July 31, 1962 R. G. PRUDEN 3,047,090

TUNED ACOUSTICAL DEVICE

Filed May 7, 1958

2 Sheets-Sheet 1

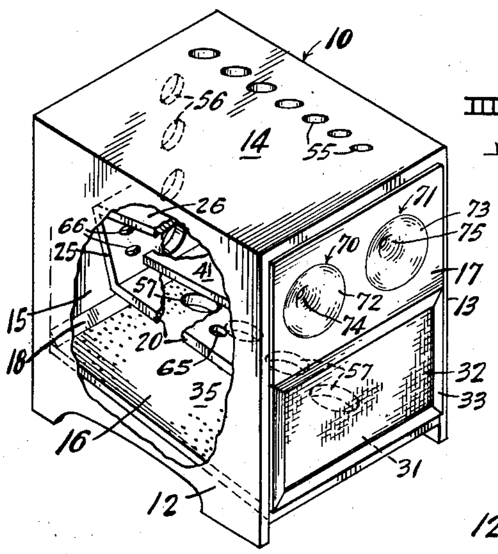


FIG-1-

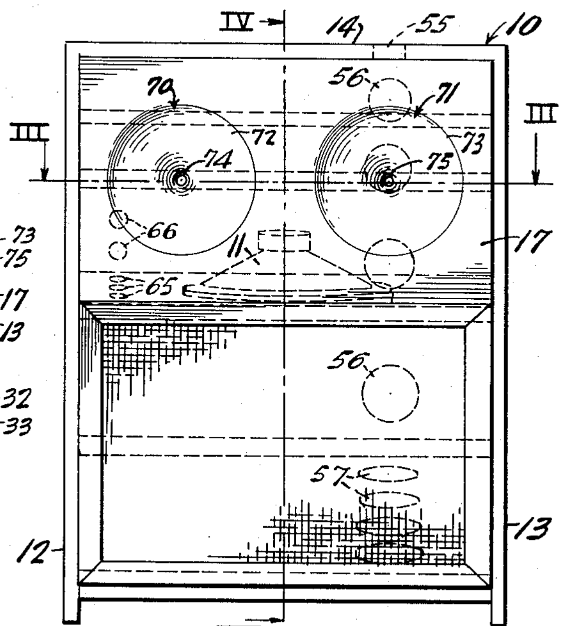


FIG-2-

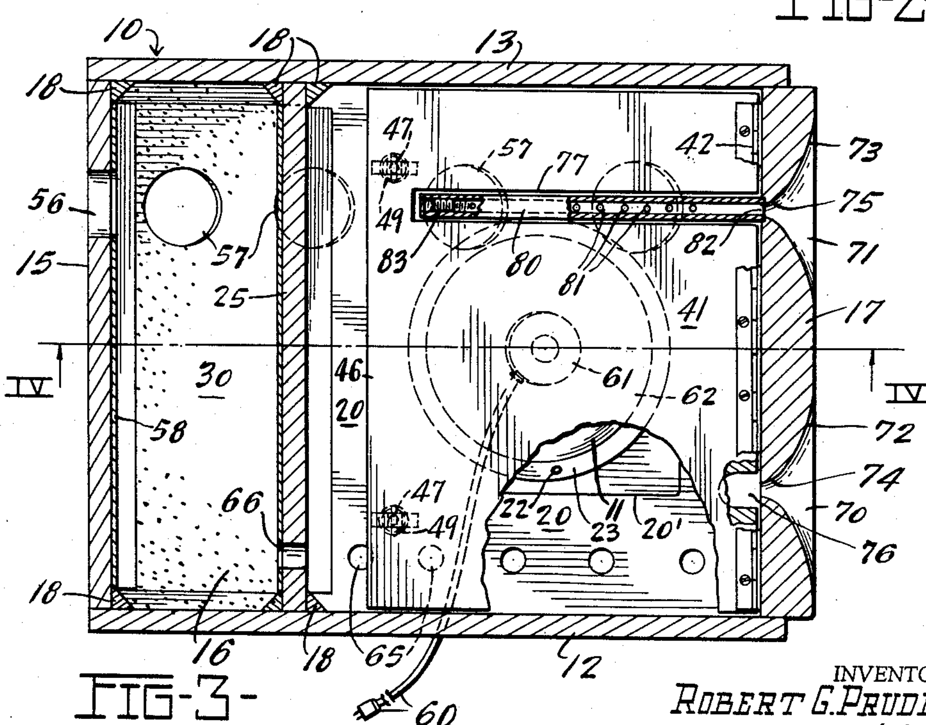


FIG-3-

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TUNED ACOUSTICAL DEVICE

Filed May 7, 1958 2 Sheets-Sheet 2

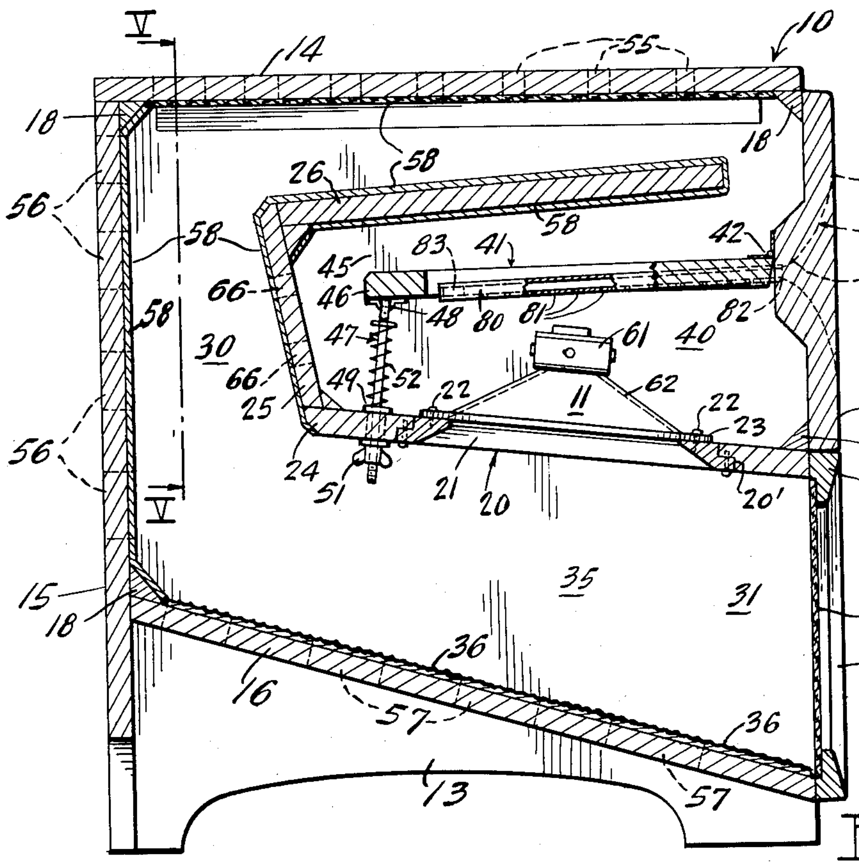

FIG-4-

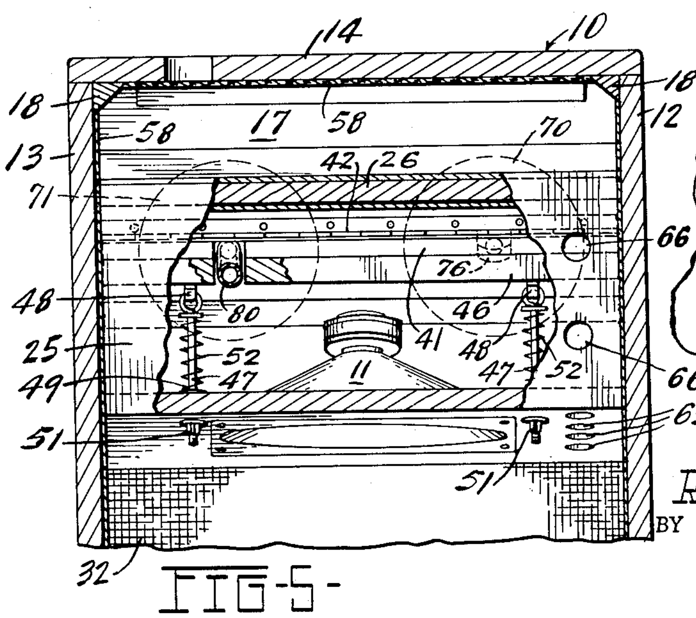

FIG-5-

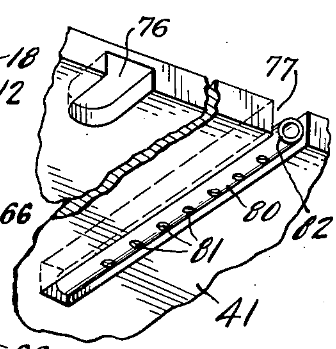

FIG-6-

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3,047,090

# TUNED ACOUSTICAL DEVICE

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13 Claims. (Cl. 181—31)

This invention relates to a tuned acoustical filter device. More particularly, it deals with an acoustical cabinet for a loudspeaker which may employ a plurality of acoustically tuned filters or horns to accentuate certain basic musical tones and damp other and undesirable tones present in said circuit, as well as to increase the bass and treble boost of the device as the volume level is decreased so as to conform better to the Fletcher-Munson hearing curves.

It has long been realized that the loudspeaker is the weakest component in the audio circuit. The loudspeaker is required to acoustically reproduce the sounds of all the musical instruments, as well as the human voice, not only individually, but simultaneously; and therefore it is not surprising that a single-unit loudspeaker cannot adequately cover the complete audio-frequency range. Thus, when the loudspeaker is called upon to reproduce these complex wave forms, the cone of the loudspeaker must then reproduce many different frequencies in the audio band simultaneously