

Sept. 1, 1964

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3,146,848

HI-FIDELITY SPEAKER

Filed Aug. 25, 1958

2 Sheets-Sheet 1

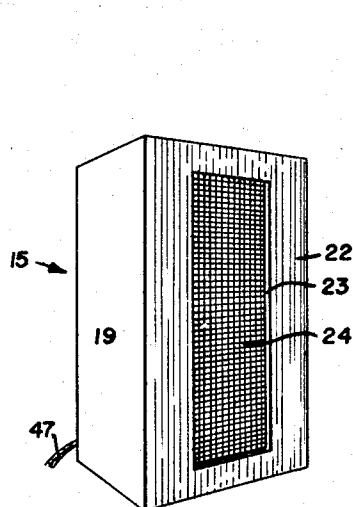


Fig. 1

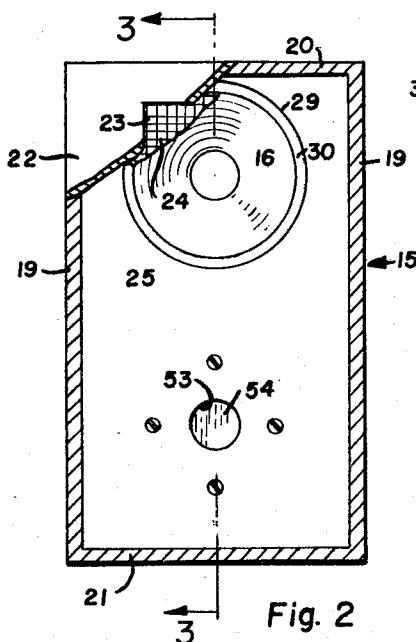


Fig. 2

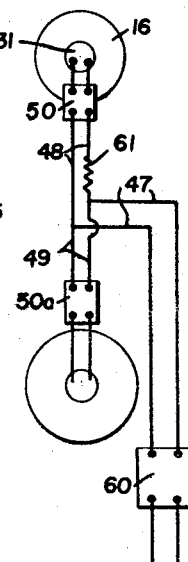


Fig. 5

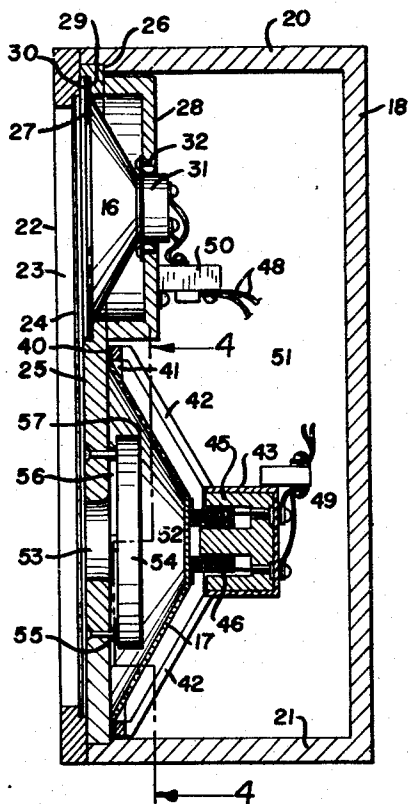


Fig. 3

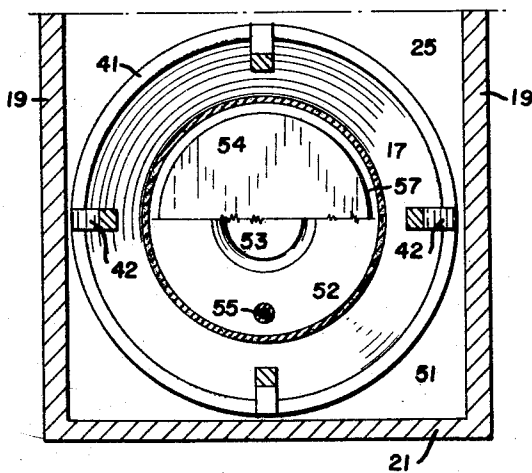


Fig. 4

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Fig. 6

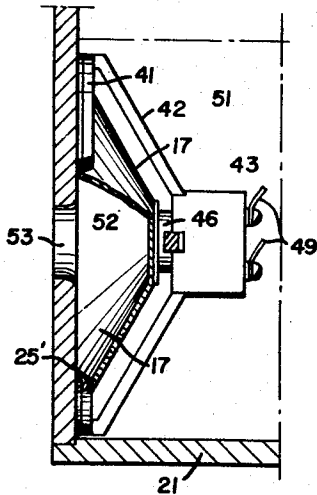


Fig. 7

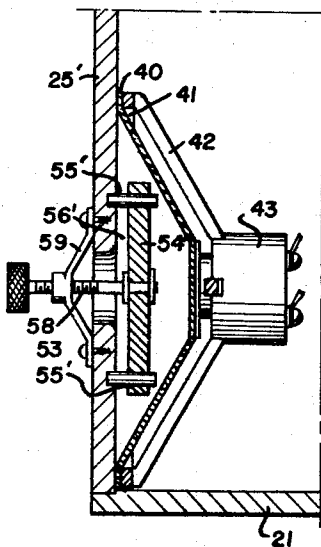
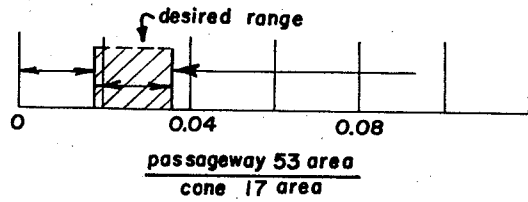


Fig. 8

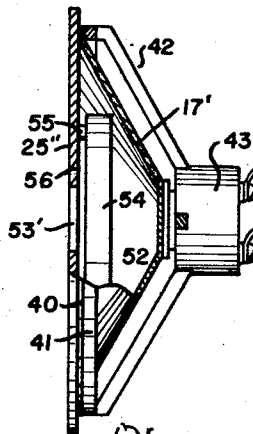


Fig. 9

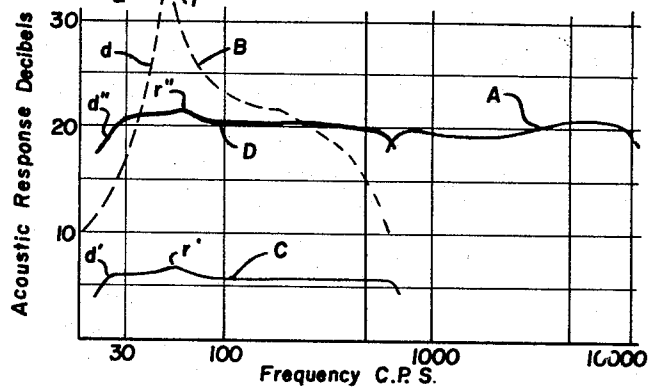


Fig. 10

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HI-FIDELITY SPEAKER

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1 Claim. (Cl. 181-31)

This invention relates to sound reproducing apparatus and more particularly to that class of sound reproducing apparatus having a plurality of speakers and acoustical enclosures therefor, for reproduction of sound over a wide range of audio frequencies.

In the art of sound reproduction, the desired end is to have an output of sound which faithfully reproduces the input. The sound input, from whatever source, is converted into electrical energy, suitably amplified and converted back into sound by the reproducing apparatus. The electrical energy to the reproducing apparatus is substantially a true reproduction of the input and the primary problem of high fidelity sound reproduction lies in obtaining a proper design and construction of the reproducing apparatus. This is especially so in the field of music where sounds occur at all frequencies throughout the audio range, from 25 to 16,000 cycles per second.

None of the commonly used speakers of the moving-cone-coil type can operate over such a frequency range and produce a substantially constant acoustic response for a given power input at all frequencies. The best that can be obtained is for a cone to operate in a definite frequency range where the response is reasonably constant and at each limit of this range the acoustic response will drop sharply. In many cone speakers prominent peaks in the response will occur, especially at the bass resonant frequency, which are to be avoided if good fidelity is to be obtained.

A conventional high fidelity speaker system will therefore include two or more speaker cones of different size to reproduce tone at all frequencies. The larger bass speaker, the "woofer" will be adapted for the low frequency range, and the smaller speaker, or speakers, the "tweeter," will be adapted for the high frequency range. When properly designed, the acoustic response of one speaker will blend with that of the other speaker in such a manner as to provide for a substantially constant, or flat, response throughout the complete range of sound vibrations, the "woofer" operating at the low frequencies and the "tweeters" operating at the high frequencies.

These speakers are conventionally connected to the energy transmitting source in parallel with by-pass filters in each speaker circuit to obtain the selected frequency ranges at the individual speakers at which they best respond.

