Feb. 9, 1943. P. W. KLIPSCH 2,310,243

HORN FOR LOUDSPEAKER

Filed Feb. 5, 1940

Fig. 1

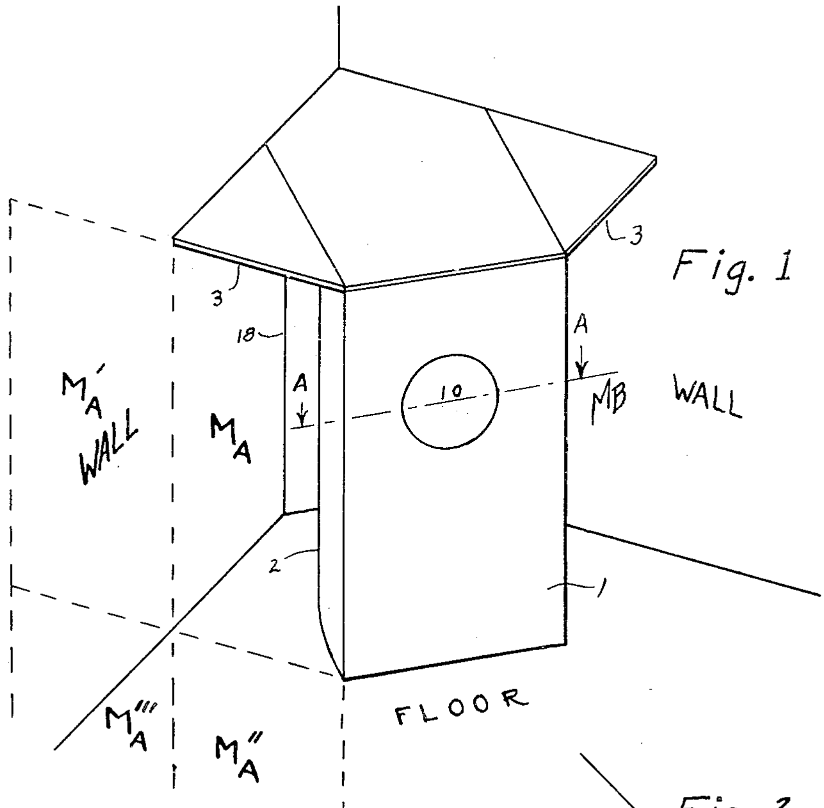


Fig. 2

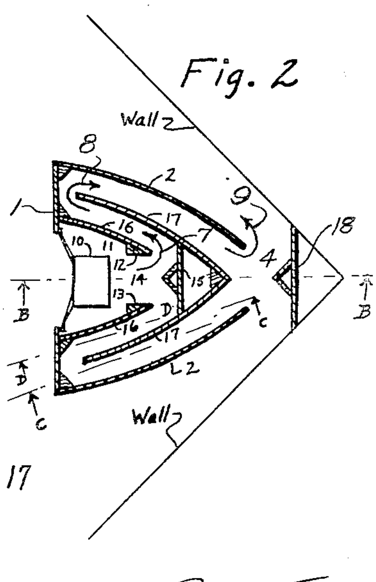


Fig. 3

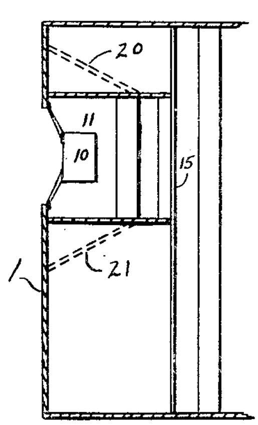
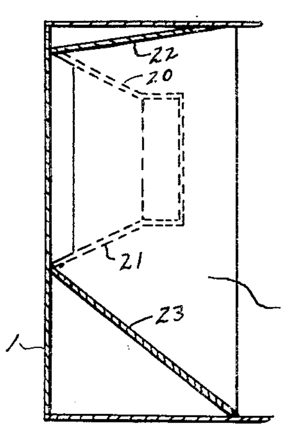


Fig. 4



INVENTOR.

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2,310,243

HORN FOR LOUD-SPEAKER

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7 Claims. (Cl. 181—27)

This invention relates to horn loud-speakers, particularly to the type wherein the horn is curled or folded to shorten its overall dimensions compared to the axial length of the horn.

