May 30, 1961 J. C. PERKINS, JR 2,986,229

LOUDSPEAKER ENCLOSURES

Filed Jan. 15, 1957 2 Sheets-Sheet 1

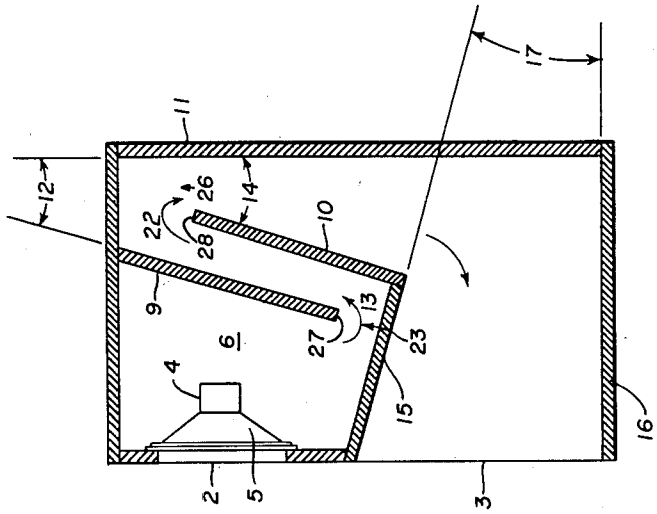


FIG. 2

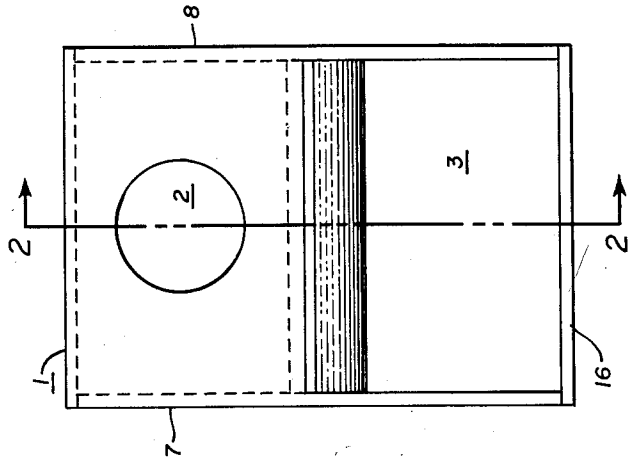


FIG. 1

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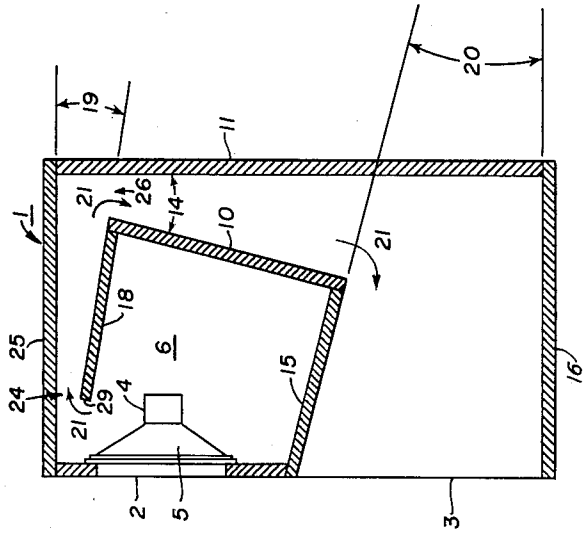


FIG. 4

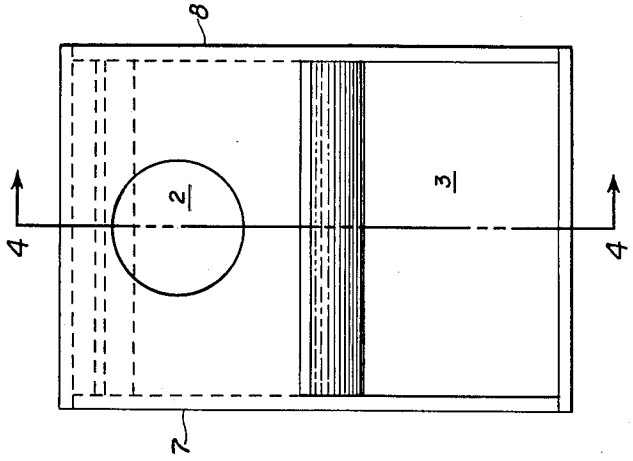


FIG. 3

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LOUDSPEAKER ENCLOSURES

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Filed Jan. 15, 1957, Ser. No. 634,139

4 Claims. (Cl. 181—31)

My invention relates to loudspeaker enclosures and more particularly to loudspeaker enclosures of the absorbent-walled, tortuous-path type sold under the trademake "Acoustical Labyrinth."