and therefore different areas of said cone will be vibrating at different frequencies at the same time. Further, at the higher frequencies breakup of the loudspeaker occurs, i.e.; longitudinal waves will form along the cone and the outside section of said cone will be out-of-phase with the portion near the cone apex. Thus, a loudspeaker does not reproduce only the sound which was to be reproduced from the recording or radio station, but it also creates many non-musical tones which tend to cancel and mask the true musical tones which were intended to be reproduced.

It has been shown by data compiled by Fletcher and Munson (see "Loudness, Its Definition, Measurement and Calculation," Journal of the Acoustical Society of America, October 1933, page 82) that the average human ear is most sensitive to a change in intensity at a relatively high volume level and at a medium range of frequencies. For this reason, bass and treble boost are needed when a sound reproducing system is operated at a low volume level. This compensation has been accomplished by electronic tone-compensated volume controls in the past; which devices adjusted the frequency response of the amplifier as the volume level was changed. However, there are several inherent disadvantages in this type of a sound reproducing system, such as: separate tone controls for the bass and treble boosts; a range switch in addition to the normal tone controls to adjust the frequency range of the system for the different types of recordings reproduced on said system; and the use of high quality and therefore expensive components for the amplifying system. Also the additional equipment needed for said compensation of bass and treble increases the power requirements of said system and therefore increases the cost of operating the same.

It is an object of this invention to produce an efficient, simple, effective, economic, pure and accurate acoustical reproducing circuit.

Another object of this invention is to produce an acoustical reproducing circuit which will require only one loudspeaker to cover the complete audio-frequency range.

Another object is to produce an acoustical reproducing system which will accentuate only the musical tones and will automatically damp all the undesirable tones.

Another object is to produce an acoustical device which will have a relatively flat response curve throughout the audio-frequency range.

Another object of this invention is to produce an acoustical reproducing circuit which may utilize a low power amplifier and relatively low priced components and still faithfully reproduce the intended sounds.



Another object is to produce an acoustical reproducing system in which the above mentioned disadvantages of a loudspeaker can be largely overcome.

Another object of this invention is to produce an acoustical circuit which reinforces the pure bass and/or treble tones of a loudspeaker.

Another object of this invention is to produce an adjustable tuned acoustical cabinet which may be tuned to the resonant frequency of the speaker or any one of a class of speakers.

Another object is to produce such a tunable acoustical cabinet which is attractive and compact in appearance, as well as a cabinet which efficiently uses the sound coming from both sides of the speaker in such a manner that the sound from one side will not cancel that from the other, but instead will be changed in phase to reinforce it.

