May 12, 1931. P. B. FLANDERS 1,804,759

ACOUSTIC DEVICE

Filed April 28, 1928

FIG. 1.

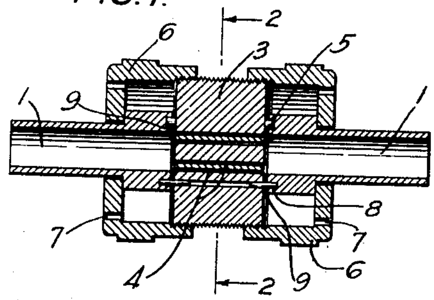


FIG. 2.

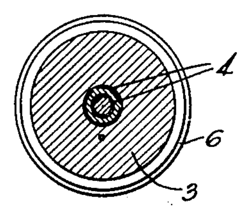


FIG. 3.

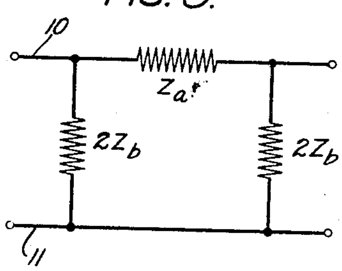
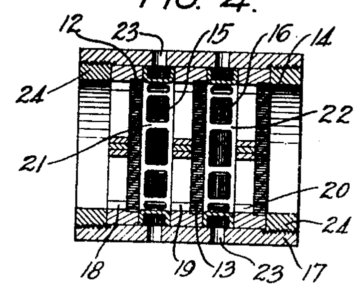


FIG. 4.



6 FIG. 5. 6

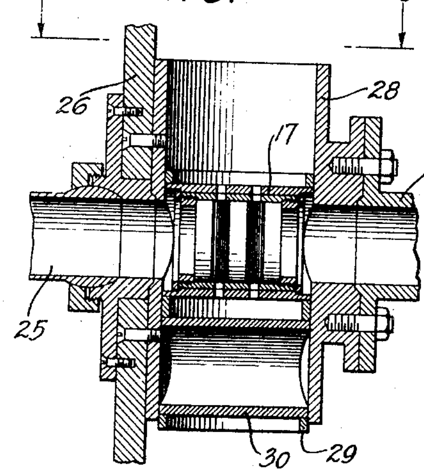
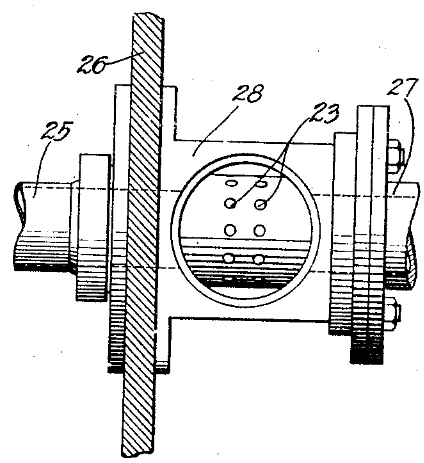


FIG. 6



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1,804,759

UNITED STATES PATENT OFFICE

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ACOUSTIC DEVICE

Application filed April 28, 1928. Serial No. 273,524.

This invention relates to acoustic devices and particularly to an acoustic attenuator comprising series and shunt impedance elements having a negligible reactance component at speech frequencies.

In accordance with the present invention there is provided an attenuator comprising series and shunt impedances which have a negligible reactance component at speech frequencies. Resistance elements suitable for use in such an attenuating network are disclosed and claimed in one of my copending applications, Serial No. 273,523, filed of even date herewith. In accordance with one of the several specific embodiments of the invention herein shown and described the resistances forming the acoustic attenuator comprise sound passages in the form of parallel walled slots less than 0.003 inch in width in a direction substantially perpendicular to the direction in which acoustic waves are transmitted therethrough. The sound passage comprising a series resistance is so positioned that acoustic waves pass therethrough in going from one portion to another of the acoustic transmission line of which the attenuator forms a part, and the sound passage comprising a shunt resistance extends from the acoustic transmission line to the free atmosphere. By the use of very small separations of the order mentioned above, between the walls of the passages, a purely resistive character of the impedance is ensured for a range of frequencies wide enough to include all the essential frequencies of speech or music. The attenuation produced by the device is therefore substantially uniform at all frequencies in this range, and the device is therefore suited for the accurate control of sound volume in an acoustic system, without causing any distortion of the sound intensity-frequency characteristic.

