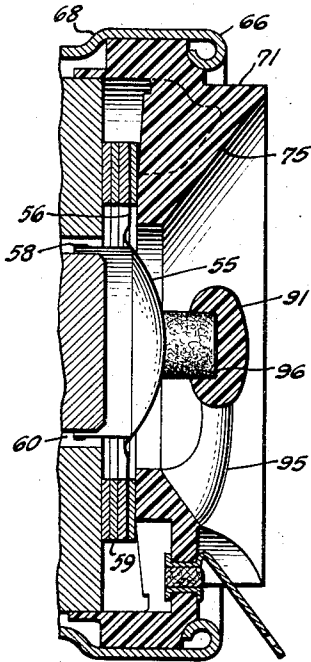


Fig. 12.

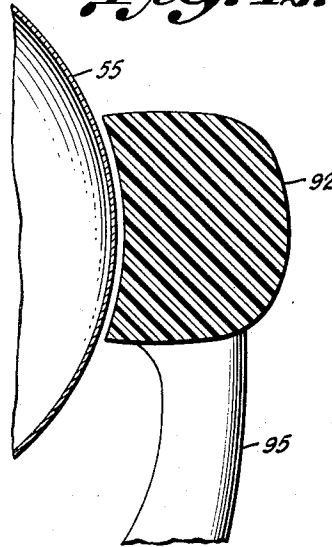


Fig. 13.

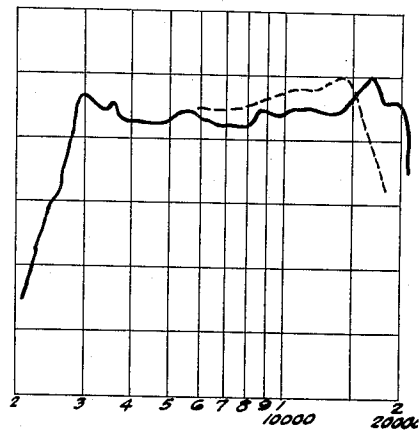
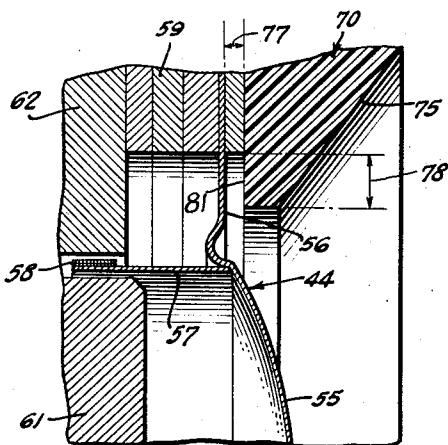


Fig. 10.



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14 Claims. (Cl. 181—31)

This invention relates to loudspeakers, and more particularly to a dynamic speaker having a relatively small diaphragm, a conoidal tapered cavity over the diaphragm, and a miniature baffle.

The primary object of the invention is the provision of an improved dynamic tweeter loudspeaker having an extremely high frequency range, such as fifteen to twenty thousand cycles per second, and wide angular dispersion.

In loudspeakers having such a frequency range constructed according to the prior art, it has been necessary to utilize special means such as ultra-thin diaphragms actuated electrostatically by the use of a high electric potential, or the like. Horn-type tweeters have been constructed which have a range to approximately 14,000 cycles, but the necessity for transmitting sound from the diaphragm through the interstices of a horn throat has so far precluded transmission to the neck of a horn of frequencies between 14,000 and 20,000 cycles without severe attenuation.

It is the object of this invention to provide a tweeter utilizing practical commercial diaphragms and a standard dynamic magnetic system, and having a mechano-acoustic coupler adapted to be economically die cast or molded in one piece complete with a diaphragm seat, a tapered cavity, and a miniature central baffle.

The term "mechano-acoustic coupler" is used to describe the central element of the speaker. This term will be found in the text-book by Beranek, "Acoustics," McGraw Hill Book Co., Inc., New York, 1954, page 75, where the author describes a "mechano-acoustic transducer."

It is another object of the invention to control the extreme high frequency range of the tweeter, for instance 10 to 20 kilocycles per second, by the shape of the central baffle and suitable mechanical damping means.

Another object is to provide means for centering the diaphragm driving coil in the magnetic air gap as an integral part of the mechano-acoustic coupler.

Another object is to provide an outer casing which will support and protect the tweeter without impairing the high frequency performance.