There are several difficult problems involved in the design of a good speaker system and especially in the design of the bass cone and a satisfactory cabinet for it. A typical speaker cone has poor acoustic response at frequencies less than the bass resonant frequency, a peak response at the resonant frequency, a gradually decreasing response as the frequency increases and a sharp loss of response at its high frequency limit. It is desirable to level off the resonant peak response and keep the response as constant or as level as possible to a point where the high frequency limit occurs.

Because a speaker does not operate satisfactorily at frequencies less than the bass resonant frequency it is important to build a bass cone with as low a natural frequency as possible. The bass speaker cone must also be baffled and/or mounted in a cabinet or compartment to separate the air bodies at the front and the back of the cone, since, at the low frequency range such air bodies transmit sound waves which are out of phase with each

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other, with a resulting dip in response. Moreover, it is necessary to have cabinets and baffles having a low natural frequency in order to avoid harmonic distortion at the lower frequencies of the speakers. The prior art includes cabinets, horns, and the like which are extremely large relative to the size of the speakers employed. The prior art also includes smaller cabinets relative to the size of the speakers which obtain a low resonant frequency by use of a structure akin to a Helmholtz resonator.

While the conventional cabinets are formed in many different ways and use circuitous paths, baffles, slotted apertures, and the like, in every instance the designs are based upon not only the desire to eliminate distortion but also the desire to obtain an acoustic response having a substantially level characteristic, for a given power input and a response which will blend well with that of the high pitch cones.

Another problem commonly occurring in the design of a bass cone and cabinet therefor relates to the power input that can ordinarily be used. When the cone vibrates at low frequency, an increase of power to reproduce a louder tone increases the amplitude of vibration and there will be generated harmonics, doubling and tripling of the fundamental frequency and excessive power will cause the cone to rupture. Further problems concern the cabinet itself is that the enclosure will cause a resonance of its own.

With the foregoing and other considerations in view, the present invention was conceived and developed by approaching the problem of designing a complete speaker system which includes an enclosure having one or more cones for bass and high pitch reproduction and means for placing the low pitch speaker in a resistive environment. The arrangement as hereinafter described in detail provides for a level undistorted acoustic response through a wide frequency range, including bass tones at a lower pitch than heretofore considered possible to attain by any but the largest speakers.

It follows that the objects of the invention are to provide a novel and improved speaker system which may be contained within a small, compact cabinet; does not require special sound absorbent surfaces within the cabinet to eliminate spontaneously induced or stray tones; is adapted to reproduce sound over a wide range of audio frequencies at a substantially constant level of acoustic response, including frequencies as low as 25 cycles per second; eliminates sound distortion caused by overtones, harmonics, and similar resonating tones formed on the bass cone; lowers rather than raises the natural base resonant frequency of the cone which is installed in a cabinet and flattens out and practically eliminates the peak response ordinarily occurring at the bass resonant frequency; does not require special expedients and devices such as the inertia loading of a speaker cone and permits the use of a speaker cone having a good transient response and good damping characteristics; and is a simple, low-cost, reliable, rugged, and durable unit.

With these and other objects in view, all of which more fully hereinafter appear, my invention comprises certain novel and improved constructions, combinations, and arrangements of parts and elements, as hereinafter described in detail, and defined in the appended claim, and illustrated in a preferred embodiment in the accompanying drawing in which:

FIGURE 1 is a perspective view of a cabinet which may be used to form the improved speaker.

FIGURE 2 is a front elevation view of the cabinet shown at FIG. 1, but on an enlarged scale and with the front panel being removed to show portions otherwise hidden from view.

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FIGURE 3 is a sectional view as taken from the indicated line 3—3 at FIG. 2, but on a further enlarged scale.

FIGURE 4 is a fragmentary sectional elevation view as taken from the indicated line 4—4 at FIG. 3 with portions of the elements being broken away to show parts otherwise hidden from view.

FIGURE 5 is a diagram of an electrical circuit interconnecting the cones with the power input source.

FIGURE 6 is a fragmentary elevational view of a portion of the structure illustrated at FIG. 3, but illustrating further a modified form of a part of the invention in its simplest aspect to set forth the basic principles of the invention.

FIGURE 7 is a linear diagram depicting certain selected relationships which illustrate a principle of the invention.

FIGURE 8 is a fragmentary sectional elevation similar to FIG. 6, but illustrating another modified form of a part of the invention.

FIGURE 9 is a side elevation view of a speaker cone constructed in accordance with a principle of the invention for installation in a conventional speaker cabinet where it is desired to modify the cabinet in accordance with the invention.