This application is a continuation-in-part of an application by the same applicant, J. Carter Perkins, Jr., for a Loudspeaker Enclosure, Serial No. 356,405, filed May 21, 1953, now abandoned.

An "Acoustical Labyrinth" loudspeaker enclosure is shown in Olney Patent 2,031,500, issued February 18, 1936, and assigned to the same assignee as the present invention. An Acoustical Labyrinth housing for a loudspeaker of the cone diaphragm type may have a back enclosure to provide acoustical stiffness for the back radiating surface of the loudspeaker, first and second ports for radiating sound respectively from the front and back radiating surface of the speaker, and a sound path between the back enclosure and the second port. This path may be tortuous in configuration in order to conserve space, and may be defined, at least on some walls, by a series of baffle plates or partitions placed within the cabinet. The walls of the path are made of material which absorbs frequencies above a predetermined low frequency, usually about 150 cycles per second. As explained in the Olney patent, the Acoustical Labyrinth loudspeaker enclosure affords improved loudspeaker reproduction through the elimination of cavity resonances and apparent change in pitch of low notes associated with the usual open back loudspeaker mountings.

It is primarily an object of my invention to provide an improved loudspeaker enclosure of the type having absorbent walls and a tortuous passage which radiates low frequencies with greater volume than loudspeaker enclosures known heretofore, yet with a greater uniformity of radiation intensity over the low frequency range.

It is also an object of my invention to provide an improved loudspeaker housing having a tortuous path of exponentially increasing cross-sectional area positioned within the housing in such a manner that the housing occupies a minimum of space, yet tends to both improve the loading characteristics and retain the desirable damping characteristics present in the Acoustical Labyrinth enclosure.

It is a further object of my invention to provide a method for the uniform generation of sound in the low frequency range.

In general, I achieved the foregoing and other objects of my invention by arranging the baffle plates or partitions of the absorbent walled housing in such relation as to define a passage or sound path whose cross-sectional area increases, preferably exponentially at least to a first approximation, in the acoustical direction extending toward the second port. The flaring nature of this passage increases the efficiency of low frequency radiation from the back radiating surface of the loudspeaker since it approximates a finite horn which increases the radiating resistance presented to the diaphragm and consequently the coupling between the horn and the diaphragm. This

increased loading of the diaphragm by the horn shaped path, also allows the speaker to be driven by greater amplitude low frequency signals before the speaker chatters due to "bottoming."

According to the invention, the baffles and the housing walls, forming the back enclosure of the speaker and the sound path are so arranged that the horn shaped sound path has a cut-off frequency of less than 50 cycles per second. This is possible since the path formed doubles in size less than three times when traversing a path length from throat to mouth of four feet or more. Thus the mouth area which is substantially greater than the diaphragm area, is less than eight times as large as the throat area of the path and cut-off frequencies in the range of 30–40 cycles per second can easily be obtained by making the path length greater than four feet. Thus according to applicant's invention, a compact housing is provided having a flare cut-off frequency below 50 cycles per second.

However, since the path formed is not an infinite exponential horn but is an approximation of a finite horn having a mouth area whose effective diameter is only a fractional part of a wave length at the lowest frequency transmitted, impedance curves of the horn shaped path in free air show that impedance variations and reflections will occur. The first and the greatest peak will occur above the cut-off frequency of the path. However, when the path is coupled to the back enclosure, the resultant impedance curve will be shifted downward in frequency due to the capacity or compliance of the enclosure then being connected in shunt with the horn. The resultant impedance curve will then be displaced to a lower frequency than it was before it was connected to the enclosure. The size of the enclosure and the parameters of the path may be so arranged that the lowest peak, of the combined impedance curve i.e. the lowest anti-resonant condition will coincide with the frequency of resonance of the speaker. This results in the cancellation of the resonance peak of the speaker by the first impedance peak of the combined path in such a manner that the response curve of the housing and speaker is substantially free of resonant points in the range of frequencies near the speaker resonant point.

Thus by changing the size of the enclosure and the sound path the first anti-resonant point of the impedance curve may be made to substantially coincide with the speaker resonant point. The curve may be shifted downward in frequency to a limited extent, by either increasing the length of the path or by increasing the compliance of the enclosure. The curve may be shifted upward in frequency by decreasing the length of the path or by decreasing the compliance of the enclosure.

