SOUND ATTENUATING DEVICE

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Fig. 1.

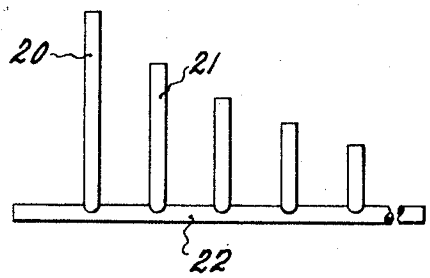


Fig. 2.

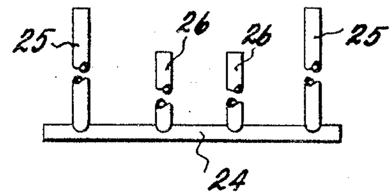


Fig. 3.

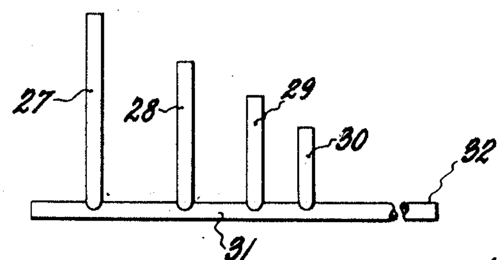


Fig. 5.

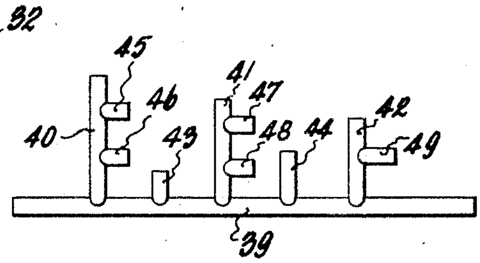
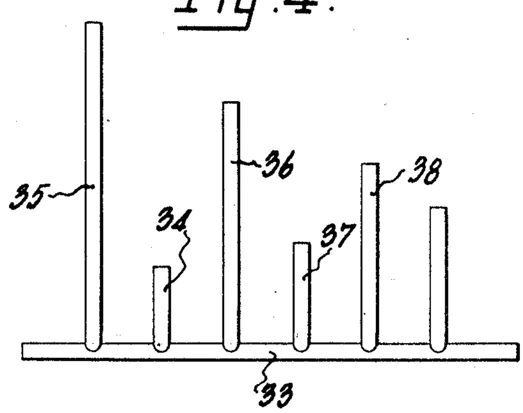


Fig. 4.



INVENTOR.
ROLAND B. BOURNE
BY Chapin and Neal
ATTORNEYS.

March 30, 1937. R. B. BOURNE 2,075,263

SOUND ATTENUATING DEVICE

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Fig. 6.

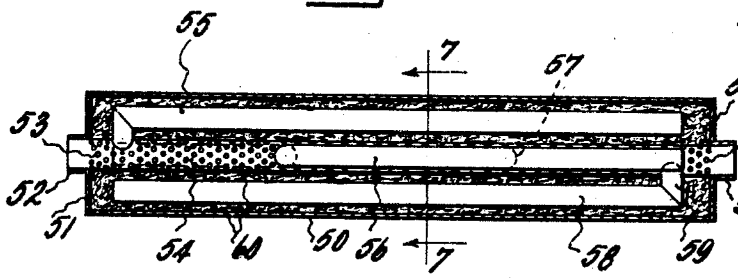


Fig. 7.

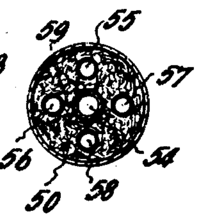


Fig. 8.

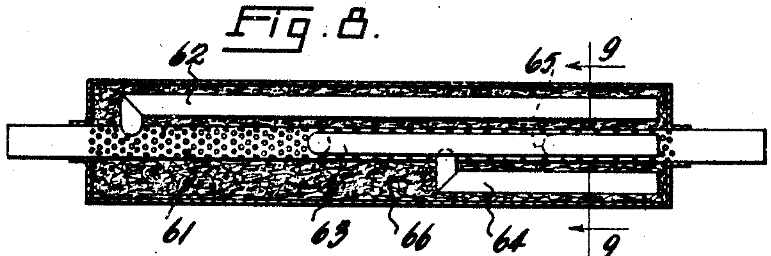


Fig. 9.

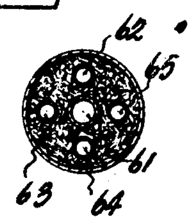


Fig. 10.