The nature of the invention will be more fully understood from the following detailed description of a selected number of its embodiments, and from the accompanying drawings of which:

Figs. 1 and 2 are cross-sectional views of one embodiment of the invention;

Fig. 3 is an impedance diagram corresponding to Fig. 1;

Fig. 4 illustrates a preferred form of the invention; and

Figs. 5 and 6 illustrate the adaptation of the device of Fig. 4 to an acoustic transmission system.

In Fig. 1 the main sound conduit is formed by the tubular elements 1, and the slots by which the attenuation is produced are formed in the block 3, and at the junctions of this block with the elements 1. In series with the main sound passage are two concentric circular slots 4, these being formed in the block 3 by the insertion of concentric cylindrical plugs in a circular hole through the centre of the block. The diameters of the plugs should be such as to provide slots of about .003″ in width, the actual width depending upon the degree of attenuation desired. The plugs may be held in concentric relationship by means of axial pins. Shunt leakage paths 9 are provided at the ends of block 3 in the form of narrow radial crevices between the block and the tubular elements. The width of these crevices is determined by the height of a plurality of pins, such as 5, inserted in the end of the elements 1. Screw caps 6, engaging a thread on the outside of block 3 serve to clamp the tubes 1 and the center block together as a unit. Holes 7 in the ends of the screw caps permit the air leaking through the crevices 9 to escape to the outer atmosphere. A pin 8 inserted in block 3 and engaging holes in the ends of elements 1 aids in keeping the assembly in alignment. The cross section of the assembly along the line 2—2 is shown in Fig. 2.

Fig. 3 illustrates schematically the impedances of the device of Fig. 1, the usual electrical conventions for the representation of a wave transmission system being employed. Conductors 10 and 11 correspond to the main acoustic channel formed by tubes 1. Shunt impedances $2Z_b$ correspond to the impedances of leakage paths 9 and series impedance Z_a represents that of the concentric slots 4. The acoustic impedance of an acoustic path is defined as the ratio of the excess pressure intensity, i. e. the wave pressure applied to the path, to the volumetric rate of displacement of air in the path. For a very narrow parallel slot the impedance is resistive and has substantially the value given by the equation

$$Z=\frac{12\mu}{d^2}\cdot\frac{l}{A}, \quad (1)$$

where Z is the impedance,

μ is the coefficient of viscosity of the medium,

d is the width of the slot,

l the length in the direction of wave propagation, and

A the cross-sectional area.

In c. g. s. units μ has the value 1.86×10^{-4} for air. The above formula enables the impedances Z_a and $2Z_b$ to be computed from the physical dimensions of the slots, but in applying the formula to the radial paths 9, it is necessary to make an approximation to the cross-sectional area, since the area increases from the inner end of the path outwards. It is sufficient to take the area at the mid-section between the inner and the outer end of the path and to assume that the path has this uniform area throughout its whole length.

To avoid wave reflection effects it is desirable that the resistance combination should be designed with respect to the acoustic line in which it is inserted. The combination represented by the three impedances of Fig. 3 may be regarded as a symmetrical section carved out of an infinite line of recurrent structure, comprising series impedances Z_a and shunt impedances Z_b. The impedance Z_b of such a line, if measured at the middle of a shunt branch, i. e., terminated by a shunt branch $2Z_b$, has the value

$$Z_h=\frac{\sqrt{Z_aZ_b}}{\sqrt{1+\frac{1}{4}\frac{Z_a}{Z_b}}} \quad (2)$$

If now the values of Z_a and Z_b are so chosen that the impedance Z_h is the same as the characteristic impedance of the main acoustic line in which the device is inserted, then there will be no wave reflection in the system.

If the device is to be inserted in an acoustic conduit of cross-sectional area A_o, the acoustic impedance of which is given by

$$Z_o=\frac{41.3}{A_o}\text{ c. g. s. units} \quad (3)$$

Then to avoid wave reflection the following design condition is imposed

$$Z_o=\frac{\sqrt{Z_aZ_b}}{\sqrt{1+\frac{1}{4}\frac{Z_a}{Z_b}}} \quad (4)$$

Further if it is desired to reduce the vibration velocity in the ratio ϵ^{-T}, where e is the base of the natural logarithms, the second design condition is imposed, that

$$\sqrt{\frac{Z_a}{4Z_b}}=\sinh\frac{T}{2} \quad (5)$$

From equations 4 and 5 the simplified design relations follow:

$$Z_a=Z_o\sinh T$$

$$Z_b=\frac{Z_o}{2}\coth\frac{T}{2}.$$

For the development and further consideration of the foregoing equation reference is made to the article by G. A. Campbell, The physical theory of the electric wave filter, Bell System Technical Journal vol. 1, No. 2, November, 1922.

