Oct. 22, 1957 W. J. D. VAN DIJCK 2,810,448

LOUD-SPEAKER ENCLOSURE

Filed Dec. 27, 1954 2 Sheets-Sheet 1

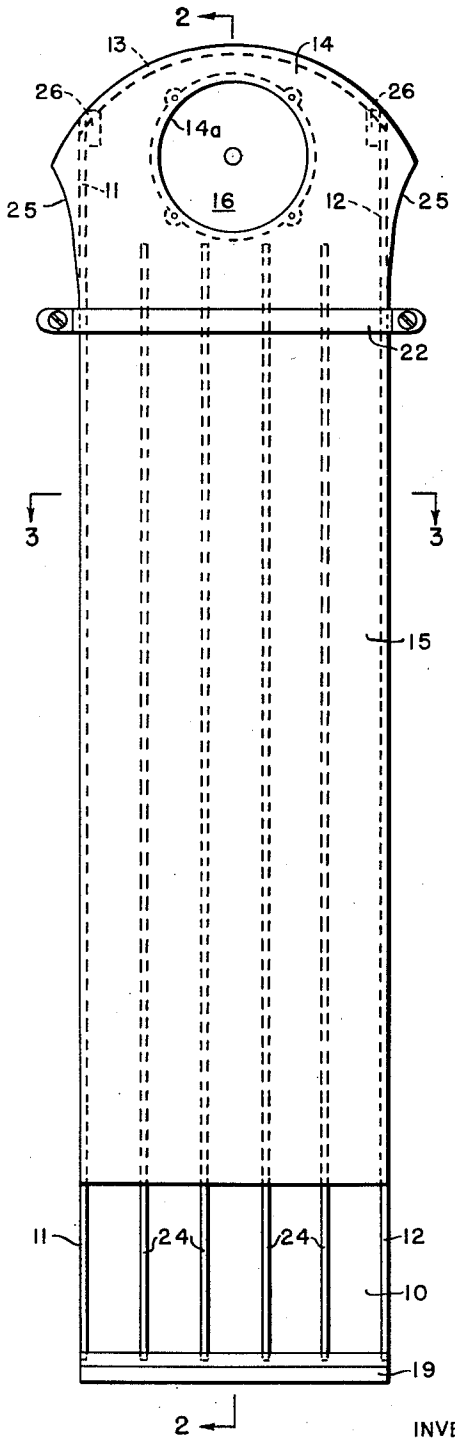


FIG. 1

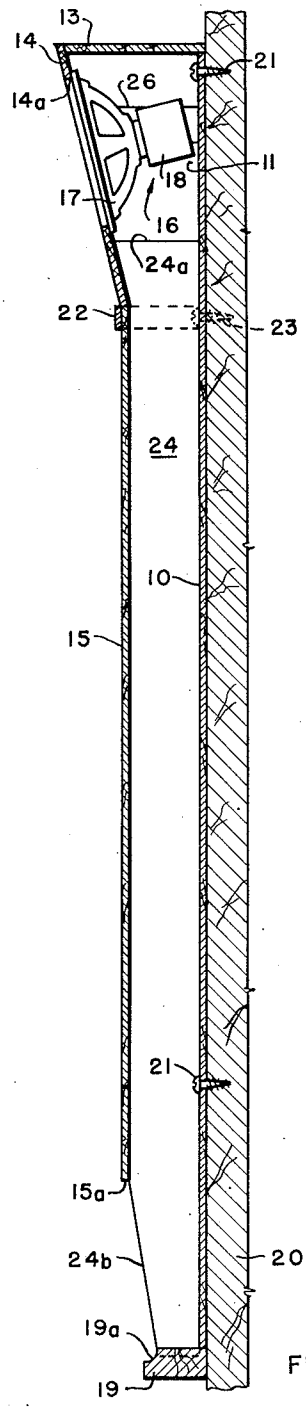


FIG. 2

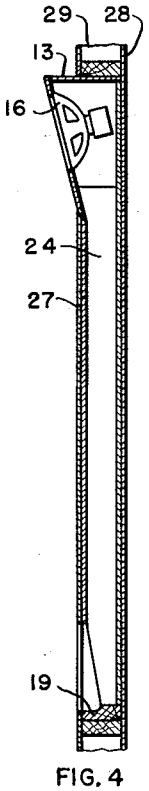


FIG. 4

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Filed Dec. 27, 1954 2 Sheets-Sheet 2

