This invention relates to loud speaker systems in general and more particularly relates to a means for obtaining improved bass response in speaker systems having moderate size cavities. One embodiment of this invention represents an improvement over the structure illustrated in my copending application Serial No. 421,008 filed December 24, 1964.

Loud speaker systems for home use have been deficient in reproducing sounds in the bass or low audio frequency range. Attempts to improve response in the base region have not met with great success apparently because of space limitations.

One such attempt at improving bass response is known as a bass-reflex or phase-inverter structure. This is essentially a Helmholtz resonator wherein the loud speaker diaphragm or driver unit is mounted so that the rear surface thereof drives an acoustic chamber and the front surface radiates into space. A port or opening in the chamber couples the chamber to the outside space. At certain low frequencies sound pressures radiating from the port are relatively in phase with radiation from the front surface of the diaphragm.

The bass-reflex system may be regarded as a double source of sound whose relative phase depends upon radiated frequency. Since the back wave is reversed in phase with respect to the front wave at the diaphragm, the rear wave must be reversed at the port with respect to the rear of the diaphragm in order that the rear wave radiated from the chamber may reinforce the front wave. Unfortunately, in common types of bass-reflex systems complete phase reversal of the back wave is not obtained in the desired frequency range. That is, in conventional size cabinets, say in the order of two cubic feet, complete phase reversal occurs only over a very narrow frequency band and generally well above 50 c.p.s.

In the device of the instant invention, with essentially the same size housing as prior art speaker systems, complete phase reversal will occur over a wide frequency range at the low end of the audio spectrum with this range being typically below 50 c.p.s. This is achieved by feeding the back wave into an elongated transmission line cavity loaded at its far end by a constricting port. Phase delay is introduced in the back wave by the length of the cavity and when this delay results in the wrong polarity, energy is cut off by the port. However, over the lowest portion of the frequency spectrum energy is radiated from the port with essentially the correct polarity to augment the front wave.

It is the nature of this transmission line cavity terminated by a constriction to attenuate higher multiple frequencies which would otherwise possess recurring resonances. Tuning of the transmission line together with the port characteristics results in a strong fundamental resonance which appears at the port 180° out of phase with radiation from the rear surface of the speaker diaphragm and therefore is in phase with radiation emanating from the front surface of the diaphragm. At the same time any tendency to produce antiresonances, multiple higher frequencies where cancellations occur, is sharply attenuated since the transmission line and port act as a highly effective low pass filter. The structure of the instant invention should not be confused with an acoustic labyrinth. The latter achieves phase reversal by virtue of time delay by conducting the back wave through a series of zig-zag channels to an opening in the speaker enclosure. However, because of the total length of the labyrinth the back wave will resonate in phase with that of the front wave at the first half wave length of duct length and thereafter be improperly phased.

A labyrinth approximately 11 feet long is required to achieve reinforcement of the front wave by the back wave at 50 c.p.s. At this frequency the labyrinth is so long that it requires an enclosure much larger than the two cubic foot size of the home speaker unit. In addition, in order to suppress antiresonances the labyrinth must be lined with sound absorbing material resulting in excessive damping. Further, in order to achieve reasonable Q, the cross-sectional area of the labyrinth must be relatively large resulting in a shorter length for a given size cabinet. If cross-section is reduced to obtain greater length, then over damping results in diminished efficiency at the desired inverted frequency, thereby defeating the original intent of utilizing the labyrinth.

Accordingly, a primary object of the instant invention is to provide a novel construction for a loud speaker system in which the back wave generated by the woofer diaphragm is radiated from the system enclosure in phase with the front wave over a relatively wide frequency band at the low end of the audio spectrum.

Another object is to provide a loud speaker system of this type in which the back wave of the woofer or bass speaker is directed along an elongated path terminated by constricting opening venting to the atmosphere.

Still another object is to provide a loud speaker system of this type in which the back wave of the woofer is directed through a series of elongated parallel duct sections joined end to end with the end of the duct remote from the speaker having a constricted opening venting to the atmosphere.

A further object is to provide a loud speaker system of this type in which the woofer faces downwardly with the front wave venting through an annular opening positioned below the woofer and the back wave being conducted through an elongated transmission line cavity loaded at the far end by a constricting port which acts as a low pass filter.

A still further object is to provide a loud speaker system of this type in which the back wave of the woofer feeds into an elongated transmission line cavity comprised of a plurality of concentric telescoped tubes.

These and other objects and advantages of the present invention will become readily apparent after reading the following description of the accompanying drawings in which:

FIGURE 1 is a perspective of a speaker system constructed in accordance with the teachings of the instant invention with portions of the enclosure and internal partitions thereof cut away to better reveal details of construction.

FIGURE 2 is a longitudinal cross-section of the speaker system of FIGURE 1.

FIGURES 3 and 4 are views similar to FIGURE 2 illustrating other embodiments of the instant invention.