Since the throat impedance of the horn shaped path increases with frequency, and the impedance of the enclosure decreases with frequency a point is reached at which the throat impedance is equal to the enclosure impedance. This point is called the cross-over frequency. At this point, the two impedances are essentially equal and thus approximately half of the back radiated wave is being coupled to the horn while the other half is being dissipated in the compliance of the enclosure. As the frequency increases beyond the cross-over frequency, a smaller proportion of the back radiated wave is coupled to the horn until a point is reached at which the throat of the horn presents such a high impedance and the compliance of the enclosure such a small shunt impedance that no further radiation occurs through the horn path. It therefore may be seen that beyond this point the back enclosure is no longer coupling the back radiated wave to the throat of the horn but is then acting solely as a compliance. According to my invention,

the cross-over frequency is approximately 150 cycles per second and the predetermined frequency at which the horn ceases to radiate is approximately 300 cycles, which is essentially the upper limit of the low frequency range.

In order for back enclosure **6** to act as a non-resonant compliance throughout the low frequency range, the depth of the enclosure should not exceed a half wave length at the highest frequency of the range and preferably should be less than a quarter wave length. Since a quarter wave length at 300 cycles per second is greater than 11 inches, the enclosures of both embodiments will act as non-resonant compliances throughout the low frequency range since the average depth of the enclosures is less than 11 inches. Thus it may be seen that the back enclosure of both embodiments will act as non-resonant compliances in the low frequency range.

The sound absorbing walls become effective above the cross-over frequency to absorb the higher frequencies traversing the horn thereby tending to aid in the suppression of signals traversing the sound path above the cross-over frequency. Since a majority of the impedance peaks of the path above the first cancelled peak, will occur in this range they also are substantially reduced by the sound absorbing action of the walls.

When the applicant uses the term "exponential" in the specification or claims he doesn't intend to be limited to a classic or a pure exponential curve ($S=S_1e^{mx}$) but intends to include any function that varies according to a variable exponent.

Further objects and advantages of my invention will become apparent as the following description proceeds and the features of novelty which characterize my invention will be pointed out with particularity in the claims annexed to and forming a part of the specification.

For a better understanding of my invention, reference may be had to the accompanying drawings in which:

Fig. 1 is a front view of one embodiment of my invention, and

Fig. 2 is a sectional view, taken along line **2—2** of the embodiment of Fig. 1,

Fig. 3 is a front view of another embodiment of my invention, and

Fig. 4 is a sectional view taken along line **4—4** of the embodiment of Fig. 3.

In Fig. 1, there is shown a loudspeaker housing **1** having a first port **2** and a second port **3**. More clearly revealed in Fig. 2 is the position of loudspeaker **4** behind port **2**. Loudspeaker **4** has a conical diaphragm **5** with the front radiating surface radiating through port **2** and back radiating surface radiating into back enclosure **6**. The tortuous sound path is preferably divided into first, second and third sections, each having two opposite walls of the housing.

The first section, which is provided for coupling the rear of port **2** to the remaining sections of the path, has its remaining two walls defined by a first baffle member **9** and a second baffle member **10**. Baffle **9** forms the rear of the back enclosure **6**, and its top extends toward back **11** of the housing at an angle **12** relative to back **11**. Sound pressures in back enclosure **6** enter the first section of the tortuous path at the bottom of the back enclosure through throat **23** which is defined by the lower end **27** of baffle **9** and baffle **15**, as indicated by arrow **13**.

The second baffle member **10** is located at an angle **14** relative to the back **11** of the housing. Member **10** and back **11** thus define the remaining two walls of the second section of the tortuous path which has a throat **26** defined between upper edge **28** of baffle **10** and back **11**. Angle **14** is chosen so that the cross-sectional area of the second section of the tortuous path increases, preferably exponentially, in a downward direction from throat **26**; and angle **12** is chosen to equal angle **14** so that the first section has substantially parallel sides.

Baffle **15** which defines the bottom of back enclosure **6** and the bottom **16** of the housing define the third section of the tortuous path according to my invention. Baffle **15** is located at an angle **17** relative to bottom **16**. Angle **17** is so chosen that the cross-sectional area of this third section increases exponentially, at least to a first approximation, in the direction toward the second port **3**. It will be noted that the cross section of each of the three sections of the tortuous path is rectangular in shape, but that the tortuous path has a cross-sectional area which increases exponentially, at least to a first approximation, from its start at the back enclosure to its exit at the second port **3**.

Throat **23** has an area of approximately 56 square inches. The actual length of the sound path to the mouth at port **3** is approximately 63 inches and since the mouth area of the sound path is approximately 337 square inches it may be seen that the sound path double approximately 2½ times in traversing the path thereby resulting in a cut-off frequency of approximately 30 cycles per second.