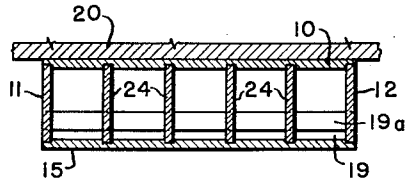


FIG. 3

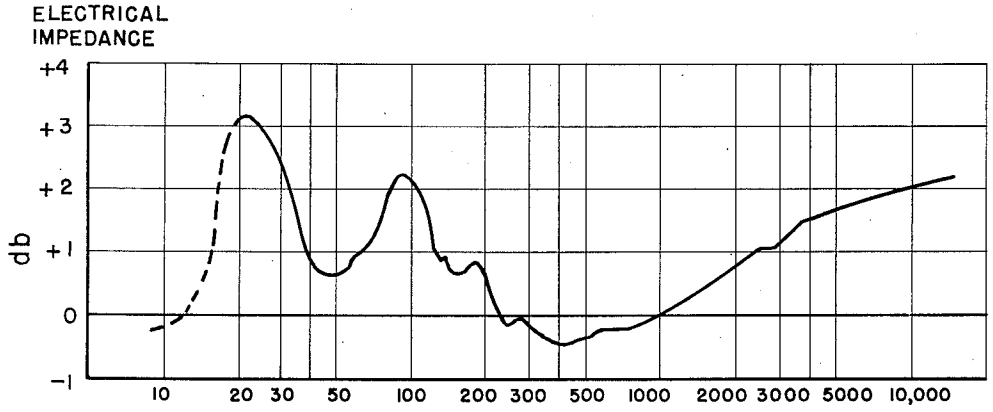


FIG. 5

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LOUD-SPEAKER ENCLOSURE

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Application December 27, 1954, Serial No. 477,753

20 Claims. (Cl. 181—31)

This invention relates to sound reproduction systems and is more particularly concerned with an improved enclosure or cabinet for a direct-radiator loud-speaker and with a loud-speaker system that includes such an enclosure, combining the features of conveniently small size and high fidelity of frequency response, particularly in the low part of the frequency range, including a good reproduction of transients.

For a faithful reproduction of sound it is known that the reproduction apparatus should have an equal reproduction of all the frequencies the ear can hear, that also the transients should be reproduced faithfully and that, in particular for orchestra music, the non-linear distortions must be extremely small.

It is also known that the special distribution of the sound in the various directions should be uniform and should resemble the distribution of the original performance. This poses for the higher frequencies certain problems which can be overcome, however, by distributing devices and most effectively by using two or more identical loud speakers in phase.

Less attention, however, is given to the proper inclination of the front of the sound wave, which is also important. In a concert hall the normal to the sound front tends to dip into the absorbing audience, so that the sound seems to emanate from a virtual source above the musicians. This effect is as a rule enhanced by the reflection characteristics of the back wall of the podium. For a faithful reproduction the loud speaker should therefore be placed at a moderate elevation above the floor and the axis, pointing in the average direction toward the ears of the audience, should be inclined downwards at an angle of about 10°–15° from the horizontal. This at the same time eliminates the casting of sound shadows by furniture or other listeners; in many installations wherein the loud speakers are placed low to the floor such shadows make the high frequency performance of otherwise high fidelity equipment completely illusory.

The necessarily elevated position of the loud speaker, however, poses a severe problem how to construct the loud speaker enclosure essential for the faithful reproduction of the low frequencies and the transients of low tone percussion instruments. The usual enclosures or baffles are bulky and spacious and a large-diameter speaker has heretofore usually been required to achieve sufficient radiation at low frequencies. The installation of such appliances on or within the walls of buildings is impracticable or expensive and such appliances do not lend themselves very well to an aesthetic or at least an acceptable construction at an elevated position on a wall.

If, for example, one wishes to avoid destructive interference with sound radiation from the front of the speaker by radiation emitted from the rear by mounting the speaker in a speaker opening formed in a baffle or screen, the baffle must have a diameter of about 8 ft. for faithful reproduction of frequencies as low as 50 cycles per sec.