FIGURE 4A is a cross-section taken through 4A—4A of FIGURE 4 looking in the directions of arrows 4A—4A.

FIGURE 5 is a perspective of another embodiment of this invention with portions of the enclosure broken away to reveal elements disposed therein.

FIGURE 6 is a plan view of a further embodiment of the instant invention similar to the embodiment of FIGURE 5, with the top of the enclosure cut away to reveal the elements within the enclosure.

Now referring to the figures and more particularly to FIGURES 1 and 2. The structure illustrated in FIGURES 1 and 2 is for the most part described in detail in my afore-
said copending application 421,008. Briefly, the structure described in my copending application 421,008 is the cylindrical tubular housing 10 closed at its top by rigid cover 11 and at the bottom by the diaphragm 12 of woofer 13. The latter is located at the bottom of cylinder 10 with diaphragm 12 facing downward so that the front wave generated thereby is directed toward a truncated conical acoustic impedance element 14. The latter is mounted to the upper surface of circular base plate 15 positioned in closely spaced relationship with respect to the bottom edge of cylinder 10 with the spaced relationship being maintained by means of standoffs (not shown). Thus, the front wave generated by diaphragm 12 is radiated through a narrow 360° aperture at the bottom edge of cylinder 10, this aperture being covered with decorative cloth 16. Midrange speaker 17 and tweeter 18 are secured to the back surface of plate 19 which covers a side opening in cylindrical enclosure 10.

The improvement provided by the instant invention consists of cylindrical tubular partition 20 telescoped within cylinder 10 and concentric therewith. Annulus 21, extending outwardly from the lower edge of inner tube 20 to the inner surface of outer tube 20, prevents upward propagation of the back wave generated by diaphragm 12 in the space 22 between tubes 10 to 20. The upper edge of tube 20 is spaced from top cover 11 so as to provide an annular window 23 leading from the center of tube 20 to space 22. Annular window 23 is a projection of tube 20 extending upward to top cover 11.

The back wave generated by diaphragm 12 is directed upwardly through inner tube 20, to the sides through window 23 and then downwardly in space 22 to apertures 24 where a portion of the back wave is radiated into space. Apertures 24 extend through tube 10, are arranged in a circular array about the cylindrical axis 25 and are positioned diametrically above partition 21. The path taken by the back wave is effectively an elongated transmission line terminated by a constriction formed by apertures 24. This constriction produces inductive effects acting to cut off higher frequencies and thereby prevent radiation thereof into space. The portion of the back wave emitted through apertures 24 is made to be in phase with the front wave generated by diaphragm 12 over a relatively wide frequency range falling below 50 c.p.s., by appropriately proportioning tubes 10, 20, window 23 and apertures 24. The area of window 23 should be in the range from 0.5 to 1.0 times the cross-sectional area of tube 20 while the cross-sectional area of space 22 should be in the range from 0.5 to 2.0 times the cross-sectional area of tube 20.

It is desirable to have the cross-section of tube 20 as large as the diameter of diaphragm 20 at the inner boundary of compliant edge 12a. While an appropriate range of relative sizes between window 23, space 22 and tube 20 has been given, it is desirable to have window 23 and the cross-sectional area of space 22 each approximately equal to the cross-sectional area of tube 20. In a typical practical construction the key dimensions are: tube 10, 2/5 inches long with an inner diameter of 12 inches; tube 20, 20 inches long with an inner diameter of 8 inches and a wall thickness of 1/4 inch; and window 23, 13/4 inches high.

In the embodiment of FIGURE 3 the back wave generated by diaphragm 31 of woofer 32 is directed upwardly through center tube 33, through annular window 34 to space 35 between cylinder 33, 36, through annular window 37, upwardly in the space 38 between middle tube 36 and outer tube 39 and is radiated into space through the series of apertures 40 circularly arranged about the tubular axis and positioned just below the top closure 41 for cylinder 39. Partition 42 extends outwardly from the lower end of tube 35 to the inner surface of tube 39 thereby sealing the entire back wave generated by diaphragm 31 upwardly through inner tube 33. Annular window 34 is formed by the space between the upper end of tube 33 and the bottom surface of cover 41. The upper edge of middle tube 36 abuts the inner surface of top cover 41 while the lower edge 36a of tube 36 is spaced from partition 42 to form annular window 37.

It should be apparent to those skilled in the art that even though the outer dimensions in the speaker enclosures of FIGURES 2 and 3 are shown or described as being equal, this has been done only for simplicity of illustration. Naturally, the structure of FIGURE 3 will enable the acoustic benefits of the structure of FIGURE 2 to be achieved in a shorter housing having greater transverse dimensions. In addition, different frequency ranges of sound reinforcement by the back wave may be achieved by constructing the transmission line cavity of appropriate length and diameter.