FIGURE 10 is a diagram showing the relations of the frequency response for the different cone systems forming the improved combination and further setting forth the results attainable by application of the principles of the invention.

Referring more particularly to the drawing, my improved speaker system includes a box-like cabinet 15 which houses the combination of a high pitch speaker cone 16 and a bass speaker cone 17 which are necessary to reproduce sound throughout a wide range. The bass cone reproduces the low frequencies from about 30 cycles per second to approximately 750 cycles per second and the high pitch cone reproduces the higher frequencies, up to 15,000 cycles per second or higher, to the audio limit.

The cabinet 15 is a closed type and includes a back wall 18, side walls 19, top 20, bottom 21, and front wall 22. The shape and size of this cabinet is determined primarily by the size of the two speaker cones 16 and 17 which are preferably of standard size, such as a six-inch diameter high pitch cone 16 and a twelve-inch diameter bass cone 17. The cones may be arranged one above the other to give the cabinet a simple box-like form, as illustrated.

Using the cone sizes specified, the cabinet size may be approximately 14 inches wide by 22½ inches tall and approximately 9¾ inches in depth. Using reasonably thick material to provide a rugged construction, the net interior volume of such a cabinet does not need to exceed one cubic foot. This is a marked departure from conventional cabinets having a volume of at least six cubic feet. Moreover, its construction is basically very simple, for there need be no special passageways in the body of the cabinet to achieve a Helmholtz resonator effect or the like.

The front wall 22 may be formed with a central rectangular opening 23 which is approximately half the width of the front wall and extends from a point near the bottom to a like point near the top of the wall 22, for a neat-appearing design. This opening 23 is preferably covered by a loosely woven cloth 24 or a similar grill which will not substantially impede air movement occurring by sound vibration.

The speaker cones are mounted upon and behind a face board 25 which is substantially the size of the front wall of the cabinet. This face board is mounted within the cabinet against the front wall to close off the interior, except where the speakers are positioned. It may be held securely in position in any suitable manner, as by rabbeted ledges 26 as in the top 20 and bottom 21.

The high pitch speaker cone 16 is mounted on this face board in any conventional manner such as within a circular cavity formed by an orifice 27 in the face board 25 and a cupshaped container 28 attached to the backside of the face board. The mounting illustrated includes a

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peripheral rabbet seat 29 extending about the orifice 27 wherein the flange 30 of the cone is seated. The driver mechanism 31 of the cone 16 is conveniently carried in a socket 32 at the base of the container 28.

The bass cone 17 is mounted at the backside of the face board 25 beneath or otherwise offset from the high pitch speaker cone 16. The bass cone 17 itself is constructed in a conventional manner with the peripheral edge or rim 40 being affixed to a reinforcing ring 41. The legs of a spider 42 are affixed to this ring 41 and extend rearwardly and behind the cone 17 to support a cuplike retainer 43 at their nave wherein the driver 44 of the speaker is mounted. This driver 44 is conventional and includes a fixed magnet 45 in the retainer 43 and an armature 46 which operatively extends into a suitable socket in the magnet 45 and is affixed to the apex of the cone 17.

This cone 17 is mounted against the backside of the face board 25 with the flange rim 40 being tightly secured against the surface of the back board as by gluing or bolting the unit thereto.

Both the high pitch cone 16 and the bass cone 17 are powered from a common power circuit 47 which enters the cabinet in any suitable manner to bifurcate within the cabinet and connect the cones in parallel. One leg 48 of this circuit 47 extends to the high pitch cone driver 31 and the other leg 49 extends to the bass cone driver 44. A suitable high frequency by-pass filter 50 is interposed in the circuit leg 48 and a suitable low frequency by-pass filter 50a is interposed in the circuit leg 49 to avoid distortion by preventing low frequency impulses from being transmitted to the high pitch cone 16 and high frequency impulses from being transmitted to the low pitch cone 17.

The rim 40 of the cone 17 is tightly secured to the backside of the face board 25 to provide proper isolation of the front and back of the cone, with a closed chamber 51 back of the cone. Communication at the front 52 of the cone is effected by a comparatively small orifice 53 through the face board 25 whose axis preferably, but not necessarily coincides with the axis of the bass cone 17.