If, on the other hand, one wishes to suppress the radiation from the rear by mounting the loud-speaker in the wall of a closed, sound-absorbent cabinet, the latter must have a volume of about 18 cu. ft. A more favorable appliance is a box with an aperture and acting as a Helmholtz resonator which is tuned to the resonant frequency of the loud-speaker; such a device is known as a bass-reflex cabinet or an acoustical phase inverter. Thus, for a 12-in. diameter loud-speaker, having a resonant frequency of 60 cycles per sec., the required size of such a cabinet is about 5.3 cu. ft. Recently a further improvement in the last-mentioned device was introduced by W. Joseph and F. Robbins (Audio Engineering, vol. 37, pp. 19, 20 and 67–71, January 1953); by increasing the damping effect of the resonance system they were able to reduce the size to about 2.7 cu. ft.

Elimination of the cavity resonance has been sought by the use of acoustic labyrinths; such a system, involving baffles made of or lined with sound-absorbent material arranged to define a folded tube providing a tortuous path for repeated reflections of sound waves, the closed end of the tube being coupled acoustically to the speaker and the tube having a length corresponding to the half wave-length of a low frequency where the speaker is deficient, is described by Benjamin Olney (U. S. Pat. 2,031,500; Journal of the Acoustical Society of America, vol. 8, pp. 104–111, October 1936). This approach, likewise, leads to a bulky installation, about 4 cu. ft. being required for a speaker with an 8-in. diameter cone. The use of labyrinths, which necessarily involve sudden changes in directions and other variations in the acoustical characteristics of the sound duct, results in reflections and poor reproduction of transients.

It is an object of this invention to provide an improved enclosure system and an enclosure or cabinet suitable for direct-radiator loud-speakers which is capable of faithful reproduction of sounds in the low part of the audible frequency range as well as giving excellent transient response and which has a still smaller volume than prior devices.

A further object is to provide an enclosure system and an enclosure of the type described which fulfills all the acoustical desiderata as above-stated and is not only more aesthetically acceptable than the generally cubic boxes used in prior systems, but can be shaped to have a shallow depth, which facilitates convenient installation, for example, against or within an ordinary wall of a building.

Still another object is to provide an enclosure system and an enclosure for loud-speakers that will effectively reproduce sounds down to and including those in the lowest part of the audible sound range with a direct-radiator loud-speaker having a cone diameter smaller than that required for like reproduction with the prior appliances considered above.

In summary, the enclosure according to the invention has confining walls defining an elongated, substantially straight passage that is closed at one end and open at the other, in the nature of a covered organ pipe, having an effective length close to one-fourth the wave length of sound corresponding to the natural resonant frequency of the free loud-speaker, the speaker being tightly coupled acoustically to the closed end of the passage, and the enclosure contains partition means, such as a plurality of longitudinal partition walls that terminate short of the closed end and subdivide the passage into a plurality of narrow channels having a combined cross section which is advantageously approximately equal to the area of the speaker cone, said channels being open at both ends thereof and in communication with a common terminal space at the closed end of the passage to which the speaker is coupled, the channels having sound-absorbent walls and the channel widths being sufficiently

small to achieve effective damping of the higher harmonics of the fundamental frequency of the enclosure.

The speaker is mounted in a speaker opening formed in an outer wall of the enclosure bounding the said terminal space at the closed end, the expression "speaker opening" being used herein to designate an opening having a shape and size to fit the loud-speaker diaphragm or frame so that the diaphragm is sealed to the wall to insure tight acoustic coupling. The said outer wall thereby prevents sound radiation from the rear of the speaker from passing around the immediate edge of the speaker for interference with the radiation from the front of the speaker. Although but one loud-speaker is specifically mentioned herein, it is evident that the invention is applicable also to the case wherein a plurality of speakers, connected electrically to have their coil-driven diaphragms operate in phase, are mounted in individual speaker openings at the closed end of the enclosure; such speakers may be given different orientations to give a desired directional characteristic to the sound radiated from the front of the system.

The resonant or natural frequency of the free speaker referred to herein is the lowest resonant frequency within the audible range, in cases where the speaker has more than one resonant frequency.

