Nov. 5, 1957 J. P. YOUNG 2,812,033

ACOUSTIC BAFFLE

Filed June 4, 1954 2 Sheets-Sheet 1

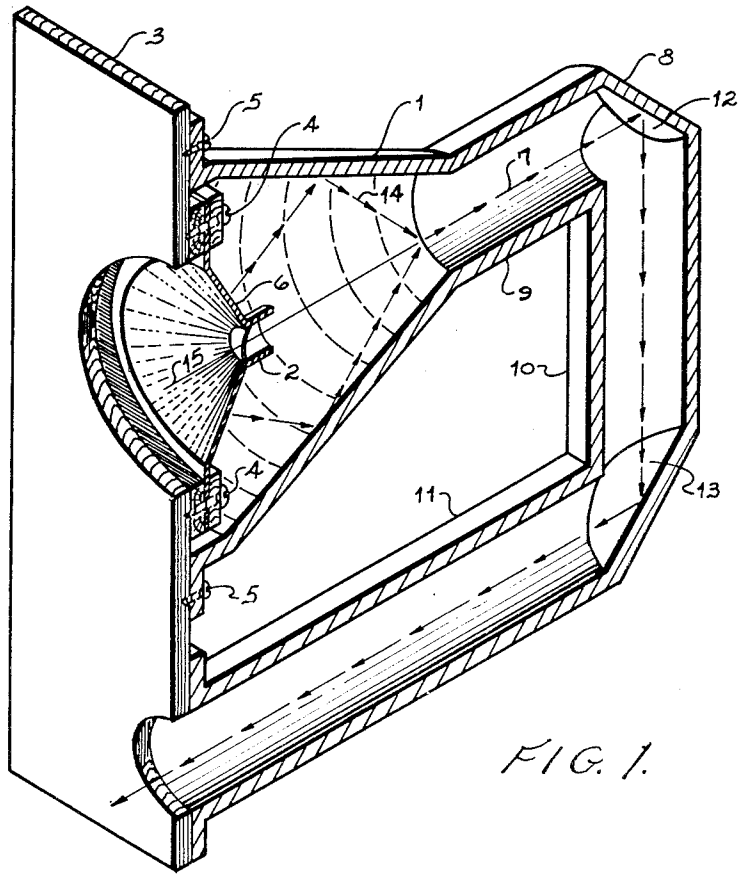


FIG. 1.

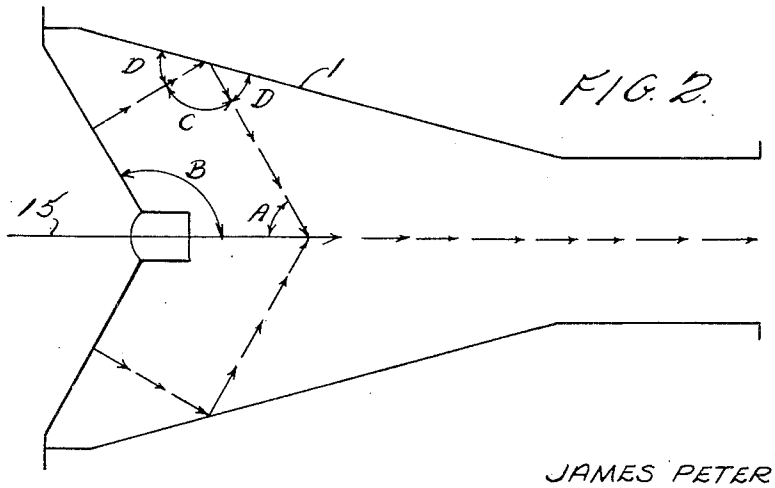


FIG. 2.