Another object is to produce a tuned acoustical cabinet for a speaker in which the pure tones from the speaker are increased and the distortion is decreased, by damping out intermediate frequencies and providing feedback, all of which is equivalent to what could be produced in a much more expensive electronic frequency mixing circuit.

Generally speaking, an acoustical circuit of this invention comprises a transducer or loudspeaker for reproducing amplified sound from a sound source, and an enclosure or cabinet for said loudspeaker. However, this invention primarily relates to the loudspeaker enclosure comprising a baffle for mounting an indirectly radiating loudspeaker for reproducing the complete audio-frequency range from both sides of the loudspeaker's cone, and at least one peaked-tuned horn for accentuating either the low or the high frequency range, or separate peaked tuned horns for accentuating both the low and the high frequency ranges, from at least one side of the loudspeaker's cone.

The low frequency accentuating horn or horns may include peak-tuned, folded, constant and/or multiple-flared hyperbolic, conical or exponential horns, which may extend from a chamber behind the loudspeaker around through the enclosure to the front of the loudspeaker and thence to the front of the enclosure. This chamber behind the loudspeaker may have the shape of a section of an exponential horn and may have a plurality of feedback ports adjacent the loudspeaker to reduce or eliminate undesirable cancellations or resonances at certain frequencies produced by the characteristics of the cabinet and/or loudspeaker itself, so as to produce a substantially flat response curve. This low frequency horn is also so constructed so that its length is resonant one quarter of the wave length of the resonant frequency of the loudspeaker so that the acoustical energy from the rear portion of the loudspeaker will be in phase with and thereby reinforce the acoustical energy emanating from the front of the loudspeaker. This low frequency horn may be tuned by a plurality of ports spaced along its length, the spacing of said tuning ports being such that the pure musical tones are accentuated and the undesirable tones are automatically damped. The throat opening of said low frequency exponential horn from the chamber behind said loudspeaker may be varied so as to compensate for the different acoustical characteristics of different speakers, such as by providing said chamber with a hinged top member forming one side of the throat of the low frequency horn. Furthermore, the low frequency accentuating horn may be lined with an acoustical damping material to absorb the middle and higher frequencies, so as to minimize the destructive interference which may occur therein with the lower frequencies. This damping material may extend through the major central part from near the throat of the horn. The mouth portion of this horn, however, may be lined with a metallic or hard surfaced material, preferably having an irregularly patterned or pebbled surface, to reflect and distribute equally the acoustical energy emanating from the front portion of said loudspeaker which herein is directed into said mouth portion.

The high frequency horn or horns also may emanate from the chamber behind the loudspeaker, and lead to the front of the enclosure or cabinet. A constant flared tuned high frequency horn, for example, may be mounted in a slot in the hinged top wall of the chamber and from there lead into a bell shaped high frequency horn, such as an exponential horn, mounted in the front of the cabinet, adjacent another similar bell-shaped high frequency horn mounted in the front of the cabinet. In fact, a pair of high frequency horns may be mounted throat to throat between this chamber and the front of the cabinet, to accentuate the high-frequency range of musical tones emanating from said loudspeaker.

The above mentioned and other features and objects of this invention and the manner of attaining them will become more apparent and the invention itself will be best understood by reference to the following description of embodiments of the invention taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is an isometric view of one embodiment of the loudspeaker enclosure of this invention, with parts thereof broken away;

FIG. 2 is a front view of the embodiment of FIG. 1 showing the position of the loudspeaker in dotted lines with respect to the mouths of the exponential horns;

FIG. 3 is a horizontal sectional view showing the high frequency horns taken through line III—III of FIG. 2 in the direction of the arrows, and with parts broken away showing a part of the loudspeaker and the feedback ports;

FIG. 4 is a vertical sectional view taken through line IV—IV of FIG. 2 or 3 showing the chamber behind the loudspeaker and the positions of the cancellation or phase correcting and tuning ports, and the adjustable throat of the low frequency horn;

FIG. 5 is a view of a section taken through line V—V of FIG. 4 and with parts broken away showing the positions of some of the phase correcting ports in the loudspeaker supporting baffle; and

FIG. 6 is an isometric view of the slots in the hinged top of the chamber behind the loudspeaker, in one of which a tuned high frequency horn is mounted.