It is well established that loud-speakers, in order to reproduce a given frequency range, must have dimensions comparable to the longest wave length corresponding to the lowest frequency in the range. In the case of horns the rate of flare, the length of horn tube, and the area of the mouth opening all must be determined by the wavelengths to be reproduced. It is customary to shorten the outside dimensions of horns by folding, but even then the dimensions of the mouth opening must be large if the frequencies to be reproduced include very low frequencies. For residential use the non-directional or flat baffle is usually employed in conjunction with a large conical diaphragm, such constructions being suitable from the standpoint of physical size, but possessing the disadvantage of low efficiency, especially at low frequencies. The combination of a folded horn for low frequency reproduction and a second radiating region for the high frequencies has been proposed and used to some extent for domestic radio and sound systems. One such arrangement in which the same diaphragm served for both sources was described by Olson and Hackley in a paper "Combination Horn and Direct Radiator Loud-Speaker," Proc. I. R. E. Dec. 1936, page 1557.

It is the object of this invention to provide means for efficiently reproducing the lower range of the audio spectrum with acoustic elements of restricted size.

More specifically, it is an object of the present invention to provide a loud-speaker for the lower audio frequency register consisting of a horn or directional baffle which is folded to reduce its outside dimensions, and in which the walls of a room in which the speaker is to be operated form a part of the boundaries of the horn tube.

A further object is to provide a horn baffle formed with a series of tubes bounded by rigid walls, the tubes expanding from a throat at a suitable rate of flare, and terminating in a mouth opening of insufficient size to radiate the lowest frequencies whereby the total size of the horn unit is satisfactory for use in rooms of ordinary size, the outer walls or baffle of the horn being so arranged that when placed in the corner of a room the walls of the room cooperate with the enclosure to form an additional length of expanding horn terminating in a mouth opening adequate to deliver efficiently sounds of the lowest frequency it is desired to transmit. Incidentally, the physical size of the unit is such that it will go through an average size door, which might well be stated as another object of the invention.

These and other objects will be evident from the following description taken in connection with the illustrations in which:

Fig. 1 is an oblique projection view of a loud-speaker in accordance with the present invention,

Fig. 2 is a sectional view from the top taken on line A—A Fig. 1 and showing the baffles constituting the folded horn,

Fig. 3 is a section view from the side taken on line B—B Fig. 2 and showing the arrangement of transducer and throat, and

Fig. 4 is another sectional view from the side taken on line C—C Fig. 2 and showing the guides or baffles in the next to last section of horn.

While outdoor sound installations are common, the normal environment of a loudspeaker is a room or hall. The vast public acceptance of broadcasting has resulted in an enormous number of loud-speakers situated in the rooms of residences. Such loud-speakers are designed to be complete within themselves so that they are suitable for any environment. Since, however, the room is the normal environment, it seems justified to design a loud-speaker for such environment to utilize the properties of the environment for the improvement of the speaker performance.

In the present invention, the effect of room walls flaring away from a corner is taken advantage of to complete the length of tube at suitable flare rate of a horn type loud-speaker.

The design shown in the drawing consists of a transducer working into the throat of an exponentially expanding horn, suitably folded to reduce the overall dimensions. As shown, the structure is too short, and the mouth too small for efficient reproduction, but when placed in the corner of a room, the walls of the room bound an additional fold or section of the horn completing the horn length and continuing the flare so that the effective mouth opening is brought up to the desired area. The saving in material otherwise required to complete this last fold is obvious, and the reduction in size of the speaker to such dimensions that it can be readily manufactured, handled, transported and placed in service is obviously of considerable value to the user. A further advantage due to wall reflection will later be made apparent.

In Fig. 1 the walls and floor forming the corner of a room also form the outside of the last fold of the horn. It will be seen that there are two mouths M_A and M_B in the particular construction shown. The last section of horn is bounded by a wall and a baffle 2, and by the floor and a wing-like cover 3. Sound is admitted to this last section of horn through the last fold (4 in Fig. 2). The baffle 2 is preferably curved to give it rigidity, but it may be flat, as shown by Olson and Massa "A compound horn loudspeaker," Journal of the Acoustical Society of America, July, 1936, pp. 48–52 wherein Fig. 6 shows horns with true exponential curves and with straight sides approximating the true curve. These authors state that comparisons indicated very little difference below 300 cycles.

Fig. 2 is a sectional view A—A of Fig. 1 and is a view from the top through transducer 10, air chamber 11 with walls 12 and 13, throat 14, and interior baffles 15, 16, and 17. The arrows show the direction of a wave generated by the transducer as it expands outward through the various sections of the horn.