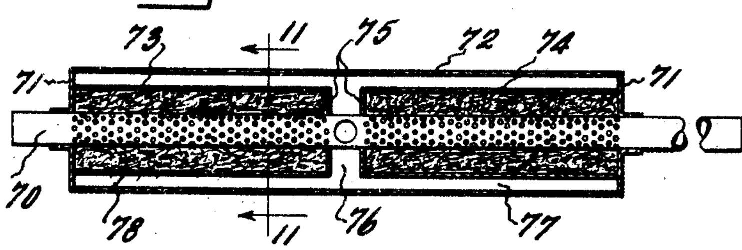


Fig. 11.

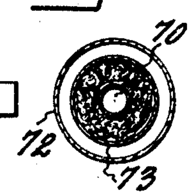
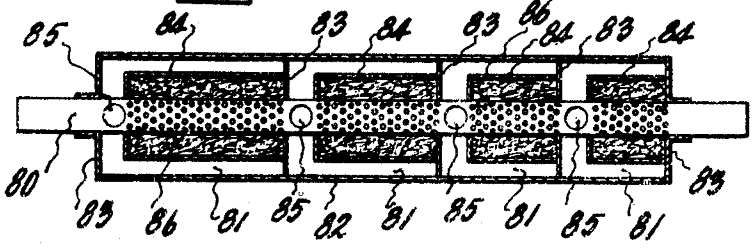


Fig. 12.



INVENTOR.
ROLAND B. BOURNE
BY Chapin and Neal
ATTORNEYS.

Patented Mar. 30, 1937 2,075,263

UNITED STATES PATENT OFFICE

2,075,263

SOUND ATTENUATING DEVICE

Roland B. Bourne, Hartford, Conn., assignor to The Maxim Silencer Company, Hartford, Conn., a corporation of Connecticut

Application October 19, 1931, Serial No. 569,711

7 Claims. (Cl. 181—48)

The present invention relates to devices for silencing sounds which are ordinarily present in conduits such as pipes and the like. Such sounds, particularly those incident to the exhausts of internal combustion engines, are generally extremely complex in character. That is to say, those sounds are made up of a great number of component sounds of different frequencies. In some cases the sound spectrum may extend more or less continuously from the lower to the upper limit of audibility.

One object of the invention is to provide a commercially practical device for attenuating sound waves over a wide range of frequencies. A further object is to provide a silencing device having a wide attenuation range which will impose practically no back pressure upon the system. A further object is to provide a device of this general character which will be compact in its overall dimensions. A further object is to provide a device of this general character in which the necessity for closely and accurately spaced walls is eliminated, thereby resulting in a decrease in the cost of manufacture. A further object is to provide a device of this general character which is inexpensive in its construction.

For the purpose of this specification, the sound spectrum is divided roughly into two groups: sounds of high frequency, which are most efficiently attenuated by the use of dissipative materials; and sounds of low frequency, which are most easily attenuated by the use of reactive side branches.

Acoustic friction devices for attenuating high frequencies may be placed in series with reactive devices for attenuating low frequencies. Such a combination, while very effective in sound attenuation, is generally commercially unwieldy and expensive. It has been found that satisfactory attenuation of both high and low frequencies may be accomplished by combining the separate means therefor in one device, simple of construction and cheap to build.

If enough acoustically absorbent material, suitably disposed, is used, it is possible to secure by this means alone satisfactory attenuation of even very low frequency sound waves. By employing reactive side branches in combination with acoustic absorbent material, the length of the main conduit and consequently the back pressure is greatly reduced and makes possible commercial embodiments possessing the further advantages of small size, light weight and a high degree of sound attenuation.

For a further explanation and understanding of the devices, reference is now made to the drawings, in which:

Figs. 1 to 5, inclusive, are diagrammatic views illustrating the acoustic principles of different forms of the invention;

Figs. 6, 8, 10 and 12 are central longitudinal sections through different forms of the invention; and

Figs. 7, 9 and 11 are sections on lines 7—7, 9—9, and 11—11 of Figs. 6, 8 and 10, respectively.

The use of closed conduits or tubes as acoustic side branches on a main acoustic channel for attenuating sound waves of certain frequencies passing therethrough is old in the art. A single such side branch may be expected to offer attenuation to those frequencies for which the side branch is resonant,—that is, since a closed pipe resonates to frequencies for which it is an odd number of quarter wave lengths long, these frequencies and those immediately above and below it will suffer attenuation. The sharpness of the resonance curve depends upon the relation of the diameter of the side branch tube to that of the main conduit, as well as on the dissipation present in the resonator. The attenuation falls off on either side of the resonant frequency. Since the problem presented is one of attenuating a continuous band of frequencies, it becomes possible to accomplish this by providing a number of closed tubes of different lengths, suitably disposed along the main sound conduit, these lengths being so chosen that the attenuation bands for the various side branches will over-lap each other.