## I. THE ENCLOSURE

Referring now to the drawings, one embodiment of the acoustical circuit of this invention comprises the enclosure or cabinet **10** constructed of a non-flexible rugged material which will not vibrate sympathetically with changes in the acoustical pressures within the cabinet caused by a transducing means such as loudspeaker **11** (see FIGS. 2 through 5), which material may comprise, for example, one-half or three-quarter inch thick plywood panels. This cabinet or enclosure **10** may comprise side-portions **12** and **13**, a top portion **14**, a back portion **15**, an inclined bottom portion **16**, and a front portion **17**. These side or wall portions are jointed together at their corners and edges and, there, may be reinforced by corner bracing means **18**, such as wooden blocks or metal gussets (see FIGS. 3, 4 and 5).

The loudspeaker **11** may be mounted on a baffle **20** (see FIGS. 3, 4 and 5) inside the enclosure or cabinet **10**, which baffle may be attached to the front portion **17** and between side portions **12** and **13** thereof. This baffle **20** is provided with a central aperture **21** over which the mouth of the speaker **11** may be mounted, such as by screws **22** or other fastening means, anchoring the peripheral rim **23** of the speaker **11** to the baffle or plate **20**. The baffle **20** also may be constructed with a separable lap joint **20'** or other device to provide accessibility for servicing the speaker **11**. In order to employ as much space as possible within the cabinet **10**, the baffle **20** does not extend completely between the front wall **17** and the rear wall **15**, but is spaced from the rear wall and may have attached to the free edge **24** thereof additional baffles or partitions **25** and **26**, located substantially at right angles to each other and extending between and attached to the side wall portions **16** and **17** to form a part of the wall or side of a bass or low frequency folded horn **30** in the cabinet **10**.

## II. THE BASS HORNS

### (*a*) *Structure*

The bass or low frequency folded horn or horns **30** in the present embodiment extends from one side or the back of the baffle **20** and back of the loudspeaker **11** to the front of the loudspeaker and other side of the baffle **20**, which is adjacent the mouth **31** of the horn **30**. This mouth may be covered by a porous sound penetrating screen **32** mounted within a frame or moulding **33** around the edge of the opening **31** in the front portion **17** of the cabinet **10**. The mouth section **35** of this bass horn **30** is shown in this embodiment to extend from one side portion **12** to the other side portion **13** of the cabinet **10** and from the lower side of the baffle **20** to the upper side of the inclined base **16**, which section **35** preferably is lined at least on the top of the base **16** with an irregular or pebbled hard surface **36**, such as of metal or a shellaced surface, to reflect all of the sound coming from the front mouth of the speaker **11** through the screen **32**.

### (*b*) *Tuning*

#### 1. TO RESONANCE OF LOUDSPEAKER

On the opposite side of the baffle **20** from the mouth section **35** of the bass horn **30**, there is provided another section or chamber **40** separated from the baffle or partition side wall **26** of the bass horn **30** by another baffle **41**, which baffle **41** may be hinged at **42** adjacent the front wall **17** and extend short of the partition **25** to provide a throat **45** for the bass horn **30** between the free edge **46** of the baffle **41** and the partition **26**. This baffle **41** may have its free end **46** adjusted up and down to change the area of the throat **45** by means of one or more screw means **47**. The cross-sectional area of this throat **45** may may vary from 15% to 25% or less of the effective cross-sectional area of the diaphragm or cone **62** of the loudspeaker **11**. These means **47** may be attached to swivel joints **48** near the edge **46** of the baffle **41**, which screw means **47** extend through bearing means **49** in the fixed baffle **20** into the chamber **35** where wing nut **51** is fastened thereto for readily adjusting the throat **45** against action of spring **52** and screw means **47**, within the chamber or section **35** of the large horn, which chamber may have easy access through the mouth **31** of the horn **30** when the screen **32** in the frame **33** is removed therefrom. The purpose of being able to adjust the throat **45** for the low frequency horn **30** is to be able to adjust its throat impedance of this low frequency horn to match the load impedance of the particular loudspeaker **11** which is mounted on the baffle **20**, in that different loudspeakers, although of the same size and type, vary slightly in their characteristics.