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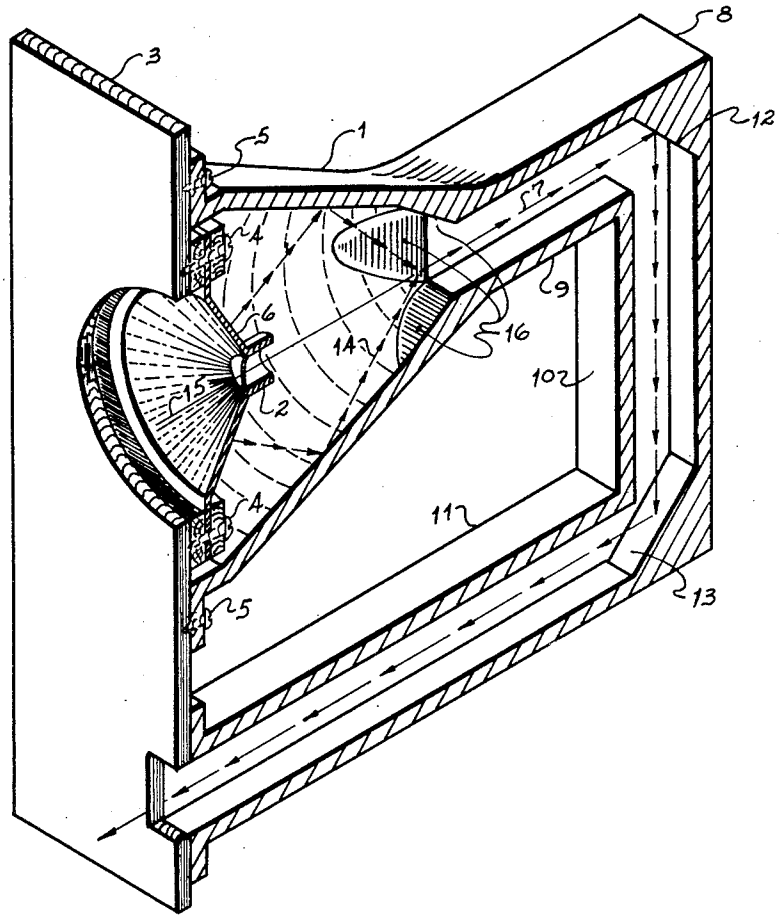


Fig. 3

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ACOUSTIC BAFFLE

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Application June 4, 1954, Serial No. 434,544

10 Claims. (Cl. 181—31)

My invention relates to loud speakers of the open radiator type and more particularly relates to baffles for use with such loud speakers.

Loud speakers of this type are transducers which convert incoming electrical signals of audio frequency into sound waves by urging the radiating element which is generally of the cone type into a back and forth reciprocating motion.

An ideal loud speaker would produce sound waves of uniform power for an incoming signal of constant amplitude regardless of the signal frequency. All loud speakers presently available, however, do not act in this fashion, but rather will only reproduce signals at the low frequency end of the audio spectrum, if at all, with greatly attenuated sound power.

In addition, it is found that these speakers, due to their mechanical construction, have resonant frequencies which fall within the low frequency audio range. The sound power of these speakers, instead of being attenuated, is sharply peaked and distorted at these resonant frequencies.

Investigations have shown that much of the sound power attenuation at low audio frequencies is caused by destructive cancellation of a first sound wave generated at the front of the radiating cone by a second and out of phase sound wave generated at the rear of the cone and transmitted toward the front of the cone. This cancellation only occurs for sound waves whose wave length is greater than the length of the acoustic path between the front and rear of the speaker cone.

Investigations have further shown that distortion and undesirable peaking of sound power at speaker resonance is created by excessive forward and backward excursions of the speaker cone.

Therefore, in order to improve the low frequency response of a loud speaker, it is necessary to eliminate or at least sharply reduce the dual effects of destructive cancellation and excessive cone excursions by lengthening the front to rear cone acoustic path and by limiting the amplitude of cone excursions at resonance.

When a loud speaker is mounted in a special type of enclosure called a baffle, it is possible to reduce either one or both of these effects to a minimum in the manner outlined above.

One type of baffle known as an acoustic labyrinth is often used to reduce these undesirable effects.

An acoustic labyrinth consists of a folded conduit or pipe containing an air column which can be resonated at a fundamental frequency determined by the length of the conduit. One end of the conduit is tightly coupled to the back of a loud speaker cone, while the other end is open to the atmosphere. The conduit is generally folded upon itself to save space and is mounted within a cabinet so that the open end is located either in the front or at the bottom of the cabinet. The cross sectional area of the conduit is generally made approximately equal to the projected area of the cone although it has been suggested that the cross sectional area may be reduced as a lower limit

to one half this projected area. The inner wall of the conduit is lined with sound absorbent material.