In the embodiment of FIGURES 4 and 4A cylindrical enclosure 51 is provided with internal partitions 52, 53 which direct the back wave of woofer diaphragm 54 through an elongated path to apertures 55. More particularly, partition 52 is a plate-like member positioned in a vertical plane extending across the diameter of cylinder 51 and dividing the interior thereof into cavity sections 56, 57. The upper end of partition 52 is spaced from top closure 58 for cylinder 51 so as to form window 59 connecting cavity sections 56, 57.

The other partition 53 is a semicircular plate abutting the lower edge of partition 52 and extending therefrom to engage half of the interior surface of cylinder 51, thereby preventing the back wave generated by diaphragm 54 from moving upwardly in cavity section 57. It is seen that the back wave generated by diaphragm 54 is directed upwardly in cavity section 56, to the side through window 59 and downwardly in cavity section 57 to apertures 55. The latter are positioned just above partition 53 extending through cylinder 51 to directly connect cavity section 57 externally of cylinder 51.

The embodiment of FIGURE 5 is a so-called book shelf type of speaker unit and includes rectangular enclosure 61 having speaker 62 secured to front wall 63 with speaker diaphragm 64 sealing aperture 65. L-shaped partition 66 divides enclosure 61 into parallel cavity sections 67, 68 connected by window 69 located at the side of enclosure 61 remote from apertures 70 in a vertical row through front wall 63 of enclosure 61. Thus, the back wave generated by diaphragm 64 travels in cavity section 67, through window 69 and cavity section 68 to apertures 70. Since apertures 70 are in combination at the end of a transmission line cavity, apertures 70 act as a low pass filter so that a portion of the back wave from diaphragm 64 will radiate through apertures 70 into space in phase with the front wave generated by diaphragm 64. In the embodiment of FIGURE 5 midrange speaker 17 and tweeter 18 are positioned between woofer 62 and apertures 70.

The embodiment of FIGURE 6 is another so-called book shelf type speaker system having rectangular enclosure 81. Woofer 82 is mounted to the front enclosure wall 82 with woofer diaphragm 83 providing the closure for centrally located aperture 84 in wall 82. L-shaped partition 86 divides the interior of housing 81 into parallel cavity sections 87 and 88 connected by window 89.

The back wave generated by diaphragm 83 is directed through cavity section 87, window 89 and cavity section 88 to apertures 90 positioned in a vertical row in front wall 82 of enclosure 81 near the side thereof remote from window 89. Vertical spaced slats 92 and center support 93 provide a false front for enclosure 81 in front of and spaced from wall 82. Mid-range speaker 97 and tweeter 98 are mounted to central section 95 directly in front of diaphragm 83.

Thus, it is seen that the instant invention provides a number of practical structures for moderate sized speaker enclosures in which improved base response is achieved. Improvement is typically over a relatively wide frequency range in the region below 50 cycles. The construction is such that antiresonances in the low frequency range are essentially eliminated.
Although there has been described a preferred embodiment of this novel invention, many variations and modifications will now be apparent to those skilled in the art. Therefore, this invention is to be limited, not by the specific disclosure here, but only by the appended claims.

1. A speaker system including an enclosure having an opening means venting to atmosphere and a tubular side wall with its tubular axis extending vertically; said opening means including a first and a second section; a bass speaker within said enclosure; said speaker including a sound generating diaphragm which when vibrated produces a front wave and a back wave of reverse phase to said front wave; said diaphragm operatively positioned in proximity to and above said first section to direct said front wave therethrough; said speaker positioned near the bottom of said enclosure with said diaphragm facing downward; said speaker being of a diameter substantially equal to the diameter of said tubular side wall; said first section comprising an annulus positioned below said diaphragm and concentric with said tubular axis; partition means within said enclosure cooperating with the inner boundary of said tubular side wall to define a transmission line acting as an elongated path directing said back wave to said second section; said second section defined by boundary means providing a constriction at one end of said path acting as a low band pass filter; said path being of a length such that portions of said back wave emitted through said second section are reversed in phase with respect to these portions of said back wave as they are generated by said diaphragm whereby these portions of said back wave are in phase with and reinforce said front wave; said path including a first portion and a second portion connected by a window portion; said first and second portions extending generally parallel to one another.

2. A speaker system as set forth in claim 1 which said second section is formed in said side wall.

3. A speaker system as set forth in claim 2 in which said partition means divides said enclosure into a plurality of telescoped tubular sections concentric about said tubular axis with the lower end of the innermost of said tubular sections communicating directly with the rear of said diaphragm; each of said tubular sections communicating with an adjacent one of said tubular sections by means of an annular window concentric with said axis.

4. A speaker system as set forth in claim 3 in which said innermost tubular portion and the tubular portion adjacent thereto are of substantially the same cross-sectional area substantially equal to the area of the window connecting these tubular sections.

5. A speaker system as set forth in claim 3 in which the innermost tubular portion is of a cross-sectional area from one to two times the cross-sectional area of the tubular portion adjacent to said innermost tubular portion and the area of the window connecting these portions.

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STEPHEN J. TOMSKY, Primary Examiner.