In the embodiment of my invention shown in Figs. 3 and 4, the housing **1** may be of comparable dimensions with that shown in Figs. 1 and 2 and may have ports **2** and **3** formed therein in similar fashion. Loudspeaker **4** is positioned behind port **2** such that diaphragm **5** may radiate through the latter and its back surface may radiate to the back enclosure **6**. Back enclosure **6** is defined by baffle members **10, 15 and 18.**

Members **10, 15** and **18** are placed at angles relative to the back, bottom and top, respectively, of housing **1** such that the tortuous or folded sound path so formed increases in cross-sectional area towards port **3** and therefore may be termed a horn shaped sound path. Top **25** of housing **1** and baffle **18** form a first section of the tortuous passage the cross-sectional area of which increases in a direction toward the next section. The first section provides means for coupling the rear of loudspeaker port **2** to throat **26** of the next section which is defined by wall **11** and baffle **10**. The cross-sectional area of this portion likewise increases in a direction toward the next section. The third and final section is that defined by bottom **16** of housing **1** and member **15**, and like the other sections, has a cross-sectional area which increases, in this case, toward port **3**. To obtain the increasing cross-sectional area, member **18** is placed at angle **19** relative to the top **25** of housing **1**; member **10** is placed at angle **14** relative to the back of housing **1**; and member **15** is placed at angle **20** relative to the bottom of housing **1**. The direction of propagation of sound pressures originating in back enclosure **6** is indicated by arrows **21**. The rate of increasing cross-sectional area into sections of the tortuous path shown in Fig. 4 is preferably exponential, at least to a first approximation.

The opening **24** formed between front edge **29** of baffle **18** and the top **25** defines a throat for the horn shaped sound path which has an area of approximately 77 square inches while the area of the mouth formed at port **3** is approximately 330 square inches. Since the actual length of the sound path is approximately 4 feet the baffle and the housing walls define a sound path having a cut-off frequency of approximately 35 cycles per second.

While I have shown and described my invention as applied to two specific embodiments, other modifications will readily occur to those skilled in the art. I do not, therefore, desire my invention to be limited to the specific arrangements shown and described, and I intend in the appended claims to cover all modifications within the spirit and scope of my invention.

What I claim is:

1. In a housing having a tortuous path with absorbent walls for a loudspeaker of the type having front and back sound radiating surfaces, said housing having a loudspeaker back enclosure, first and second ports for radiating sounds respectively from said front and back surfaces, and a tortuous sound path between said back enclosure

and said second port, the improvement which consists of placing the walls of said path to define a passage whose cross-sectional area increases in the direction of said second port, said first port being above said second port in the front wall of said housing, said path having a first section acoustically adjacent said back enclosure, a third section acoustically adjacent said second port, and a second section acoustically connecting said first and third sections; said first, second and third sections each having two opposite walls defined by opposite walls of said housing; said first section having its remaining two walls defined by the top of said cabinet and by a first member extending between said opposite sides of said housing, said second section having its remaining two walls defined by the back of said housing and a second member extending between said opposite sides of said housing, said third section having its remaining two walls defined by the bottom of said housing and a third member extending between the opposite sides of said housing; said first member being located at an angle relative to said top of said housing such that a cross-sectional area of said first section increases in the direction toward said second section; said second member being located at an angle relative to said back of said housing such that the cross-sectional area of said second section increases in a direction toward said third section; and said third member being located at an angle relative to said bottom of said housing such that the cross-sectional area of said third section increases in a direction toward said second port.

2. The improvement of claim 1 in which the rate of increase of cross-sectional area of said sections is exponential, at least to a first approximation.

3. Sound reproducing apparatus comprising in combination, a rectangular housing having a top, a bottom, a back, a pair of sides and a front, said front having a speaker port and a second port, said speaker port being spaced above said second port; a first planar baffle disposed between said sides and extending from the front above the second port part-way toward said back; a second planar baffle disposed between said sides and extending from the rear edge of said first baffle part-way toward said top, said upper edge of said second baffle being spaced from said back to define a throat; means including a third planar baffle for coupling said throat to the rear of said speaker port, said third baffle extending part-way toward said front from said upper edge of said second baffle, the front edge of said third baffle being spaced from said top to define a throat for said coupling means which is in communication with the rear of said speaker port.

4. The combination of claim 3 in which said third baffle is inclined with respect to said top so that the coupling means provides a path of generally increasing cross-sectional area from its throat to the other throat.

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