The closed chamber 51, the communicating path at the front of the cone 52, and comparatively small orifice 53 combine with the speaker to provide a novel unit as hereinafter described in detail. While the unit illustrated at FIG. 6 shows the invention in its simplest form it has been found desirable to mount a circular plate 54 at the front 52 of the cone. This plate is conveniently held in space parallelism from the face board 25 by suitable studs 55 to thereby form a circumferential slot 56 about the orifice 53 and thus modify the form and length of the communicating passageway at the front of the cone and the cabinet exterior as is clearly shown at FIGS. 3 and 4.

The plate 54 and modified passage from the front of the cone to the exterior not only provide for improved response at low frequencies as hereinafter described but also tend to eliminate and prevent transmission of high pitch tones which might be generated on the bass cone or within the cabinet in some unpredictable manner since high pitch tones are directional in nature and are not easily transmitted about a circuitous path formed by use of the plate 54. To emphasize such directional control it may be desirable to provide a plate thickness such that the peripheral corner 57 of the plate is close to the face of the cone, since the air movement must then pass the corner 57 about the edge of the plate 54 through the slot 56 and thence through the orifice 53.

A further modification of the unit is illustrated at FIG. 8 where an adjustable face plate 54' is mounted at the front of the cone by carrying the face plate 54' upon slidable studs 55' and providing an adjustable lead screw 58 through the orifice 53 and mounted upon a threaded nave of a spider 59 at the outside wall of the face board 25'. This construction provides for an adjustable pas-

sageway 56' to permit a variation of the sound volume and control of the bass tones.

According to the construction illustrated at FIG. 9 a speaker cone 17' may be provided as a unit to be placed in a conventional cabinet, and this cone includes a cover face 25' mounted directly against its flange 40 to create the enclosure at the front of the cone. The plate 25' is formed with an orifice 53' as hereinbefore described and with a plate 54 within the chamber 52. When this unit is mounted in any of the several comparatively small commercial speaker cabinets in accordance with the principles of the invention as hereinbefore described the performance in the low pitch range is substantially improved. In any speaker system there exists natural resonances and the basic elements of resonance involved in a mechanical system include, in addition to factors concerning the size of the unit, the mass, elasticity and viscosity of the air. Expressed in electrical analogue, these factors involve inductance, capacitance, and resistance. The general formula for parallel resonance in an electrical circuit may be expressed as:

$$w = \frac{1}{\sqrt{LC}} \cdot \sqrt{1 - \frac{C}{L} R^2}$$

where w is the resonant frequency in radians per second, L is the inductance, C is the capacitance, and r is the resistance. In the usual electrical circuit the resistance factor is negligible and the general formula is therefore usually expressed as:

$$w = \frac{1}{\sqrt{LC}}$$

Likewise in the conventional acoustic speaker system the resistance factor, the viscosity of the air, is considered negligible. This has been recognized in the prior art where the objectives have been to create a magnified response and high efficiency and the friction of the air movement is insignificant. In the present invention the orifice 53 is so small that air movement through it creates a significant frictional component which completely changes the acoustic response from that obtainable by conventional designs in the manner as hereinbefore described. In an electrical circuit, whenever the resistance factor becomes significant it can be demonstrated that the resistance will cause the resonance peaks that may exist to be broadened and lowered with more nearly uniform characteristics over the frequency range involved. A further advantage is that a flat impedance curve is obtained throughout the frequency range due to the lowered Q of the system. This results in an improved transient response.

Essentially, my improved cabinet construction uses a controlled viscous loading on the cone. The orifice 53 is sufficiently small so that the air movement through it creates a frictional component which is not significant in conventional designs and which completely changes the acoustic response from that of a conventional speaker. This has been recognized by the prior art where the objectives have been to create a magnified response and high efficiency.

On the other hand, the prior art has completely overlooked the nature of the acoustic response from a frictionally loaded speaker as set forth in the diagram at FIG. 10. This diagram represents a typical set of relationships of acoustic response and various frequencies for a speaker system at a given power input. The response of the high pitch speaker cone 16 is represented by the curve A which becomes effective at a frequency of approximately 750 cycles per second and remains substantially constant up to frequencies exceeding 15,000 cycles per second. A satisfactory level response is possible throughout this high frequency range by any one of several conventional types of speakers and sometimes two or even more high pitch speakers are used.