Other objects and features of the invention will appear when the following description is considered in connection with the annexed drawings, in which:

FIG. 1 is a perspective view of a loudspeaker constructed according to this invention;

FIG. 2 is an exploded view of the loudspeaker, showing the tweeter unit, the outer casing, the front grille, sound absorbent padding, and related parts;

FIG. 3 is an enlarged sectional view taken on the line 3—3 of FIG. 1;

FIG. 4 is a sectional view taken on the line 4—4 of FIG. 3;

FIG. 5 is an enlarged sectional view of the tweeter unit taken on the line 5—5 of FIG. 4, in which the front is turned toward the right, showing the mechano-acoustic coupler with a miniature central baffle of spherical shape, a mechanical damping pad, and other details;

FIG. 6 is a front elevational view of the loudspeaker of FIG. 1 with the front grille removed, showing the front of the tweeter and the sound absorbent padding;

FIG. 7 is an enlarged front elevational view of the mechano-acoustic coupler shown in FIG. 5;

FIG. 8 is a similarly enlarged rear elevational view

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of the mechano-acoustic coupler shown in FIGS. 5 and 7;

FIG. 9 is a sectional view, taken on line 9—9 of FIG. 7, of the mechano-acoustic coupler shown in FIGS. 5, 7, and 8, in which the front is turned toward the left, showing one embodiment of a miniature central baffle adapted to receive a damping pad;

FIG. 10 is a greatly enlarged partial sectional view of the tweeter shown in FIG. 5, showing a portion of the diaphragm and mechano-acoustic coupler;

FIG. 11 is an enlarged sectional view of an embodiment of a tweeter alternative to that of FIG. 5, having a miniature central baffle of oblate spherical shape, a mechanical damping pad, and other details;

FIG. 12 is a greatly enlarged sectional view of a portion of the diaphragm of a tweeter of the type shown in FIG. 5, showing another embodiment of miniature central baffle which fits closely to the diaphragm and is not adapted to receive a damping pad; and

FIG. 13 is a chart showing illustrative frequency characteristics of tweeters constructed according to the two principal embodiments of this invention.

Referring to FIGS. 1 to 6, the high frequency loudspeaker, generally indicated by the reference numeral 25, constructed according to this invention comprises an outer rear housing 26, a front grille 27, and a high frequency or tweeter unit 50 mounted therebetween. The rear housing is preferably a one-piece plastic molding, having thereon suitable projections, such as 40, for support and having therein suitable means such as the cylindrical portion 37 and its supporting rib 38 for supporting the tweeter unit 50. The grille 27 is fitted over the front and the ends 39 thereof folded around the end portions 34 of the housing. A lip 41 extends along the top and bottom edges of the grille. There is preferably a protrusion 28 in the middle of the grille 27 for the purpose of allowing the tweeter to be mounted well forward in the housing with the front edge 67 disposed flush with the front edge 42 of the housing and disposed forward thereof. If this is not done, it has been found experimentally that the response becomes irregular at high frequencies due to diffraction of sound around the edge 42 of the housing. It has also been found that the face of the housing, i.e., the grille around the edge 67 of the tweeter unit 50, is preferably made perforated, as by using porous material for the grille 27, otherwise the high frequency response is irregular. It has furthermore been found that the interior of the housing is preferably substantially filled with sound absorbent padding which eliminates the standing waves therein. The filling pads 29 and 30 illustrate a preferred form of such padding, and have portions 31 and 32 cut away to provide clearance for the various parts which occupy the housing. One of these may be the capacitor 33, which is mounted by the bracket 34. The tweeter terminals 35 and 36 are shown protruding through the inside of the housing in FIG. 2.

Referring to FIGS. 5 to 10, the tweeter unit, generally indicated by the reference numeral 50, is comprised of a diaphragm 44 driven by a voice coil 58, a magnetic system for establishing magnetic flux in the air gap 60, and the acoustic coupler 70. The magnetic system is comprised of the pole piece 61, the pole plate 62, the ring-shaped magnet 63, the pole plate 64, and the non-magnetic centering annulus 65. It is preferable to utilize high flux density of the order of 10,000 to 13,000 gauss, in order not only to secure high sensitivity but to establish electro-dynamic damping of transient response.