As regards the longitudinal partitions, it is not essential to their damping effects that they be impervious or even that they extend completely across the passage between opposed walls; thus, they may be perforated. In the preferred case of a shallow enclosure, such as will be described in connection with the drawings, for structural reasons the partitions advantageously take the form of separator walls extending fully between and fixed securely to the wider sides, which are usually the front and rear enclosure walls, thereby insuring a very stiff construction; this, together with the use of suitable material, prevents resonances in the partition walls. The use of additional partitions, arranged to produce a honeycomb or an eggcrate construction, and/or of enclosures that are not shallow, is not excluded. The walls bounding the said narrow channels should be of material having a high acoustic damping effect; thus, the partitions and/or the enclosure walls may be lined with or constructed of so-called acoustically dead material, such as pressed fiber board, soft-board, etc. The narrow channels should, however, be free from or substantially free from absorbent filling or packing material to avoid damping the lower frequency sounds and should extend for at least the major part of the length of the passage, preferably the full length save for the terminal space at the closed end, so that the channels establish free communication between the outside of the enclosure end the said terminal space. Sudden changes in cross section or substantial changes in direction or even substantial changes in damping materials along the lengths of the narrow channels, which would interfere with the faithful reproduction of transients, should be avoided and the preferred construction includes a set of straight, parallel, tubular channels of constant cross section made of uniform materials. Parallelism is, however, not an absolute requirement.

The invention is based on the principle that the following combination of features should be jointly present in the system:

(1) The enclosure is a tube that acts as an open resonator having a fundamental resonant frequency that is equal to or substantially equal to the resonant frequency of the loud-speaker, and the tube as a whole (including the several channels) produces approximately the same acoustic radiation resistance as the speaker.

(2) There is a strong acoustic coupling between the loudspeaker and the air in the tube.

(3) The acoustic system is adequately damped.

(4) No other interfering resonances are present in the range of frequencies which one wishes to reproduce.

The open resonance system which has the smallest volume, with the requisite acoustic radiation resistance, appeared on investigation to be the closed pipe, also known as the covered organ pipe, which has a fundamental resonant frequency corresponding to sound with a wave length four times that of the effective length of the pipe. In such a pipe the highest pressures occur at the closed end and so, in order to obtain a high acoustic coupling with the loud-speaker, the latter is located close to this end. To achieve adequate damping, the pipe is subdivided by longitudinal partitions into a plurality of narrow channels which must, however, open into the common space at the closed end.

In principle, the closed pipe, acting as a Helmholtz resonator, has the drawback that it may also resonate at the odd harmonics of the fundamental frequency; because these overtones are within the audible range of frequencies which one wishes to reproduce, undesirable resonances could result from this without damping. It was found, however, that by subdividing the pipe into a plurality of pipes or narrow channels with approximately the same total cross section as the speaker cone area, the damping for these overtones can be made so great that undesirable secondary effects are wholly absent; this desirable result occurs because of the rise of the acoustic absorption coefficient with frequency.

With a system according to the invention, a cabinet of only 2.2 cu. ft. suffices for a loud-speaker with a 12-in. diameter cone and a natural frequency of 60 cycles per sec. Moreover, the relatively smaller size of the enclosure is even more favorable for smaller loud-speakers, since in this system the required volume is directly proportional to the square of the cone diameter, whereas in the system of Joseph and Robbins, supra, it is directly proportional to the diameter itself. Due to the provision of a plurality of straight, narrow unobstructed channels of constant cross section and acoustic absorption characteristics, this system prevents sound reflections in the channels and gives good transient reproduction.

Moreover, the new system, due to the very tight acoustic coupling provided, makes it possible to reproduce even very low frequencies with loud-speakers of smaller diameters. With a speaker having a 7-in. diameter cone and a natural frequency of 60 cycles per sec., the cut-off frequency was found to be as low as 20 cycles per sec.

Having described the invention in general terms, it will now be described with reference to the accompanying drawings forming a part of this specification and showing by way of example two specific embodiments, wherein:

Figure 1 is an elevation view of a loud-speaker enclosure system according to the invention;

Figure 2 is a longitudinal sectional view taken on the line 2—2 of Figure 1 and showing, in addition, a part of a supporting wall;

Figure 3 is a transverse sectional view taken on the line 3—3 of Figure 1;

Figure 4 is a vertical sectional view, on a reduced scale, showing installation of the cabinet within a building wall; and

Figure 5 is a graph showing the response characteristics attained with the installation with a 7-inch loud-speaker.