This typically level response curve of the high pitch

speaker cone may be used as a basis to compare the response of the bass cone of conventional design and the improved response obtained by using the present invention. For the same power input, the conventional bass speaker will have a fundamental acoustic response curve B typical to that shown in broken lines which will have one or more resonance peaks r , which are related to the natural bass resonant frequencies of the cone and cabinet. These resonant peaks cause the familiar "booming" of many types of speaker cabinets, and the desire of good design is to level off such peaks. Such "booming" is also usually the lowest frequencies at which response can be obtained because the response drops off sharply at frequencies below the bass resonant frequencies as at the curve portion d .

With the friction loaded speaker such as herein disclosed, it would be presumed that a substantial drop in response will occur which according to conventional practice, is to be avoided. However, it was discovered that when this frictional loading became a significant factor, that, in addition to the inevitable and expected drop of response, there was a significant change in the characteristic of the response curve beyond a simple linear diminution of the response curve characteristics as the response decreased. The modified resistance-reduced response curve C obtained by the frictional loading was found to be remarkably level with the resonant peaks r substantially ironed out, and even more startling, the level portion of the response extended to frequencies below the resonant peaks r with the response drop-off d' at lower frequencies than heretofore believed possible.

To complete the invention, the power input to this friction loaded low pitch cone 17 was substantially stepped up over that required for the high pitch cone 16, as much as five to six times the initial power input, to bring the level of the modified response of the low pitch cone 17 up to that of the high pitch cone 16. This final amplified bass response curve D retains its new characteristics of levelness, flat, insignificant resonant peaks, and good response at unprecedented low frequencies. Further tests demonstrated not only the level acoustic response as illustrated, but also a remarkably flat impedance curve. A speaker constructed in accordance with the invention also possesses remarkable power handling capacities without injury to the cone or distortion of the sound by overtone or harmonics.

This power step-up may be accomplished in several ways. As illustrated at FIG. 5, a conventional amplifier 60, having the required power output may be included in the power circuit and the circuit leg 48 to the high pitch speaker will include an appropriate resistance 61 to obtain the final desired balanced acoustic response with the unbalanced power input. Another manner of obtaining the same result, not illustrated, is to provide separate power leads, such as 47, from the power source to each speaker with proper comparative amplification at the power source. A third modification, not illustrated, is to provide a conventional amplifier in the circuit leg 49 in series with the filter 50a to obtain the proper comparative amplification.

The deliberate inefficiency of the speaker thus described is apparent but not real because when the cost of the speaker, the remarkably small size of the unit, and the outstanding performance obtainable is compared with the additional cost of power, the cheapest item of all, the balance is clearly in favor of the improved construction.

The invention consists first in friction loading the bass cone 17 by providing a cone construction as hereinbefore described to the point where the response curve attains a desired flat characteristic and this friction loading is conveniently accomplished by providing a cone construction as hereinbefore described which involves the closing off of one side of the speaker cone 17 as with the face board 25 with the restricting orifice 53 or the equivalent therein, and thereby forming a small passageway. The face board must be located close to the cone to minimize the

length of the elastic column of air that is vibratorily reciprocated through the orifice and the operation is not satisfactory where the face board is spaced from the cone to obtain a large chamber in front of the cone.

The orifice size may be varied by one skilled in the art to obtain a specific response. For the cabinet hereinbefore described, having the volume of approximately one cubic foot and using a standard 12-inch speaker cone, good results were obtained when the orifice area was between 1.8 and 3.8 percent of the cone area, as shown on the diagram at FIG. 7.

Once the speaker is friction loaded to a desired degree, the next step was to increase the power output of the bass cone to obtain the same acoustic level as that of the high pitch cone as in the manner hereinafter described.

While I have described many details of construction and operation of my invention, it is obvious that others skilled in the art can build and devise yet further alternate and equivalent constructions which are within the scope and spirit of my invention. Hence, I desire that my protection be limited not by the constructions herein illustrated

and described but only by the proper scope of the appended claim.

I claim:

A loudspeaker comprising a closed cabinet having a substantially flat wall with an aperture therein, a speaker cone of substantially conical frustum shape disposed within said cabinet with the periphery of the larger end of said cone secured to said wall about said aperture, and a plate within said cabinet and within said cone, said plate being supported from said cabinet substantially parallel to said wall and being symmetrically disposed with respect to said aperture, said plate having an area at least as great as said aperture.

References Cited in the file of this patent

UNITED STATES PATENTS

2,049,767	Glen	Aug. 4, 1936
2,646,851	Chapman et al.	July 28, 1953
2,694,463	Robbins et al.	Nov. 16, 1954
2,820,526	Tavares	Jan. 21, 1958
2,982,372	Lowell	May 2, 1961