The preferred form of the attenuating device shown in Fig. 4 comprises two sections made up of three series impedance elements 12, 13, and 14, and 2 shunt impedance elements, 15 and 16, assembled together in a carrier tube 17. The series elements may each consist of a close coiled spiral of metallic ribbon, wound with a uniform pitch to give the effect of a very large slot of narrow width. This type of element and the manner of constructing it are fully described in my aforementioned copending application. The ribbon units are mounted on supporting frames 18, 19 and 20, which are assembled within the carrier tube 17. The shunt resistance elements comprise close spaced helices of metallic ribbon wound edgewise on open cylindrical frames 21 and 22. This type is also described in my above mentioned copending application. To permit the escape of the air traversing the shunt resistances the carrier tube 17 is provided with a series of peripheral holes 23. The several elements are held in position in the carrier tube 17 by means of screwed clamping rings 24.

The formulæ given for the computation of the resistances in the device of Fig. 1 may be used in this case also, but the following differences between the two structures should be noted. The device of Fig. 3 ends in series impedances and therefore corresponds to a portion of an infinite recurrent line formed by cutting at the middle points of two series branches, instead of by splitting the shunt branches. The end branches should therefore have impedances of

$$\frac{1}{2}Z_a.$$

Further there are two complete sections, and the attentuation will therefore be equal to e^{-2T}, where T is the attentuation as already defined for a single section.

Figs. 5 and 6 illustrate the use of the device of Fig. 4 in connection with a phonograph for the purpose of controlling the volume of the reproduced sound. The attenuating device is here arranged to be inserted in the sound conduit between the tone arm 25, and the horn 27 of the phonograph. For this purpose one or more complete units are assembled in a tube 29, forming transverse passages therethrough, this tube being slidably mounted in a cylindrical casting 28, forming a union between the tone arm and the horn. Fig. 5 is a transverse section of the assembly and illustrates how the various parts may be mounted together on the turntable platform 26. Fig. 6 is an external end view of the assembly as seen in the section 6—6. In the assembly illustrated a single attenuating unit is shown, the second transverse passage in tube 29 being simply an open tube. By sliding the tube 29 in the casting 28 either the open tube 30 or the attenuating device may be inserted in the sound conduit, giving a choice of two degrees of loudness of the reproduced sounds. Additional degrees of loudness may obviously be secured by the use of additional attenuating units.

What is claimed is:

1. An acoustic attenuator comprising series and shunt impendances at least one of which is in the form of a sound passage less than 0.003 inch wide in a direction substantially perpendicular to the direction in which sound waves are transmitted therethrough.

2. An acoustic attenuator comprising series and shunt resistances each of which comprises a sound passage of the order of 0.001 inch wide in a direction substantially perpendicular to the direction in which sound waves are transmitted therethrough.

3. In an acoustic transmission line, a network of series and shunt dissipative elements, said series element comprising an opening through which sound waves pass in going from one part of the transmission line to another, said shunt element comprising an opening through which sound waves pass out of the transmission line, these openings being less than 0.003 inch wide in a direction substantially perpendicular to the direction in which sound waves pass therethrough.

4. In an acoustic transmission line, a network of series and shunt dissipative elements, said series element comprising a plurality of openings through which sound waves pass in going from one part of the transmission line to another, said shunt element comprising a plurality of openings through which sound waves pass out of the transmission line, each of these openings being of the order of 0.001 inch wide in a direction substantially perpendicular to the direction in which sound waves pass therethrough.

5. In an acoustic transmission line, a network of series and shunt impedances, at least one of said impedances comprising a member formed of a thin ribbon wound in the form of a spiral, the adjacent turns of which are so closely spaced that the air passage between them has an impedance to the flow of air substantially free from reactance at speech frequencies.

6. In an acoustic transmission line, a network of series and shunt impedances, at least one of said impedances comprising a member formed of a thin ribbon wound in the form of a helix having the broad surface of the ribbon normal to the axis of the helix, the adjacent turns of which are so closely spaced that the air passage between them has an impedance to the flow of air substantially free from reactance at speech frequencies.

In witness whereof, I hereunto subscribe my name this 27th day of April, 1928.

PAUL B. FLANDERS.