Referring to Figures 1–3 of the drawings in detail, the loud-speaker enclosure includes a back wall **10** and side walls **11**, **12**, extending the full height, a curved top wall **13**, and a front wall having conjoined upper and lower sections **14** and **15**, the former section fully closing the upper part of the cabinet and the latter being parallel to the wall **10** and terminating short of the bottom at an edge **15***a*. The upper section **14** is preferably inclined outwardly with respect to the lower section not only to increase the depth of the enclosure for accommodating a direct-radiator loud-speaker **16**, but also to achieve an inclination of the speaker cone axis. The speaker is

mounted in a speaker opening **14***a* in the section **14** and has a cone **17** and voice coil **18** connected by an electrical circuit (not shown) to a signal source. The enclosure or cabinet is thus seen to be in the general form of a pipe that is closed at the upper end and open at the bottom. Although not essential to the invention, it is convenient when mounting the enclosure against or within a wall to have the bottom end, at which the low frequency sounds emanate, open toward the front; however, no marked directional effects are obtained at these frequencies. Such a front opening is achieved in the embodiment shown by providing a bottom wall **19**, which may be a part of the enclosure cabinet or may be a shelf that is a separate piece of furniture or fixed to the building wall **20**, to which the cabinet is secured by screws **21** and by a metal strap **22** and screws **23**.

The passage within the enclosure is subdivided by a plurality of longitudinal partitions **24** that extend from the back wall **10** to the front wall **14**, **15**, the upper ends terminating at **24***a*, short of the upper, closed end of the enclosure. As shown in Figure 3, the partitions are glued along their full lengths in shallow grooves fraised into the front and back walls to facilitate assembly and to promote rigidity. The upper ends of the partitions advantageously are widened to conform to the inclination of the wall **14** and reinforce the latter. The partitions thus define a plurality of narrow, vertical intervening channels that communicate with the common terminal space at the closed end, above the partitions, which contains the speaker **16**. The partitions advantageously extend downwards to the edge **15***a*; they may extend to the bottom of the enclosure, as shown, which lends a pleasing appearance but is not essential. The partitions may even terminate somewhat above the level of the edge **15***a*, although with some sacrifice in damping. The exposed edges of the partitions may be sloped inwards as shown at **24***b* and the front edge of the wall **19** may be curved concavely, as shown at **19***a*, for the sake of appearance. Also for appearance, there are false upwardly diverging walls **25**, which may be formed of thin plyboard, veneer, or the like.

Because considerable pressures are developed in the enclosure, especially at the upper, closed end thereof, it is recommended that the outer walls be made of material of adequate strength, suitably braced as is well-known in the art, e. g., by providing cleats **26** at the junctures of the side and top walls. To prevent unwanted resonances of the top wall **13**, the latter is curved concavely downward. The curvature is preferably such that the high frequencies radiating from the loud-speaker are reflected into the multiple vertical channels, in which they are absorbed, thus avoiding unwanted reflections back to the cone. This preferred curvature is achieved in the embodiment illustrated by forming the wall **13** as a part of a cylinder the horizontal axis of which is below the speaker and positioning the speaker so that the top of the speaker cone, particularly the rear part thereof, is in the focal line of the wall **13**, i. e., midway between the said axis and the wall. The outer walls and the partition walls should be covered with and/or made of sound-absorbent material. It is preferred to make these walls and partitions from material with heavy internal damping, i. e., of a so-called sound-dead material, in order to prevent resonances of said walls and partitions; common soft board is well suited.

Figure 4 shows an installation of the enclosure within a building wall; for example, the depth may be just under 4 inches and the width such as to fit between vertical studs, e. g., about 15 inches. In this view the spaced, outer wall panels are indicated at **27** and **28** and the intervening studs at **29**, the cabinet being supported by fastening the sides of the cabinet to the studs.

As regards dimensions, the effective length of the enclosure, i. e., the length from the wall **13** to the edge **15***a*, augmented by an end correction for the open end and a further correction for the increased cross section of the terminal space, is such that the enclosed passage has a fundamental resonance frequency that is approximately equal to the resonance frequency of the free loud-speaker. The former correction may be approximated for rectangular channels as shown by applying the known Helmholtz formula to a circular pipe of like hydraulic radius; hence the correction to be added to the actual cabinet length may be taken as $1.5\ A/P$, where A is the cross sectional area of one channel and P is its perimeter. The latter correction is based on the net increase in the cabinet air space in comparison to an empty tube of uniform cross section equal to the aggregate cross sectional area of the several channels, considering cabinet shape (e. g., curvature of wall **13** and slope of wall **14**) and contents (e. g., the presence of the loud-speaker and the absence of the partitions in the terminal space). The latter correction is approximately the quotient of the said net space increase divided by the said aggregate cross sectional area of the several channels; it is applied to yield an equivalent length corresponding to a tube having the said uniform cross section and containing an air volume equal to the air actually contained in the several channels and in the terminal air space.