Since I am not interested in obtaining pass bands but rather a continuous attenuation band, it is not only not necessary to obtain a matching of impedances between sections of a filter but desirable to secure mismatching, since a certain amount of attenuation is thereby possible. This attenuation is due to reflection losses. One way of obtaining this mismatching is by making the distance between side branches, along the main channel, of unequal length. Referring particularly to Fig. 1, the closed tubular side branches 20 and 21 are disposed laterally along the length of and with respect to the main channel 22. For instance, the side branch 21 is, in this case, arbitrarily taken as three-quarters of the length of side branch 20, and so on. In practice the length of the longest side branch is determined by the lowest frequency it is desired to attenuate. In some cases, where the frequencies to be attenuated are very low, the length of the side branch is necessarily excessive. It has been found that no appreciable diminution of attenuation is suffered by bending the tubular member back upon itself. This feature permits of a more compact arrangement of tubes.

In Fig. 2, the main channel **24** has disposed along its length the side branches **25** and **26**. The side branches **25** are equal in length and are at opposite ends of the channel. Between these are disposed the side branches **26**, also equal in length but shorter than the side branches **25**. In Fig. 3, the side branches **27**, **28**, **29** and **30** are not only of a progressively shorter length but also are disposed along the conduit **30** at different distances apart. In this filter is also shown a terminal impedance in the form of a straight tail pipe **32**. In Fig. 4, we have the main channel **33** with a plurality of unequal closed tubular side branches disposed along its length but in such a manner that the shorter side branches act not only as efficient attenuators for those frequencies for which they are resonant, but also act as acoustic loading on the main channel for frequencies much lower than those for which they are resonant. For instance, the side branch **34**, placed between the side branches **35** and **36**, acts to load the main channel **33** and thus simulates a greater length between the junction points of said side branches **35** and **36**. This loading, in reality, effects a rotation of phase. Similarly side branch **37** loads the main channel **33** between the side branches **36** and **38**.

The principle of phase rotation by loading may be also applied to side branches. In Fig. 5, the main channel **39** is furnished with tubular side branches **40**, **41** and **42**, and also with intermediate short branches **43** and **44** which act to load the main channel **39**. Side branch **40**, itself, is acoustically lengthened by the presence of the sub-side branch tubes **45** and **46**. Similarly, side branch **41** is acoustically lengthened by the loading action of **47** and **48**. Side branch **42** has been shown as provided with but one sub-side branch **49**. This feature makes possible the compact assembly of various side branch tubes for commercial embodiments of the invention. This acoustic loading may be also accomplished by the use of suitable volumetric side branches.

The upper limit of attenuation attainable is represented by the shortest practicable side branch. To obtain attenuation for higher frequencies, use is made of the sound absorptive properties of certain materials. The use of soft porous materials for absorbing sound is well known. Ducts and channels lined with felt, for instance, will absorb sound waves of medium to high frequencies passing therethrough. The amount of attenuation obtainable depends upon the amount of material used, its disposition, its quality, and the frequency of the sound to be attenuated. Most such materials attenuate most efficiently at frequencies of the order of 1500 cycles per second. Since attenuation by absorption is not particularly selective, this offers a means for preventing transmission through conduits of a very wide band of frequencies which lie above the point of feasible attenuation by reactive devices.

In order to utilize both types of attenuation in one device, several expedients may be employed. Fig. 6 shows one embodiment of such a device, comprising a shell **50** fitted with headers **51** and necks **52**. Extending between the two necks **52** and supported thereby is a perforated metal conduit **53** which forms the main channel **54**. Disposed along the length of said conduit **53**, in this case with their respective coupling points at equal distances apart, are the four side branches **55**, **56**, **57**, and **58**. These side branches correspond acoustically to those shown in Fig. 2. They are disposed with their axes parallel to that of the main channel **54** and are connected thereto by means of necks **59**. It will be seen that this disposition of the side branch tubes leaves considerable space between the shell **50** and the central tube **53**. This space is filled with sound absorbing, heat resisting material **60** which provides for the attenuation of the high frequencies. It will be noted that the four side branches are disposed angularly around the main tube **53**, thus providing a compact assembly. In order that the sound waves may have ample opportunity to penetrate all the sound absorbent material, the side branch tubes **55**, **56**, **57** and **58** are so disposed that the sum of the shortest peripheral distances between adjacent tubes is at least equal to the perimeter of the main conducting tube **53**. This feature applies to all devices of this character. It is found in practice that the low frequency attenuation may be affected to a slight degree by using a perforated main conduit rather than a solid one. Careful measurements of a multiple sidebranch silencing device with and without dissipation in the main channel between the points of coupling of the sidebranches show that the attenuation due to the dissipative material is simply additive over a considerable portion of the sound spectrum, becoming greater in effect, as would be expected, with higher frequencies. At points where series resonance in the main channel between the junction points of the sidebranches occurs, however, the effect of the addition of dissipative material to that portion of the main channel is strongly marked, destroying largely the adverse effect of the resonance in the main channel in amplifying frequencies which would otherwise be attenuated by the sidebranches. At these points in the attenuation curve the increase in attenuation due to the dissipative material is much greater than would be due to the sound absorptive qualities of the material itself, since dips in the attenuation curve due to series resonance may be changed to actual peaks. In acoustic devices having a plurality of sidebranches those peak attenuations which are due to the interaction between the sidebranches may be actually reduced by the addition of dissipation in the main channel, but this is not disadvantageous as these peaks are so much higher than the general level of attenuation of the device as a whole that their reduction does not cause undesirable passage of sound. In general it may be said that in addition to the general raising of the attenuation curve by the use of dissipation in the main channel between the sidebranches, which as has been stated above is enhanced in the higher frequencies, there is a valuable smoothing out of the peaks and valleys of the curve, with a greater gain in the valleys than is lost in the peaks. Careful designing, with respect to the kind of sound absorbing material used and number and size of perforations in the main conducting channel, makes it possible to obtain, in combination with the reactive side branches, satisfactory attenuation over as wide a frequency band as is desired. The presence of the sound absorbing material **60** which is packed around and between the various tubular members effectively prevents "shell noise" and also prevents metallic ringing of the interior parts of the silencer. It also confines most of the heat of exhaust gases to the interior of the silencer, an important feature in connection with interior installations.