At a frequency equal to the first half wave length resonance of the labyrinth, the sound wave transmitted through the labyrinth and appearing at the open end of the conduit is in phase with the sound wave produced at the front of the loud speaker. Consequently, these two waves are additive and the sound power at this frequency is substantially increased. The increase extends over two octaves above and below this resonant frequency, and with proper design will extend within the region of greatest low frequency attenuation.

Moreover, an anti-resonance occurs at a frequency equal to the first quarter wave resonance of the labyrinth; the sound waves are opposed in phase and cancel each other and the sound power at this frequency decreases. Therefore, it is known to match this quarter wave length anti-resonance with the resonant frequency of the loud speaker and thus reduce the sound power generated in the system at this resonant frequency.

The inner wall of the conduit is lined with sound absorbent material in order to reduce frequency distortion created through reflection of sound waves from the conduit back toward the speaker.

For high fidelity sound reproduction, the conventional labyrinth has several very serious drawbacks. For example, while the sound power is reduced at the speaker resonant frequency, thus reducing the undesirable peaking, the reduction is accomplished by cancellation of sound waves and not by limiting the amplitude of the cone excursion; consequently, the excessive excursions still introduce distortion. In addition, despite the presence of sound absorbent lining, sound waves are reflected back and forth within each section of the folded conduit and again distortion is introduced into the system. Moreover, the conventional labyrinth requires a very large volume; for example, if a 15 inch diameter speaker is used and the labyrinth is tuned to a fundamental frequency of 15 cycles per second, a volume of approximately 100 cubic feet is required.

I have invented an improved acoustic labyrinth which obviates these disadvantages.

Accordingly it is an object of the present invention to provide a new and improved baffle of the character indicated.

It is a further object to provide a new and improved acoustic labyrinth which eliminates sound reflection within the labyrinth without the use of sound absorbent lining.

Another object is to provide a new and improved acoustic labyrinth which substantially eliminates both peaking and distortion caused by speaker resonance.

Still another object is to provide a new and improved arcoustic labyrinth which requires a much smaller volume than hitherto used.

These and further objects of the invention will either be explained or become apparent to those skilled in the art when this specification is studied in conjunction with the accompanying drawings wherein:

Figure 1 shows an acoustic labyrinth of circular cross section in accordance with the invention;

Figure 2 illustrates the various geometrical relations established within this labyrinth; and

Figure 3 shows an acoustic labyrinth of rectangular cross section in accordance with the invention.

Briefly stated my invention contemplates a special coupling element for coupling a loud speaker to a labyrinth in a manner in which no sound wave can be reflected back from the labyrinth toward the speaker. The length of the labyrinth is determined in the conventional manner by the desired resonant frequency; the cross sectional area of the labyrinth, however, is greatly reduced over

that conventionally used to provide sufficient acoustic loading for the speaker in order to reduce and limit excessive cone excursions at speaker resonance to acceptable values.

The coupling element is a hollow tapering cone-like member open at both ends. The loud speaker is mounted within the larger end with its cone projecting inwardly. The smaller end is connected to a folded labyrinth. The curvature and taper of the inner surface of the element bears such a relation to the curvature and taper of the speaker cone that all sound waves produced at the rear of the cone strike this inner surface and are reflected away from the cone and toward the labyrinth. This condition exists when the angle of intersection between the direction of reflection and the axial line through the apex of the speaker cone is always less than 90°. For angles satisfying this condition, the components of all sound waves whose directions are parallel to this axial line are additive, and the components whose directions are perpendicular to this line cancel each other and thus prevent sound reflection from the labyrinth toward the speaker.

I have experimentally determined, for reasons discussed previously, that the cross sectional area of the conventional labyrinth is incorrectly chosen in relation to the area of the corresponding speaker cone. Specifically, I have discovered that this cross sectional area must be greatly reduced to fall within the range of values shown in Table 1 which appears on the following page.