Referring particularly to FIG. 10, the diaphragm 44 has a generally curved acoustic driving portion 55 as indicated and a generally flat annular supporting flange 56. The diaphragm is connected to the voice coil by the

voice coil form 57. The voice coil 58 and form 57 have a predetermined mass, to be subsequently referred to as voice coil mass. Terminals 51 and 52 (see FIG. 2) are provided by lugs affixed in apertures 85 and 86 (see FIG. 7) of the coupler 70. The flange 56 of the diaphragm is clamped in an assembly of washers 59, the washer between the flange and the rear surface of the coupler 70 having the thickness 77, which is small and of the order of .030 inch.

The front surface 75 of the mechano-acoustic coupler 70 extends from the flange portion 56 of the diaphragm forwardly and outwardly in a generally conoidal shape, which in the drawings is shown conical. The coupler thus has a generally ring shape which is symmetrical about the central axis and which has a central aperture of predetermined diameter. In the middle of the mechano-acoustic coupler is a miniature acoustic baffle, which in the embodiment shown in FIGS. 1-9 is a sphere 90 which, in the preferred embodiment, has the rear portion 96 recessed to receive a damping pad 99. The conical shape of the front surface 75 of the coupler 70, taken in conjunction with the shape of the central baffle 90, acts to provide acoustical radiation resistance loading on the diaphragm portion 55 by constricting the solid angle into which the diaphragm radiates whereby to greatly improve the efficiency over that possible without the coupler, in a manner analogous to the action of a horn. The mechanical damping of the center of the diaphragm provides a matched mechanical impedance termination for the mechanical transmission line consisting of successive annular portions of the diaphragm, along which vibrations are propagated from the voice coil forward and inward toward the middle of the diaphragm.

Referring now to FIG. 8, it will be seen that the rear surface of the mechano-acoustic coupler 70 has a flat annular portion 81 adapted to firmly engage the flange 56 of the diaphragm. The rear surface intermediate between this annular portion and the periphery is preferably skeletonized with alternate ribs 82 and spaces 84 therebetween. The rear surface 83 (see FIG. 9) of the ribs is tapered forwardly in order to avoid pressing on the portions of the washer assembly 59 external to the diaphragm flange clamping portion. See FIG. 9.

The outer peripheral portion of the mechano-acoustic coupler 70 is preferably formed with an annular shoulder 74 having an inner cylindrical surface 88 adapted to fit closely over the outer edge of the pole plate 62 for the purpose of axially aligning the coupler with the flange 56 of the diaphragm. Optionally, this surface 88 may be machined to a close tolerance, the machining operation terminating in the undercut 98 (see FIG. 9). The flange 56 is preferably cemented to the rear face 81 of the coupler, in a suitable centering jig as well known in the art, as one step in assembling this loudspeaker. This shoulder 74 then constitutes an economical means for centering the voice coil 58 in the air gap 60. The rear edge 89 is extended axially beyond the end of the voice coil 58 so that the assembly of coupler and diaphragm parts can be rested face upwards without danger of damage to the voice coil. The annular shoulder 80 is adapted to be engaged by the rim 66 of the casing 68, which is rolled over the shoulder 80 in a final assembly operation.

In the preferred embodiment of this invention, a plurality of small projecting members 97 are provided around the periphery of the front edge 67 of the mechano-acoustic coupler for the purpose of preventing damage to the acoustic baffle 90 when the assembly is placed face down upon a flat table. Alternatively, as shown in FIG. 11, the acoustic baffle may be made retracted from the edge as shown by the oblate spheroid 91, and the acoustic performance is only slightly, if any, impaired thereby.

In another embodiment of this invention, the miniature acoustic baffle may take the general form of a hemi-

sphere 92, as indicated in FIG. 12, with the rear side thereof conformant to the shape of the middle of the diaphragm 55 and adapted to be disposed in closely spaced relationship thereto.

The miniature baffle is retained, in each embodiment of this invention, by at least one rib 95 affixed to the edge of the coupler 70. Other ribs may be utilized if desired, but the aggregate section inserted thereby into the path of sound transmitted outwards from the diaphragm should be a small percentage of the total area between the conical surface 75 and the miniature baffles 90, 91, and 92.

In a preferred embodiment the acoustic baffle 90 has a diameter between one-half and three-quarters of that of the voice coil 57.