Fig. 3 is a vertical section through B—B showing a side elevation of the transducer, air chamber, and throat. The dotted lines show the baffles bounding the first section of horn opening up to the left. Baffles 20 and 21 lie between and span the space between baffles 16 and 17 of Fig. 2 whereby the wave passing from the throat 14 around the ends of the baffles 16, as indicated by the arrow 7, is permitted to expand slowly before passing around the forward edges of baffles 17 as indicated by the arrow 8.

Fig. 4 is another vertical section, through the part of the horn marked C—C in Fig. 2. Baffles 22 and 23 bound the upper and lower sides of the next to last section of horn shown in Fig. 2 as being bounded by vertical baffles 17 and 2 and from which the sound waves travel in the direction indicated by the arrow 9. The dotted lines in Fig. 4 show the upper and lower bounding baffles of the next preceding section of horn, 20 and 21 lying, as already indicated, between baffles 16 and 17 in Fig. 2.

In order to avoid an unduly large air chamber in the apex of the corner of the room, the corner baffle 18 (Figs. 1 and 2) is arranged so the sectional area of the horn increases regularly around the fold 4.

An important advantage of the arrangement shown is that the constructional dimensions of the loud-speaker are smaller than the actual mouth opening R_A+M_A, and in addition, the walls and floor form reflectors which effectively make the mouth area four times the actual area. Thus one wall forms an image M_A' of the actual mouth M_A, and the floor and its image form images M_A'' and M_A''' respectively of M_A ad M_A'. In the absence of the walls extending outwardly through the mouths of the speaker, the actual mouth opening would have to be four times as large (in area) to give equivalent performance. Or putting it the other way about, the presence of the walls bisecting a virtual or effective mouth leaves only one fourth as large a mouth opening necessary to perform the function of a given size of mouth. The dotted lines indicate the boundaries of mirror-images of the horn mouth produced by the presence of the walls. This principle is illustrated by Olson "Elements of Acoustical Engineering" (Van Nostrand, 1940) Fig. 2.1, page 21. It is shown also by Wente in United States Patent 2,135,610 wherein the presence of the ceiling produces an image and increases the effective heighth of the mouth.

The cut-off frequency of a horn is determined by the rate of flare of the horn and the area of the mouth opening. The diameter of the mouth opening must be larger than about ¼ or ½ wave length in order to transfer the wave efficiently from the horn to free space. If the mouth is not circular, the diameter of a circle having the mouth area may be used to determine the cut-off due to mouth size.

One design for a speaker of the type disclosed here consists of the following constants:

Table

Flare constant in the exponential equation defining the horn area A in terms of the throat area A_0, $A=A_0e^{mx}$, where x is the horn length expressed in inches	m=0.045
Length of horn............inches	69
Throat area............sq. in..	64
Mouth area (actual)............do..	1440
Mouth area (effective)............do..	5760
Low frequency cut-off due to flare ....cycles..	45
Diameter of equivalent circle having an area equal to the effective mouth area ....inches..	86
Frequency at which equivalent diameter of mouth is ½ wave length..cycles..	73

The front panel 1 of Fig. 1 for such a design need be only 28 inches wide and 48 inches high, dimensions of such order that the unit may be readily transported and will clear the average dwelling door. Wings 3 of Fig. 1 may be dismounted for transport.

Such a design involves dimensions at the curved parts of the passageways connecting the various folds which preclude good performance above about 1500 cycles. For this reason, the transducer 10 is arranged to radiate the high frequencies from its front surface, while the low frequencies are delivered from the rear surface to the throat to be ultimately radiated from the horn mouth. The transducer is a conical diaphragm, the front of which is open to space and the back of which is loaded by the throat of the horn. The design of the elements and the selection of a cross-over frequency from high frequency front radiation to low frequency horn operation is discussed by Olson et. al., in the aforementioned paper. The crossover frequency may be controlled by the volume of the air chamber 11 in its relation to the throat impedance.

The design illustrated assumes the choice of a large diaphragm transducer, but obviously by lengthening the horn to produce a smaller throat the horn may be fed by a small diaphragm. The horn may be used as a low frequency unit and supplemented by smaller speakers operating at higher frequency ranges, or be operated as discussed above with a single diaphragm for the two frequency ranges.