Fig. 8 shows an embodiment of the invention wherein the tubular side branches are of progressively shorter lengths and are spaced at progressively shorter distances apart along the main channel 61. The device is thus acoustically similar to that shown in Fig. 1. The lengths of the side branches 62, 63, 64 and 65 are so chosen as to cover (with the aid of harmonic resonances) the desired frequency band. A packing 66 of sound absorbing material is also employed in this case, surrounding the central perforated tube 61.

In some cases, it is desirable to use, instead of a tubular side branch, one of the volumetric type. This would be indicated in the case of an air compressor intake silencer where the surge or thump is of very low frequency and where it is desirable to provide a certain reservoir of air upon which the compressor may draw. Such a device is shown in Fig. 10. The central tube 70 which forms the main channel is supported by heads 71 fastened to an outer shell 72. Also attached to each of the heads 71 are shells 73 and 74 provided with heads 75 apertured to receive the central tube 70 and spaced apart so as to provide a space 76. This space communicates with the single annular volumetric side branch 77 which is formed jointly by the outer shell 74 and the intermediate shells 73, 74. The tube 70 is perforated so that the sound waves passing through it may contact with the sound absorbing material 78 packed between the tube and the intermediate shells 73, 74.

Fig. 12 shows an embodiment of the invention in which the main channel 80 has disposed along its length a plurality of closed volumetric side chambers 81 formed by an outer shell 82, the headers 83, and intermediate shells 84. In this case, the side branches are of progressively smaller size and communicate with said channel 80 through openings 85 therein. In addition, the channel 80 offers attenuation for high frequencies by the presence of the sound absorbing material 86 disposed more or less continuously along its length. This material is packed between the perforated channel tube 80 and the shells 84 with their individual headers.

It is obvious that many combinations using non-dissipative and dissipative side branches may be conceived and reduced to practical working embodiments. Without enumerating a large number of such arrangements, it is clear that the scope of the invention embraces many combinations not shown in detail, and I therefore do not limit myself to those exact embodiments depicted but claim additional and obvious embodiments suggestible to those skilled in the art.

What I claim is:

1. A silencer comprising an acoustically dissipative main conducting channel and a plurality of non-dissipative acoustic side branches acoustically coupled thereto at intervals along the length thereof.

2. A silencer comprising a casing, a sieve-like main conducting channel extending therethrough, acoustically dissipative material between said casing and said channel, and a plurality of non-dissipative acoustic side branches connected to said main conductive channel at intervals along the length thereof.

3. A silencer comprising a main conducting channel and an alternate series of dissipative and non-dissipative acoustic elements laterally disposed with respect thereto and acoustically coupled thereto at intervals along the length thereof.

4. A silencer comprising a cylinder-like casing, headers in said casing, a sieve-like main conducting channel extending between said headers, acoustic absorbent material between said casing and said main conducting channel, and a plurality of closed tubular side branches acoustically coupled to said main conducting channel at intervals along the length thereof, said closed tubular side branches being disposed with their axes substantially parallel to the axis of the main conducting channel, and arranged circumferentially thereabout.

5. A silencer in accordance with claim 4, the closed tubular side branches being of unequal length.

6. A silencer in accordance with claim 4, the closed tubular side branches being of unequal length and coupled to said main conducting channel at unequal intervals along the length thereof.

7. A silencer in accordance with claim 4, in which the sum of the shortest peripheral distances between said closed tubular side branches is at least equal to the circumference of said main conducting channel.

ROLAND B. BOURNE.