The acoustic performance is dependent upon the masses of the voice coil 58 and the driving portion 55 of the diaphragm, the stiffness and propagation coefficients of the diaphragm 44 and the air chamber beneath the diaphragm, the angle 76 and height 87 of the conoidal portion of the coupler and the proportions of the central miniature acoustical baffle 90. The mass of the voice coil 58 is preferably half of that of the driving portion 55 of the diaphragm, which for a voice coil having a diameter of three-quarter inch is of the order of .075 gram, voice coil mass.

In one embodiment of this invention, the voice coil is three-quarters of an inch in diameter; the diaphragm driving portion 55 has substantially uniform thickness between .002 and .003 inch with the middle no thicker than the edge; and the flange portion 56 is approximately .001 inch thicker than the driving portion 55. The preferred material is phenolic-impregnated fabric. In the preferred embodiment of this invention, the driving portion is convex, which is intrinsically best suited to radiating sound over a complete hemisphere.

As a preferred embodiment of this invention, the mean included angle 76 of the conical frustum portion is between 80 and 120 degrees.

It is essential to provide an acoustic chamber 43 behind the diaphragm. In general the proportions of this are preferably as indicated in FIG. 5, in which the chamber is bounded on the rear by the pole piece 61 and on the front by the diaphragm portion 55.

There is preferably a minute overhang of the inner edge of the acoustic coupler 70 over the diaphragm flange having the dimension 78. See FIG. 10. As this dimension is increased from zero to the width of the flange, the acoustic resistance loading on the diaphragm is increased, resulting in increased efficiency in the 3000 to 16,000 cycles per second frequency band, whereas the frequency range may be reduced from 23,000 to 16,000 cycles by this increase in the overhang 69.

Illustrative frequency characteristics taken with tweeters utilizing the various embodiments of this invention are shown in FIG. 13. All curves were taken with a capacitor having 4 microfarads in series with the tweeter unit, the impedance of the unit being of the order of ten ohms, whereby the series combination is adapted to be connected in parallel to a standard low- and mid-range loudspeaker having an impedance of approximately 10 ohms, without any other electrical networks for dividing the frequency ranges or the like.

The solid line is an untouched reproduction of a laboratory curve taken with a substantially flat microphone, on the tweeter unit utilizing a substantially spherical central baffle as shown in FIGS. 5 to 10, and without the outer housing of FIGS. 1-4. It may be seen that the response is substantially flat from 3000 to above 20,000 cycles per second. The structure of FIG. 11 has substantially similar characteristics. This is obviously greater than the frequency range of any previous electro-dynamic tweeter and extends well beyond the limits of audibility. It is more linear and free from background noise than corona-type tweeters and has, in contrast to such speak-

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ers, an indefinitely long life. It is smaller and more rugged than electrostatic speakers and has none of the disadvantages of that type.

The dashed line of FIG. 13 shows the relative response using the alternative form of miniature baffle shown in FIG. 12. It may be seen that the output is somewhat greater up to 15,000 cycles than is characteristic of the spherical baffle as shown in the solid curve, but a cutoff occurs there. This is an advantage in applications where the signal-to-noise ratio in a given audio channel drops sharply at this frequency, although where the channel is not subject to such a limitation the solid curve is preferable.

The response as shown in the solid curve is 2 to 5 db more sensitive, the greater increase occurring at extreme high frequencies, than that for the hypothetical case wherein the angle 76 of the front of the coupler is increased to the order of magnitude of 180 degrees and wherein the miniature baffle is indefinitely reduced in size. Furthermore, the solid curve is much smoother than that in the hypothetical case, which is partially attributable to the use of the damping pad 99. When the latter is omitted, the response is generally more ragged, especially between 15,000 and 20,000 cycles.

The frequency response of the tweeter assembled in the housing, as shown in FIGS. 1 to 4, is at least as flat as that shown in the solid curve of FIG. 13, the slight rise at the extreme high frequency end being compensated by the action of the grille. The polar characteristics of the resultant tweeter may be described as being substantially uniform over a solid angle of 180 degrees up to 10,000 cycles, above which frequency the response is somewhat more restricted. At 15,000 cycles, for instance, the response is 8 db reduced at an angle of 30 degrees from the central axis.

The invention has been described as embodied in a loudspeaker, though it is to be understood that the same construction is usable as a sound pickup device.

The drawings and description are to be taken generally as illustrative rather than restrictive on the broad invention. Various changes may be made in manufacture, such as different locations of the casting parting surfaces, and the like.

In the claims the term transducer is used to indicate a sound-translating device, usable either as loudspeaker or microphone.