Table 1

Loud Speaker Diameter in Inches	Conventional Labyrinth Cross Sectional Area in Square Inches	Range of Cross Sectional Areas of My Labyrinth in Square Inches
6	27–36	4–12
8	48–64	7–22
10	75–100	11–33
12	108–144	15–48
15	169–225	23–75

It will be apparent from the above table that the cross sectional area of my labyrinth has been reduced to between ⅓ and 1/10 conventional size. The length of my labyrinth is determined in conventional manner.

Referring now to Figure 1, a coupling element of the character indicated is identified generally at 1. In this example, the element is a hollow right circular conic section open at both ends. A loud speaker 2 is secured by screws 4 within a panel section 3 of a cabinet (not shown). The section 3 is tightly fastened to the larger open end of element 1 by means of screws 5 so that the circular cone 6 of speaker 2 projects inwardly into the element. The axis of the speaker cone is aligned with the axis of the element 1.

The smaller open end of element 1 forms the entrance 7 to an acoustic labyrinth 8 which, in this example, comprises three folded sections 9, 10 and 11. Of course, any convenient number of sections can be used. The labyrinth is cylindrical in shape and has a uniform cross sectional area equal to the area of the smaller open end of element 1. The axis of section 9 is aligned with the axis of element 1. Guide members 12 and 13 are respectively inserted at the junction of sections 9 and 10 and the junction of sections 10 and 11. The function of these members will be discussed hereafter.

The cross sectional area of the labyrinth is related to the size of the speaker cone in accordance with the values set forth in Table 1.

The length of the labyrinth is selected to match the speaker resonant frequency with the anti-resonance of the labyrinth.

When sound power is supplied to speaker 2, sound waves 14 are emitted in a direction perpendicular to the rear surface of the speaker cone, strike the inner surface of element 1, and are reflected in the manner shown. It will be apparent that as long as the angle A established between the sound waves 14 and the axis 15 of the speaker cone is less than 90°, the components of sound waves 14 which are parallel to the axis 15 are additive and travel into the labyrinth. By virtue of the symmetry of the system, the sound wave components perpendicular to this axis cancel each other and hence no wave can be reflected back toward the speaker cone.

In order for A to have this desired value, the taper angle of element 1 and the taper of the speaker cone must depend upon each other in the manner shown in Figure 2.

B is the angle formed between the rear of the speaker cone and axis 15. A sound wave 14 traveling perpendicular to the rear surface of the cone strikes the inner wall of element 1 and is reflected toward axis 15. The angle between this reflected wave and axis 15 is defined as A. Because of the well-known properties of sound waves, the angle of incidence D at which the wave strikes the inner wall of element 1 is equal to angle of reflection D at which the wave is reflected from the inner wall.

Therefore,

$$90°+B+C+A=360°$$

Where,

$$C=180°-2D$$

And

$$A<90°$$

Consequently,

$$90°+B+180°-2D+A=360°$$

$$B-2D+A=90°$$

$$B-2D>0$$

$$D>\frac{B}{2}$$

Therefore the angles of taper of the speaker cone and element 1 must be so chosen that the angle of incidence at which the sound wave strikes the inner wall of element 1 must always be larger than one half the angle included between the rear of the speaker cone and the axis of the cone.

For optimum sound power, angle A must be quite small so that the components of sound waves parallel to axis 15 will be as large as possible.

The length of element 1 must have a minimum value sufficient to allow sound waves generated near axis 15 to be properly reflected. Consequently, as angle A is decreased, this length must be increased accordingly. I have found that satisfactory results are obtained for a 15 inch speaker diameter when $A=60°$ and the length of element 1 is 16 inches.

In order to eliminate parasitic sound reflection within each folded section of the labyrinth, I provide guide members 12 and 13 to guide sound waves 14 in the manner shown in Figure 1 and thus prevent any reflection of this kind.

It will be apparent from the preceding discussion that other speaker cone configurations can be used with appropriately modified coupling elements to provide the same type of non-reflective coupling.