#### 2. TO PURE BASS NOTES

The low frequency horn besides being a quarter wave length of the resonant frequency of the loudspeaker **11**, may also have provided therein, such as along one side thereof, a plurality of tuning holes **55**, **56**, and **57** of increasing size extending from toward the throat end of the low frequency horn **30** through the top portion **14**, back portion **15** and bottom portion **16**, respectively, of the cabinet **10**, which holes are spaced according to the Branch Transmission Theory of Acoustical Filtration (see article by W. P. Mason, Bell System Technical Journal, volume 6, page 258 (1927)), or may be spaced similar to those holes found in air or wood wind instruments or lower or bass frequencies, such as the bass or baritone saxophone, bass clarinet, contra bass, sarrusophone, bassoon, and so forth. The specific bass horn **30** disclosed in the embodiment of this invention, shown in FIG. 4, has a horn length and multiple rate of flare and port diameter in spacing similar to that of a bass saxophone. These tuning holes accentuate the pure tones of lower frequency emanating from the speaker **11** so as to increase the resonance of the cabinet **10** for the pure tones of lower frequencies.

Thus the lower frequency or bass horn **30** may not only be an exponential horn and be tuned to match the characteristics of the speaker **11** by varying the throat **45** thereof from the chamber **40**, but also may have tuning ports **55**, **56** and **57** therealong, so as to correspond to two separate low frequency horns. These low frequency horns change the shape of the frequency response curve of the speaker **11** so as to approach the Fletcher--Munson curve. However, since these horns are the same length and shape, they need not be separated by a vertical partition in the cabinet and are combined as one horn of rectangular cross-section as disclosed herein. Nevertheless, these low frequency horns **30** may have other cross-sectional configurations, such as elliptical, whichever may fit best into the structure of the cabinet **10**. Furthermore these low frequency horns may be increased in length by additional folds and S-shaped turns within the cabinet, located above and/or below the baffles **20** and **41**, to correspond with loudspeakers having lower resonance frequencies which require longer bass horns.

In order to damp the high frequencies from the low frequency horn **30** the major central portion of the low frequency horn **30** may be lined with a sound absorbing material **58** which may extend from near the throat **45** of the horn to the mouth section **35** thereof, thus only the lower frequencies which are to be resonated and accentuated by this horn or horns **30** are passed through and accentuated by them.

### (c) *Phasing*

Because of the variable angle of the baffle **41** with relation to the plane of the baffle **20**, the chamber **40** may take the form of a section of an exponential horn, as do the folded portions of the bass or low frequency horn **30** including its mouth section **35** on the opposite side of the baffle **20** from the chamber **40**. Thus the loudspeaker **11** is mounted between two exponential horn shaped sections or chambers **35** and **40** within the cabinet **10**, in which the sound from one and the front side of the loudspeaker **11** is indirectly projected and reflected from the hard pebbled irregular surface **36** on the bottom wall **16** in the section **35** out through the mouth **31**, while the sound from the back of the loudspeaker **11** which is 180° out of phase therewith, is more indirectly directed from the chamber **40** through the throat **45** of the exponential folded multi-flared low frequency horn **30** as well as through a plurality of high frequency horns emanating from the chamber **40** as will be described in section III below.

When electrical impulses are supplied to loudspeaker **11**, such as through electric cable **60** (see FIG. 3) in the side of the cabinet to the electroacoustical transducer **61** of the loudspeaker **11** which produces vibrations that are transmitted to its paper cone **62** to cause it to vibrate correspondingly, there emanates from both the front and rear faces of the cone **62** sound waves that are 180° out of phase with each other. Therefore, in order to eliminate cancellations of these sound waves, the low and high frequency horns from the chamber **40** are constructed to be of one-quarter wave-length in length for the lowest frequency to be reproduced by them. In addition to this, the low frequency horns also may be provided with phasing or feedback port means **65** and **66** (see FIGS. 3 and 5) in the baffle **20**, and also in the wall or baffle **25** attached thereto, to further reduce cancellations and correct the phasing of the acoustical energy or sound waves emanating from the rear portion of the loudspeaker **11** in the chamber **40** to that in the chamber **35** adjacent the mouth of the low frequency horn **30**. Accordingly, the sounds and energy from the back of the loudspeaker **11** will be in phase with the sounds and energy emanating from the front portion of the loudspeaker and thereby reinforce them. The spacing of these phasing ports **65** and **66** may be determined by obtaining the frequency response curve from the particular loudspeaker **11** and by noting the frequency $f$ in cycles per second at which the dips or valleys occur in its response curve, which dips and valleys may be due both to the cabinet and loudspeaker resonances. The distance $d$ in inches from the sound emanating means **61** may then be calculated by the formula