It will be obvious to those skilled in the art that various changes may be made in the invention without departing from the spirit and scope thereof, and therefore the invention is not limited by that which is shown in the drawing and described in the specification, but only as indicated in the appended claims.

I claim:

1. In a transducer of the type described, a tweeter unit comprising: a diaphragm with a domed-shaped acoustic driving portion, symmetrical about a central axis, said diaphragm having an annular rim; and a voice coil concentric therewith having a preselected diameter; a magnetic system having a concentric air gap for surrounding the voice coil; a mechano-acoustic coupler having a generally ring shape symmetrical about said central axis, the front thereof having a generally conoidal frustum shape with a predetermined included angle, said front disposed concentrically with the axis of the diaphragm, and having a central opening therein, a generally planar rear surface juxtaposed to the annular rim of the diaphragm and acoustically sealed thereto; said dome-shaped driving portion being convex with respect to said coupler and extending into said opening, an exterior annular peripherally disposed shoulder on said coupler concentric with said conoidal portion; miniature baffle means adjacent to the center of the convex dome portion of said diaphragm in spaced relationship thereto and having a diameter smaller than that of the voice coil; means for supporting said baffle means on said coupler comprising at least one

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rib; and a casing surrounding the magnetic system and diaphragm and affixed to said annular shoulder.

2. In a transducer as described in claim 1, characterized by the front surface of said conoidal frustum portion having a mean included angle between 80 and 120 degrees.

3. In a transducer as described in claim 1, means for damping resonant vibrations of the center of the diaphragm comprising a damping pad interposed between the front of the diaphragm and the rear of the miniature baffle means.

4. A tweeter unit and cabinet combination comprising a tweeter unit as described in claim 1, a rectangular cabinet having an open face covered by an open-mesh grille, an outwardly domed portion in the middle of the grille, means for supporting the tweeter unit juxtaposed to the inner side of said domed portion and sound absorbent padding substantially filling the cabinet around the tweeter.

5. In a tweeter unit as described in claim 1, said diaphragm having a thickness at the center substantially equal to and no greater than that at the edge thereof.

6. In a tweeter unit as described in claim 1, wherein compliant air cushioning means are coupled to the rear of said diaphragm comprising a chamber bounded in part by the rear surface thereof and having a mean thickness of at least one-quarter of the diameter of the voice coil.

7. A mechano-acoustic coupler having a generally ring shape portion symmetrical about a central axis and having a central aperture of predetermined diameter, a front surface having the shape of the frustum of a conoid and a rear surface having a centrally disposed flat annular portion; baffle means disposed in centrally spaced relationship to the front surface of the coupler having a mean diameter smaller than that of the central aperture and lying within the confines of said front surface, at least one rib connecting the baffle means with the ring shape portion, the ring shape portion and the baffle means forming an acoustic coupler for a flanged diaphragm affixed by its flange to the rear flat annular portion; the rear surface of the ring shape portion having a peripheral rearwardly-extending flange with an interior cylindrical surface concentric with the central axis for aligning the coupler with a magnetic system.

8. A mechano-acoustic coupler having a generally ring shape portion symmetrical about a central axis and having a central aperture of predetermined diameter, a front surface having the shape of the frustum of a conoid and a rear surface having a centrally disposed flat annular portion; baffle means disposed in centrally spaced relationship to the front surface of the coupler having a mean diameter smaller than that of the central aperture and lying within the confines of said front surface, at least one rib connecting the centrally disposed member with the ring shape portion, the ring shape portion and the central member forming an acoustic coupler for a flanged diaphragm affixed by its flange to the rear flat annular portion, the rear surface of the ring shape portion having a peripheral rearwardly-extending flange with an interior cylindrical surface concentric with the central axis for aligning the coupler with a magnetic system, and a peripherally disposed annular shoulder on the front surface of the ring shape portion concentric with the central axis for mating with the rim of a casing.

9. A mechano-acoustic coupler as described in claim 8 consisting of one integral die-formed piece.

10. A mechano-acoustic coupler having a generally ring shape portion symmetrical about a central axis and having a central aperture of predetermined diameter, a front surface having the shape of the frustum of a conoid and a rear surface having a centrally disposed flat annular portion; a spheroidal baffle member disposed in centrally spaced relationship to the front surface of the coupler having a mean diameter in the plane perpen-

dicular to the central axis smaller than that of the central aperture and lying within the confines of said front surface, the spheroidal member having at least one rib connecting the spheroidal member with the ring shape portion, the ring shape portion and the central member forming an acoustic coupler for a flanged diaphragm affixed by its flange to the rear flat annular portion.