The size of the cabinet is selected to make the said aggregate cross sectional area of the several channels and, hence, of their openings to the outside, approximately equal to the area of the speaker cone, preferably between 0.6 and 1.5 times the cone area, so that the tube as a whole has approximately the same radiation resistance as the speaker. The depth of the cabinet may be selected as desired, a shallow depth, such as less than one-third the width, being usually preferred to facilitate mounting on or within a building wall.

The number of partitions **24** should be sufficient to achieve effective damping of the harmonics of the fundamental resonant frequency of the cabinet. Since only odd harmonics appear, the third harmonic is the lowest one to be considered. Using common soft board and materials of similar absorption characteristics, the damping is sufficient when the quotient A/P is between 0.5 and 1.0 in., A and P designating the quantities previously defined. Under these conditions no sound having a frequency above 1,000 cycles per sec. should emanate audibly from the open ends of the channels. The partitions should be made of material of sufficient stiffness and thickness (preferably over ¼ inch) not to be able to resonate in audible frequencies.

Example

Two cabinets constructed as shown in Figures 1–3 were each used to enclose a speaker having a 7-inch diameter cone. The electrical impedance of each free speaker was found by measurement to be constant below 1,000 cycles per sec., except for a sharp peak at 60 cycles per sec. The free speakers therefore had a resonance at the latter frequency. To match this speaker the cabinet was built to the following dimensions: Total height, 61 inches, including ⅜ in. for the thickness of the top wall **13**, 11¾ in. for the height of the interiorly exposed face of section **14**, 41 in. for the height of the section **15** and 7⅞ in. for the height of the front opening; internal width, 13¾ in., subdivided by four partitions of sound-absorbent pressed fiber board each ⅜ in. thick, providing five narrow channels each slightly under 2½ in. wide. The partitions extended 3⅛ in. above the top of the wall section **15**. The internal depth between walls **10** and **15** was 3¼ in. and the internal depth at the top of the section **14** was 6¼ in. Each cabinet, therefore, had five channels with a ratio of cross sectional area to perimeter of about 0.7 in. and an internal air space, reckoned above the edge **15***a* and corrected for the volume occupied by the partitions and the speaker, of about 2,215 cu. in. or 1.28 cu. ft. The aggregate cross sectional area of the channels being 39.8 sq. in. and the end correction being taken as 1.1 in.,

the fundamental resonant frequency of the cabinet was calculated to be 60 cycles per sec. at a speed of sound 1130 ft. per sec. The electrical impedance of each speaker when mounted in the cabinet was measured; the average of the results for the two systems is shown in the graph of Figure 5. In this graph frequencies are plotted as abscissae on a logarithmic scale and the electrical impedance as ordinates, expressed as decibels related to the impedance at 1000 cycles per sec. The meter was unreliable at frequencies below 20 cycles per sec.; this part of the curve is shown by a dotted line. The complete absence of the original resonance at 60 cycles per sec. is evident, as well as the enhanced impedance at the lower frequencies down to 20 cycles per sec.

The loud-speaker enclosure system described is advantageously mounted in a room at a height such that the axis of the wave-front from the speaker cone reaches the ear in a slightly downwardly inclined direction as it does in a concert hall, e. g., at an angle of between 10° and 15° to the horizontal, i. e., 75° to 80° to the axis of the channels when the latter are vertical. The position of the open end of the enclosure is relatively immaterial, since low frequency sound is radiated from this opening, and the opening may even be directed axially with respect to the enclosure. A design that satisfies these requirements, is also pleasing to the eye, and facilitates convenient installation with space economy achieved by mounting the enclosure vertically, with the speaker at the top, with the speaker axis inclined downwards, as shown.

A particularly useful system includes a pair of or several identical speakers mounted at a common height on or within the same wall of a room and spaced laterally, the speakers being matched and connected electrically to operate in phase; this gives the perfect illusion of a distant source of sound. The small size and shallow depth possible with the system according to the invention make such multiple installations entirely feasible.

I claim as my invention:

1. A loud-speaker enclosure system including a wall structure defining an enclosed common space and a plurality of narrow, essentially straight damping channels, each said channel being in communication at one end thereof with said common space and being open to the outside of said wall structure at the other end, said channels being of essentially uniform cross section and having substantially the same acoustic absorption characteristics along the lengths thereof, and a direct-radiation loud-speaker having only one side of the diaphragm thereof coupled acoustically with air in said common space and the other side of said diaphragm coupled acoustically with air outside of said wall structure.