$$d=\frac{v}{f}$$

where $v$ is the velocity of sound in air (which is approximately 13,200 inches per second at room temperature). The number and location of these phase correcting or feedback holes **65** and **66**, therefore, depends upon the particular speaker **11** and the structure of the cabinet **10** which is to be employed. However, in mass production the location of these holes or ports **65** and **66** for the same parts will not vary materially.

## III. TREBLE HORNS

Referring now to the front portion **17** of the cabinet **10** as shown in FIGS. 1, 2 and 3 there is shown a pair of treble or high frequency horns **70** and **71**, which may be symmetrically arranged in the upper portion of the front wall **17** about the mouth **31** and grille **32** for the bass or low frequency horns **30**. These high frequency horns **70** and **71** may be either formed in the front wall portions **17** or may be formed from a metal casting inserted into apertures provided therefor in the front wall **17**. These horns **70** and **71** also are one-quarter wave length type horns to reinforce the high frequencies from the loudspeaker **11**. The mouth diameter of these horns **70** and **71** may be calculated for a predetermined rate of flare from the formula

$$\frac{S_2}{S_1}=e^{kx}$$

where $S_1$ is throat area $S_2$ is the cross-sectional area of the horn a distance $x$ from the throat $S_1$ and K is the rate of flare or flare constant for the horn and may be determined for an exponential horn by the formula

$$K=\frac{4\pi f_c}{c}$$

when $f_c$ is the cut-off frequency and $c$ is the velocity of sound in air. The throat sections **74** and **75** may be determined by the size of the driving unit of these horns **70** and **71** therefor. The cross-sections of these horns **70** and **71** between their mouths and their throats may vary conically, exponentially, hyperbolically, and/or the like, however, it is preferable in this case that the horn sections expand exponentially between their respective throats and mouths as disclosed in the illustrated embodiment of this invention.

The throats **74** and **75** of the horns **70** and **71** open into the chamber **40**, and may as shown herein open into notches or grooves **76** and **77**, respectively, in the pivoted baffle **41**, as more clearly seen in FIGS. 3 and 6. In the slot **77** communicating with the exponential horn section **71**, there may be provided a high frequency constant flared or straight tuned horn section **80** having tuning holes **81** therealong, and its mouth **82** adjacent the throat **75** of the horn **71** to form a unit peaked-tuned horn of sections **71** and **80**. The tuning holes **81** may correspond in spacing to that determined from The Branch Transmission Theory of Acoustical Filtration (supra) or from the spacing of ports in wind instruments of treble or high frequencies, such as a flute, piccolo, fife, recorder, flagolet, etc. The particular tuned horn **80** shown herein is a metal tube having tuning holes spaced like those in a piccolo, and may have a variable tuning plug **83** threaded in its closed end opposite its mouth **82**.

Since the higher frequency tones from the chamber **40** are accentuated by the high frequency horns **70**, **71** and **80**, it is desirable that the interior of the chamber **40** have a hard surface finish, and may be covered with a metallic foil, so that as few as possible of the high frequency vibrations to be accentuated through the horns **70**, **71** and **80** will be lost or damped in the chamber **40**.

Thus, there are also a plurality of high frequency horns reinforcing the sound waves from the back of the loudspeaker **11** in chamber **40**, which horns comprise exponential horns tuned to the highest frequency to be reproduced, and tuned horns as **80** for accentuating the pure tones of the higher frequencies to approach the Fletcher-Munson curve.

Additional high and low frequency tuned and exponential horns as disclosed herein may be combined in or with the cabinet or resonant device of this invention, as well as additional and other phasing holes and the baffles therefor, in order to approach a response still closer to the Fletcher-Munson curve for the human ear, without departing from the scope of this invention.

One or more of the acoustical loading circuits according to this invention may be employed to correct inadequate features of the smallest to the largest loudspeakers without departing from the scope of this invention.

While there is described above the principles of this invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of this invention.