11. In a transducer of the type described, a tweeter unit comprising: a diaphragm with a generally curved acoustic driving portion, symmetrical about a central axis, said diaphragm having a front and rear surface and having a thickness at the center substantially equal to and no greater than that at the edge thereof; a generally flat, annular rim; and a voice coil concentric therewith having a preselected diameter; a magnetic system having a concentric air gap for surrounding the voice coil, the central pole having a flat front surface; compliant air cushioning means coupled to the rear of said diaphragm comprising a chamber bounded by the rear surface thereof and by the flat surface of the magnetic pole; a mechano-acoustic coupler having a generally ring shape symmetrical about said central axis, the front thereof having a generally conoidal frustum shape with a predetermined included angle, said front disposed concentrically with the axis of the diaphragm, a generally planar rear surface juxtaposed to the annular rim of the diaphragm and acoustically sealed thereto: an exterior annular peripherally disposed shoulder on said coupler arranged concentric with said conoidal portion; miniature baffle means in juxtaposition to the center of the diaphragm in spaced relationship thereto and having a diameter less than that of the voice coil; means for supporting said baffle means on said coupler comprising at least one rib; and a casing surrounding the magnetic system and diaphragm and affixed to said annular shoulder.

12. In a transducer of the type described, a tweeter unit comprising: a diaphragm with a generally curved convex acoustic driving portion, symmetrical about a central axis, said diaphragm having a flange with a peripheral flat annular rim; a voice coil concentric therewith having a preselected diameter; a magnetic system having a concentric air gap for surrounding the voice coil; a mechano-acoustic coupler having a generally ring shape symmetrical about said central axis, the front surface thereof having a generally conoidal frustum shape with a predetermined included angle and disposed concentrically with the axis of the diaphragm, the rear surface thereof having a first flat annular shoulder for sealing to the flat annular rim of the diaphragm and a second generally flat annular shoulder offset forwardly from the first and overhanging the flange of the diaphragm; and miniature baffle means adjacent to the center of the convex portion of the diaphragm in spaced relationship thereto and having a diameter smaller than that of the voice coil.

13. A tweeter comprised of a generally ring-shaped

member having a central axis, the inner surface having the shape of an inverted conoidal frustum that has an included angle of between 80 and 120 degrees and symmetrical about said central axis, an end on the ring-shaped member, said end having a planar annular surface perpendicular to the said central axis, a diaphragm having a convex domed portion and a generally flat flange portion, means for affixing part of said flange portion to the planar annular surface, the diaphragm dome portion having a thickness at the middle no greater than that at the edge of the dome, a voice coil suspended from the edge of the dome on the concave side thereof, and a baffle-like member suspended in the middle of said ring-shaped member having a diameter between one-half and three quarters that of the diameter of said voice coil and disposed in closely spaced relationship to the convex side of the dome, whereby the combination of the conoidal frustum and the baffle-like member comprise a horn-like mechano-acoustic coupler having a miniature acoustic baffle in the middle thereof, whereby to provide acoustical radiation at extreme high frequencies over a wide angle.

14. A tweeter and cabinet assembly comprising, in combination a tweeter characterized by mechano-acoustic coupling means comprised of a generally ring-shaped member having a central axis, the inner surface having the shape of an inverted conoidal frustum having an included angle between 80 and 120 degrees and symmetrical about the central axis, a diaphragm having a convex domed portion and a generally flat flange portion, means for supporting said flange portion adjacent a planar annular surface on said ring-shaped member, the diaphragm dome portion having a thickness at the middle no greater than that at the edge of the dome, a voice suspended from the edge of the dome, and a baffle-like member suspended in the middle of the ring-shaped member having a diameter between one-half and three-quarters that of the domed portion and disposed in closely spaced relationship thereto, whereby to provide acoustical radiation at extreme high frequencies over a wide angle; a cabinet having a perforated front wall and solid rear wall and a top having a frontal edge; said tweeter being affixed to said cabinet with the front surface of said tweeter disposed substantially in a plane perpendicular to the central axis of the tweeter and intersecting the frontal edge of the top wall; and sound absorbent padding mounted in the cabinet around the tweeter.

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