2. A loud-speaker enclosure system according to claim 1 wherein said damping channels are of equal lengths and equal cross sectional areas, and wherein the aggregate of the cross sectional areas of the openings of the channels to the outside is between 0.6 and 1.5 times the area of said diaphragm, whereby said openings have approximately the same radiation resistance as the loud-speaker.

3. A loud-speaker enclosure system including a wall structure defining an enclosed common space and a plurality of narrow damping channels, each said channel being in communication at one end thereof with said common space and being open to the outside of said wall structure at the other end, and a direct-radiation loud-speaker having only one side of the diaphragm thereof coupled acoustically with air in said common space and the other side of said diaphragm coupled acoustically with air outside of said wall structure, said channels having ratios of cross sectional areas to perimeter of between 0.5 and 1.0 inch, to achieve effective damping of harmonics of the fundamental resonant frequency of the wall structure.

4. A loud-speaker enclosure system including confining walls enclosing an elongate passage which is open at one end and closed at the other end, partition means for subdividing said passage into a plurality of essentially straight, narrow channels each of which is tightly coupled acoustically at one end thereof to a common terminal space at the closed end of the passage and communicates at the other end thereof with the exterior of said confining walls, and a direct-radiator loud-speaker mounted with only one side of the diaphragm thereof coupled acoustically with air in said terminal space and the other side of said diaphragm coupled acoustically with the air outside of said confining walls.

5. A loud-speaker enclosure system according to claim 4 wherein the volume of said terminal space and the length of said passage are such as to have a fundamental resonant frequency that is substantially equal to the resonant frequency of the free loud-speaker.

6. A loud-speaker enclosure system according to claim 4 wherein said partition means includes a plurality of longitudinal partition walls of acoustically dead material terminating short of the closed end of the passage but in close proximity to the loud-speaker and extending substantially to the open end of the passage, said channels having constant cross sections and substantially uniform sound absorption characteristics along their lengths and being totally unobstructed.

7. A loud-speaker enclosure system including an elongate cabinet having confining walls enclosing a straight, elongate passage which is open at one end and closed at the other end, partition walls extending longitudinally within said cabinet and subdividing the said passage into a plurality of straight, narrow, longitudinal damping channels of constant cross sections, said partition walls terminating short of the closed end of the cabinet to place said channels into communication with a common terminal space at the said closed end and extending at least for the major part of the length of the cabinet, said channels communicating with the outside of the cabinet at the said open end thereof, and a direct-radiator loud-speaker mounted in a speaker opening in a front wall bounding said terminal space.

8. A loud-speaker enclosure system according to claim 7 wherein said cabinet is generally rectilinear from the said open end to the said terminal space and is widened toward the front thereof at the said terminal space, and the loud-speaker is mounted at said widened part of the cabinet.

9. A loud-speaker enclosure system including an elongate cabinet which is open at one end and closed at the other end, partition walls extending longitudinally within the cabinet for at least the major part of the length thereof and subdividing the cabinet into a plurality of narrow damping channels, said partition walls terminating short of the closed end of the cabinet to place said channels into communication with a common terminal space at the said closed end, said channels communicating with the outside of the cabinet through said open end thereof, and a direct-radiator loud-speaker mounted in a speaker opening in a wall of said cabinet bounding said terminal space, the volume of said terminal space and the length of said cabinet between the open and closed ends thereof being such that the cabinet has a fundamental resonant frequency that is substantially equal to the resonant frequency of the free loud-speaker and the aggregate cross sectional area of the channel openings to the outside is between 0.6 and 1.5 times the area of the loud-speaker cone, whereby said channel openings have approximately the same radiation resistance as the loud-speaker.

10. An enclosure cabinet for a direct radiator loud-speaker including confining walls defining an elongate passage that is open at one end and closed at the other end, and partition means for subdividing said passage into a plurality of essentially straight, narrow channels of essentially like acoustic characteristics each of which is tightly coupled acoustically at one end thereof to a common terminal space at the closed end of the cabinet and communi-

cates at the other end thereof with the exterior of the cabinet, a wall of said cabinet bounding said terminal space having a speaker opening.

11. An enclosure cabinet according to claim 10 wherein the aggregate cross section of said channels is between about 0.6 and 1.5 times the area of said opening.