The design data in the table shows an effective mouth area of 5760 square inches, whereas the front panel 1 (Fig. 1) plus the actual mouths M_A and M_B possess a combined area of only 2740 square inches or less than half the effective mouth area. In the absence of the walls and floor extending out from the mouths, the effective mouth area would be so reduced that its equivalent diameter would be of the order of one-half wave-length at a frequency of about 150 cycles.

In the present invention, the presence of the walls and floor are taken advantage of to increase the effective mouth opening, whereby a slowly flared horn may develop its full capability in the low frequency register without the necessity of exceedingly large horn or baffle structures.

Any material possessing suitable rigidity may be used for the baffles. Molded material, plywood, and the like which have been used in other horn and directional baffle structures may, of course, be used here.

The terms horn and directional baffle have been used synonymously, both being used to designate flaring horn structures, the term horn being generally used to designate one having a small throat adapted to load a small diaphragm, and directional baffle designating a large throat horn adapted to load a large conical diaphragm. For a given frequency performance, the only difference is the length since the mouth opening and the rate of flare must be the same in each case.

Obviously the speaker just described may be fitted with outer side walls to take the place of the walls of the room. If such side walls extend out from the mouths to form reflectors, the same performance will be obtained as if the speaker shown were operated in the corner of a room. In such event a sufficient outward extension would be of the order of the width of the actual mouth opening. Thus a speaker as described is adapted for more versatile service and need not be limited to its room corner environment; it might, for example, be operated in the open, or on a theater stage, by fitting it with artificial walls.

I claim:

1. In a loud speaker horn adapted to be located in a corner formed by and to cooperate with three mutually perpendicular walls so that said walls together with the horn structure form a part of the horn the combination of, a pair of non-parallel baffles perpendicular to one of said surfaces, a panel extending between said baffles at their most widely separated edges and transversely of the plane bisecting the angle formed by the other two of said mutually perpendicular walls, a cover fitting upon said panel and parallel to said first surface and baffles, said cover extending sidewardly therefrom to abut the two side walls, said baffles being more closely spaced to said side walls at their most closely spaced edges than at their most widely spaced edges by an amount substantially of the rate of one-half for each increment of length along the side walls of $\lambda_0/18$ where λ_0 is the longest wave length to be transmitted by said horn, and means within the enclosure formed between the pair of baffles forming an elongated horn section, said section at its large end communicating with the air column formed by the baffles and the side wall surfaces and at its small end communicating with a sound source.

2. In a horn type loud speaker wherein three mutually perpendicular wall surfaces cooperate to form a part of the speaker which comprises, a substantially rectangular panel extending substantially normal to a plane bisecting the angle formed by two of said wall surfaces and to the third wall surface, said panel being of a width to provide open spaces between its side edges and the two wall surfaces, baffles with edges abutting said side edges and other edges in abutting relation with said third wall surface and extending convergingly from said panel toward the corner formed by said two surfaces whereby a speaker enclosure is formed by the panel, baffles and the third wall surface, said baffles terminating in spaced relation with each other and the said wall surfaces, a cover member in abutting relation with said baffles, said panel and said two wall surfaces whereby a horn section is formed between said wall surfaces and said baffles and whereby said horn section is divided by the enclosure formed by said baffles, panel and cover member, and additional baffles within the speaker enclosure forming a further length of tapered horn terminating at its large end in the divided horn section formed by the mutually perpendicular wall surfaces and the first mentioned baffles and at its small end terminating in an air chamber adapted to be closed by a vibrating diaphragm sound source, two of said additional baffles being arranged within the speaker enclosure and forming with the first mentioned baffles a pair of horn sections opening into the first mentioned horn sections.

3. In a horn type loud speaker wherein three mutually perpendicular wall surfaces cooperate to form a part of the speaker which comprises, a substantially rectangular panel extending substantially normal to a plane bisecting the angle formed by two of said wall surfaces and to the third wall surface, said panel being of a width to provide open spaces between its side edges and the two wall surfaces, baffles with edges abutting said side edges and other edges in abutting relation with said third wall surface and extending convergingly from said panel toward the corner formed by said two surfaces, said baffles terminating in spaced relation with each other and the said wall surfaces, a cover member in abutting relation with said baffles, said panel and said two wall surfaces whereby a horn section is formed between said wall surfaces and said baffles and whereby said horn section is divided by the enclosure formed by said baffles, panel and cover member, and additional baffles within the speaker enclosure forming a further length of tapered horn terminating at its large end in the divided horn section formed by the mutually perpendicular wall surfaces and the first mentioned baffles and at its small end terminating in an air chamber adapted to be closed by a vibrating diaphragm sound source, two of said additional baffles extending substantially parallel with said first mentioned baffles and forming therewith a pair of horn sections opening divergingly into the first mentioned horn sections.