What is claimed is:

1. An acoustical cabinet for a loud speaker, comprising: a flared folded horn in said cabinet having a mouth and a throat defined in part by said cabinet, a mounting plate for said loud speaker whereby acoustical energy emanates from both the front and rear sides of said loud speaker and its mounting plate, an acoustic loading chamber for said loud speaker opening to the throat of said horn, said loud speaker and said mounting plate located in said cabinet to form a common wall of said chamber and of said horn, said loud speaker oriented in said cabinet so said rear side of said loud speaker opens into said loading chamber and said front side of said loud speaker opens into said horn near said mouth, tuning holes along said horn, and feedback phase correcting tuning holes in said plate.

2. A cabinet according to claim 1 wherein said horn is a low frequency accentuating horn.

3. A cabinet according to claim 1 including at least one horn resonant at a high frequency extending from said chamber to the exterior of said cabinet.

4. A tuned horn transducer comprising an enclosure, a baffle in said enclosure, an indirectly radiating electro-acoustical transducing means for emanating sound waves from two opposite sides thereof and mounted on said baffle, a tuned low frequency accentuating folded horn having a throat and a mouth, said horn extending from one side of said baffle around said baffle configured to include said baffle as a part of said horn between said throat and said mouth, an acoustic impedance matching chamber for said horn throat on one side of said baffle, said chamber opening to said throat, phase correcting porting means in said baffle between said chamber and said horn, and a second horn extending directly from said chamber to the exterior of said enclosure and resonant at a higher frequency than that of said folded horn.

5. An acoustical cabinet for an electrically operated loudspeaker, comprising: a mounting plate for said loudspeaker in said cabinet, a horn section shaped chamber behind said loudspeaker, a low frequency folded horn extending from said chamber in said cabinet and having a throat and a mouth opening into one side of said cabinet, said loudspeaker opening into said horn adjacent said mouth, a high frequency horn extending from said chamber and opening into said one side of said cabinet, adjustable means for tuning said low frequency horn comprising a baffle forming a wall of said chamber hinged to said cabinet and extending into said cabinet to form a portion of the periphery of said low frequency horn throat, tuning holes along said low frequency horn, tuning holes along one side of said high frequency horn, and pre-determined feed-back phase correcting holes between said chamber and said mouth end of said low frequency horn.

6. A cabinet according to claim 5 comprising a pair of exponential high frequency horn sections extending from said chamber to the exterior of said cabinet, one of said exponential high frequency horn sections being fed by a tuned tubular section.

7. A tuned horn transducer comprising an enclosure, a baffle in said enclosure, an indirectly radiating electro-acoustical transducing means emanating sound waves from two opposite sides thereof and mounted on said baffle, a chamber on one side of said baffle fed by sound waves from said transducing means, phase correcting porting means in said baffle, at least one folded horn extending from said chamber around said baffle to the other side of said transducing means for accentuating the lower frequencies from said transducing means, and a plurality of high frequency horns also extending from said chamber for accentuating the higher frequencies from said transducing means.

8. A transducer according to claim 7 wherein said low frequency tuned horn has tuning holes therealong.

9. A transducer according to claim 7 wherein one of said high frequency tuned horns has tuning holes therealong.

10. An acoustical cabinet for a loudspeaker comprising: a mounting plate for said loudspeaker in said cabinet whereby acoustical energy emanates from both sides of said loudspeaker and its mounting plate, a first acoustical loading chamber for said loudspeaker on one side of said loudspeaker and said plate, a second chamber on the other side of said loudspeaker and said plate, each of said chambers being a horn section, a horn extending from said first chamber to said second chamber, and a second horn extending directly from said first chamber to the exterior of said cabinet and resonant at a higher frequency than that of said horn between said chambers, said second chamber having an opening providing a mouth for said horn separate from the opening connecting said second chamber to said horn, whereby said second chamber acts as a mixing chamber for the sound from said other side of said loudspeaker and said horn.

11. A cabinet according to claim 10 wherein said horn includes tuned holes therealong.

12. A cabinet according to claim 10 wherein said plate includes feedback phase correcting holes connecting said chambers.

13. A cabinet according to claim 10 wherein at least one of said chambers is shaped like a section of an exponential horn.

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