12. An enclosure according to claim 10 wherein at least the major parts of the walls bounding said narrow channels are of acoustically dead material such as soft board to avoid acoustical resonance of said walls.

13. An enclosure according to claim 10 wherein said partition means includes a plurality of longitudinal partition walls terminating short of the closed end but in close proximity to said speaker opening and extending substantially to the open end of the cabinet, whereby the narrow channels defined between the said partitions have lengths equal to at least the major part of the length of the cabinet.

14. An enclosure according to claim 10 wherein said cabinet is shallow and has a width at least three times the depth thereof, said open and closed ends of the passage being at remote ends of the cabinet and the passage being straight.

15. An enclosure according to claim 14 wherein said partition means includes a plurality of parallel, spaced, longitudinal partition walls, each said partition wall extending throughout the depth of the cabinet and being secured to the opposed wider walls thereof to afford rigidity thereto, said partition walls terminating short of the closed end of the cabinet and extending throughout the major part of the length of the cabinet.

16. An enclosure for a direct-radiator loud-speaker including a shallow, elongated cabinet having a width in excess of three times the depth thereof, a wider wall thereof constituting the front, said cabinet being open at one end and closed at the remote end thereof and being shaped to provide a straight passage between said closed and open ends, the portion of said front wall near the closed end having a speaker opening therein, and a plurality of longitudinal partitions extending between said front and rear walls and secured thereto to afford rigidity, said partitions being spaced apart to subdivide said passage into a plurality of narrow channels and extending longitudinally substantially from the open end of the cabinet to points close to but short of said speaker opening, whereby said channels communicate with a common terminal space adjoining said speaker opening and have lengths equal to at least the major part of the length of the cabinet.

17. An enclosure according to claim 16 wherein said portion of the front wall having the speaker opening therein is inclined toward the front in a direction toward the closed end at an angle of about 10° to 15° and the said front wall is foreshortened in relation to the rear wall at the said open end, whereby the cabinet is open toward the front and the axis of said speaker opening is inclined downwardly in the average direction of an audience when the enclosure is mounted vertically at an elevation above a floor with the said terminal space uppermost.

18. A loud-speaker enclosure system including confining walls enclosing a straight elongate passage which is open at one end and closed at the other end with a width at least three times the depth thereof, and a plurality of parallel, spaced, longtiudinal partition walls subdividing said passage into a plurality of narrow channels, each said partition wall being secured along opposite edges thereof to the opposed wider walls bounding the said passage to afford rigidity thereto, said partition walls extending throughout the major part of the length of the passage and terminating short of the closed end thereof to leave a common terminal space at the said closed end, one end of each of said narrow passages being acoustically coupled to said common terminal space and the other end thereof being in communication with the exterior of said confining walls, and a direct-radiator loud-speaker mounted with only one side of the diaphragm thereof coupled acoustically with air in said terminal space and the other side of said diaphragm coupled acoustically with the air outside of said confining walls.

19. A loud-speaker enclosure system including confining walls enclosing an elongate passage which is open at one end and closed at the other end, partition means for subdividing said passage into a plurality of essentially straight, narrow channels, each of which is coupled acoustically at one end thereof with a common terminal space at the closed end of the passage and communicates at the other end thereof with the exterior of said confining walls, and a direct-radiator loud-speaker mounted with only one side of the diaphragm thereof coupled acoustically with air in said terminal space and the other side of said diaphragm coupled acoustically with the air outside of said confining walls, said speaker having the axis thereof at an angle of about 75° to 80° to the axis of said passage and inclined toward the open end of said passage, whereby said speaker axis is inclined in the average direction of an audience when the system is mounted vertically at an elevation above the floor with said closed end uppermost.

20. A loud-speaker enclosure system including confining walls enclosing an elongate passage which is open at one end and closed at the other end, said closed end including a terminal wall that is curved concavely toward said open end, partition means for subdividing said passage into a plurality of essentially straight, narrow channels each of which communicates at one end thereof with a common terminal space adjoining said concave terminal wall and communicates at the other end thereof with the exterior of said confining walls, and a direct-radiator loud-speaker having a diaphragm which includes a cone situated with the part thereof which is near said terminal wall situated substantially in the focal line of said curved terminal wall and having one side of said diaphragm coupled acoustically with air in said terminal space and the other side of said diaphragm coupled acoustically with the air outside of said confining walls, whereby high-frequency sound radiated from said cone is reflected from said terminal wall into said channels.

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