4. In a horn type loud speaker wherein three mutually perpendicular wall surfaces cooperate to form a part of the speaker which comprises, a substantially rectangular panel extending substantially normal to a plane bisecting the angle formed by two of said wall surfaces and to the third wall surface, said panel being of a width to provide open spaces between its side edges and the two wall surfaces, baffles with edges abutting said side edges and other edges in abutting relation with said third wall surface and extending convergingly from said panel toward the corner formed by said two surfaces, said baffles terminating in spaced relation with each other and the said wall surfaces, a cover member in abutting relation with said baffles, said panel and said two wall surfaces whereby a horn section

is formed between said wall surfaces and said baffles and whereby said horn section is divided by the enclosure formed by said baffles, panel and cover member, and additional baffles within the speaker enclosure forming a further length of tapered horn terminating at its large end in the divided horn section formed by the mutually perpendicular wall surfaces and the first mentioned baffles and at its small end terminating in an air chamber adapted to be closed by a vibrating diaphragm sound source, said additional baffles being arranged in pairs extending in opposite directions and forming successive diverging pairs of horn sections, the outermost of said horn sections opening into the first mentioned horn sections.

5. In a loud speaker horn wherein three mutually perpendicular wall surfaces cooperate to form a part of the horn the combination of, a substantially rectangular panel extending substantially perpendicular to a plane bisecting the angle formed by two of said wall surfaces and to the third wall surface, said panel being of a width to provide open spaces between its side edges and the two wall surfaces, baffles with edges abutting said side edges and other edges in abutting relation with said third wall surface and extending convergingly from said panel toward the corner formed by said two wall surfaces, said baffles terminating in spaced relation to each other and the said wall surfaces, a cover member in abutting relation with said baffles, said panel and said two wall surfaces whereby a horn section is formed between said wall surfaces and said baffles and whereby said horn section is divided by the enclosure formed by said baffles, panel, and cover member, and additional baffles within said enclosure forming a further length of tapered horn terminating at its large end in said divided horn section and terminating at its small end in an aperture adapted to be closed by a vibrating diaphragm sound source.

6. In a loud speaker horn wherein three mutually perpendicular wall surfaces cooperate to form a part of the horn the combination of, a substantially rectangular panel extending substantially perpendicular to a plane bisecting the angle formed by two of said wall surfaces and to the abutting third wall surface, said panel being of a width to provide open spaces between its side edges and the two wall surfaces, baffles with edges abutting said side edges and other edges in abutting relation with said third wall surface and extending convergingly from said panel toward the corner formed by said two wall surfaces, said baffles terminating in spaced relation to each other and the said wall surfaces, a cover member in abutting relation with said baffles, said panel and said two wall surfaces whereby a horn section is formed between said wall surfaces and said baffles and whereby said horn section is divided by the enclosure formed by said baffles, panel, and cover member, and additional baffles within said enclosure forming a further length of tapered horn terminating at its large end in said divided horn section and terminated at its small end in an apertured member, and a vibrating diaphragm sound source closing said aperture.

7. In a loud speaker wherein three mutually perpendicular surfaces cooperate to form a part of the horn the combination of, a substantially rectangular panel extending substantially perpendicular to a plane bisecting the angle formed by two of said wall surfaces and to the third wall surface, said panel being of a width to provide open spaces between its side edges and the two wall surfaces, baffles with edges abutting said side edges and other edges in abutting relation with said third wall surface and extending convergingly from said panel toward the corner formed by said two wall surfaces, said baffles terminating in spaced relation to each other and the said wall surfaces, a cover member in abutting relation with said baffle, said panel and said two wall surfaces whereby a horn section is formed between said wall surfaces and said baffle and whereby said horn section is divided by the enclosure formed by said baffles, panel and cover member, additional baffles within the said enclosure forming a further length of tapered horn terminating at its large end in said divided horn section and terminated at its small end by an apertured member arranged and constructed for the aperture therein to be closed by a vibrating diaphragm sound source, and baffles diverging from said panel toward the corner and extending between and forming a passage diverging toward the free edges of the converging baffles.

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The above entitled patent was extended October 2, 1951, under the provisions of the Act of June 30, 1950, for 6 years and 120 days from the expiration of the original term thereof.

Commissioner of Patents.