Figure 3 shows a system similar to that shown in Figure 1 wherein like components are identified in like manner. However, for ease of construction, the cross sectional area of the labyrinth is rectangular and preferably in the shape of a square. It is therefore necessary to modify the shape of element 1 so that the smaller open end of this element can be coupled to the labyrinth of rectangular cross section. This is done by flattening selected inner surfaces 16 of element 1 adjacent to the smaller open end in the manner shown. Due to the different labyrinth cross section, guide members 12 and 13 must also be modified in the manner shown.

I have installed a 15 inch diameter permanent magnet

speaker having a nominal 8 ohm impedance in my labyrinth and have plotted the measured changes in the speaker impedance against changes in applied frequency as this frequency was incrementally increased from 20 C. P. S. to 1000 C. P. S. The total impedance variation over this entire range was on the order of 2 ohms. Similar tests conducted on conventional systems produced variations on the order of 20–30 ohms and higher over an applied frequency range between 20 C. P. S. and 100 C. P. S.

While I have described and pointed out my invention within the environment illustrated by the embodiments shown, other modifications within the scope and sphere of my invention will be apparent to those skilled in the art. It is my intention therefore to be limited only as indicated by the scope of the claims which follow.

What is claimed is:

1. In an acoustic baffle, an acoustic labyrinth; a tapered hollow generally conical coupling element open at both ends, the smaller end being coupled to said labyrinth; and a loud speaker mounted in the larger end of said element and provided with a speaker cone projecting inwardly into said element, the extended center line of said labyrinth, said element and said loud speaker being coincident.

2. In an acoustic baffle, an acoustic labyrinth having a uniform cross sectional area; a tapered hollow generally conical coupling element open at both ends, the smaller end being coupled to said labyrinth and having an opening whose area is equal to said uniform area; and a loud speaker mounted within the larger end of said element and provided with a speaker cone projecting inwardly into said element, the extended center lines of said labyrinth, said element and said speaker being coincident, the area of a circle defined by the diameter of said speaker being between 3–10 times as large as that of said uniform area.

3. The baffle as set forth in claim 2 wherein the inner surface of said element has a taper angle at which all sound waves emitted by said cone and striking said surface have an angle of incidence which is less than 90°.

4. In an acoustic baffle, a folded labyrinth having a constant cross sectional area; a hollow truncated conical section, the smaller end of said section having an area equal to said labyrinth cross sectional area and coupled to the labyrinth entrance; a loud speaker mounted in the larger end of said section and provided with a speaker cone projecting inwardly into said section, the taper angles of said section and said cone having a selected relation at which all sound waves generated rearward from said speaker strike the inner surface of said section at an angle of incidence less than 90°.

5. The baffle as set forth in claim 4 wherein said angle of incidence is larger than one half the angle included between the rear of the speaker cone and the cone axis.

6. The baffle as set forth in claim 4 wherein the ratio of the area of the small end of said section to the large end thereof has a maximum value of substantially 1 to 3, said ratio resulting in substantial elimination of excessive cone excursions at the speaker resonant frequency.

7. In an acoustic baffle, a folded labyrinth having a predetermined cross sectional area and a selected resonant frequency and first quarter wave length anti-resonant frequency; a truncated hollow conical section, the smaller end of said section being coupled to the entrance to said labyrinth and having the same cross sectional area; and a loud speaker mounted within the larger end of said section and provided with a speaker cone projecting inwardly into said section, the plane projected area of said speaker being substantially equal to the area of said larger end, the area ratio of said larger end to said smaller end ranging between 10 to 1 and 3 to 1, said speaker having a resonant frequency which equals said anti-resonant frequency.

8. In an acoustic baffle, in combination with an acoustic labyrinth and a loud speaker provided with a speaker cone, a tapered hollow generally conical coupling element open at both ends, the smaller end being coupled to said labyrinth, said loud speaker being mounted in the larger end of said element with said speaker cone projecting inwardly into said element, the extended center line of said labyrinth, said element and said loud speaker being coincident.

9. An acoustic baffle as set forth in claim 4 wherein said angle of incidence is larger than one half the angle included between the rear of the speaker cone and the axis of said section.

10. An acoustic baffle as set forth in claim 4 wherein said labyrinth is provided with a plurality of folded sections and a like plurality of sound guide members, each member being mounted in one end of the corresponding section to prevent parasitic sound reflection therein.

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