Feb. 16, 1932. R. B. BOURNE 1,845,903

SILENCER

Filed Feb. 3, 1928

Fig. 1.

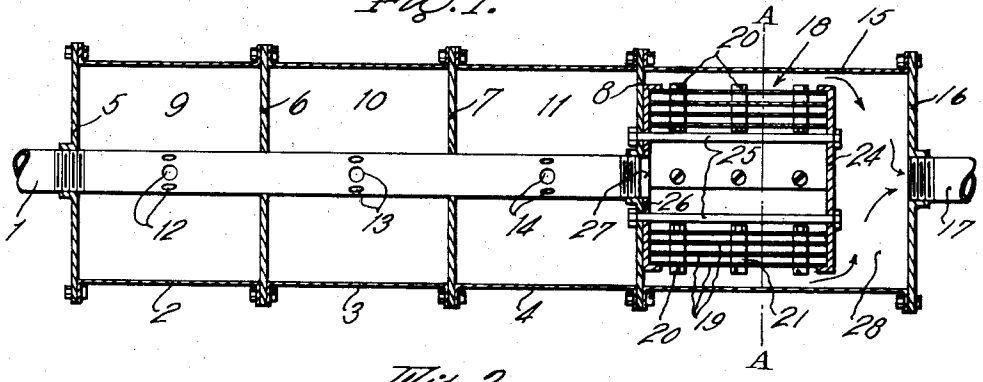


Fig. 3.

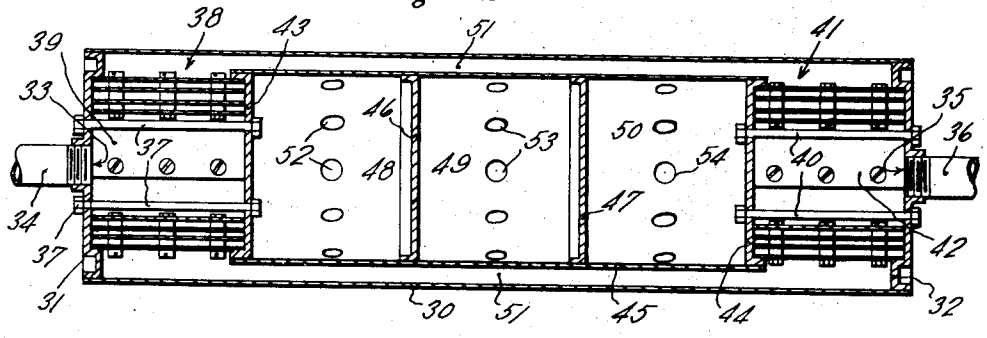
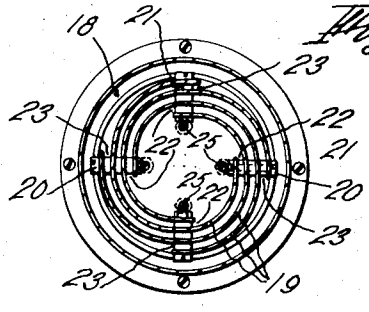


Fig. 2.



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UNITED STATES PATENT OFFICE

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SILENCER

Application filed February 3, 1928. Serial No. 251,674.

This invention relates to silencers for the exhausts of internal combustion engines, the discharge of vacuum pumps, the intake of blowers, air compressors or the like, and has for its object the provision of a simple and economical structure capable of freely conducting a gaseous medium to or from such apparatus and of limiting the transmission of sound waves therethrough.

The noises from such apparatus caused by the exhausting, discharging or sucking of masses of gas are necessarily complex in character, being made up of a mixture of sound waves of both high and low frequency, and it is often found that a very efficient silencer for high frequency waves gives poor results with low frequency waves and vice versa. Low frequency in the present discussion may be regarded as one in the order of 500 cycles or less. The present invention makes use of certain dispositions which discriminate in a broad sense with respect to silencing efficiency between high and low frequency sound waves, and these dispositions are so combined as to handle in the most effective and simple manner a wide band of frequencies so as to produce a silencer of general all around efficiency.

For limiting the transmission of sound waves of high frequency, it is convenient and economical to make use of acoustic friction or the scrubbing action which takes place at or near the bounding surfaces of passages. For this purpose, shallow spiral passages which present a large bounding surface may be effectively employed. To prevent back pressure, it is only necessary to provide a sufficient number of such spiral passages in parallel relation to handle the desired volume of gas. The higher the frequencies involved, the more effective is friction in attenuating such frequencies. Conversely, the lower the frequency, the less effective is friction. At very low frequencies, it is substantially without effect, unless cumbersome and expensive constructions are used.

It therefore becomes desirable to adopt other means for limting the transmission of low frequencies. For this purpose, it is convenient to make use of the reactive effect of side chambers suitably disposed with respect to a main acoustic channel, upon alternations of pressure in such conduit or channel. A proper combination of suitably proportioned side chambers acoustically coupled to a channel can be designed so as to limit, to any desired degree, the transmission of sound waves or alternations in pressure, throughout a wide band of frequencies, Such devices are called acoustic wave filters, and in theory should comprise an infinite number of sections in line, each successive portion of the main channel to which a side chamber is acoustically coupled being regarded as a section.

For practical purposes, it is quite satisfactory to use only a sufficient number of sections to obtain the required attenuation and to secure the necessary terminal impedance by replacing the theoretically required infinite line of sections with a suitable terminal structure, the acoustic properties of which duplicate as nearly as possible those of the imaginary infinite line. Under these conditions, the sections of the finite series will perform as though they were but the first few of an infinite number of similar sections.

For the purposes of the present invention, the terminal structure should be acoustically an impedance of the proper value. It is convenient to construct this terminal device in such a manner that it not only provides the proper terminal impedance for the wave filter preceding it but also offers a very high resistance to sound waves of high frequencies which are unaffected by the filter and at the same time, by virtue of its construction, as hereinbefore mentioned, offers negligible opposition to the flow of exhaust gases and the like.

Such a terminal structure may comprise a plurality of thin and shallow passages of spiral or tortuous direction and with a sufficient number arranged in parallel to freely conduct the gases therethrough. A specific form of such a device at present preferred is disclosed in the co-pending application of Hiram Percy Maxim and Roland B. Bourne, Serial No. 104,458, filed April 24, 1926.

Referring to the drawings, which show several embodiments of the invention:

Fig. 1 is a view in longitudinal section of

one form of silencer in which the principles of the present invention may be embodied;

Fig. 2 is a transverse section through the terminal structure along line A—A of Fig. 1;

Fig. 3 is a view in longitudinal section of a modified form of silencer.

Referring more particularly to Fig. 1, a central pipe or tubular conduit, indicated at 1, serves as an acoustic channel and extends axially of the structure. Surrounding said pipe 1 are a series of cylindrical shells 2, 3 and 4 of considerably larger diameter than said pipe, as shown. Transversely of said cylindrical shells and fitted tightly upon the outside of pipe 1 are partitions 5, 6, 7 and 8 which, together with said cylindrical shells, form a series of annular chambers 9, 10 and 11 surrounding said pipe 1. The pipe 1 is preferably provided with a series of openings such as 12, 13 and 14 at intervals along its length to afford communication between the pipe and the annular chambers 9, 10 and 11. It will be understood that each series of perforations 12, 13 and 14 is disposed circumferentially around said pipe 1 and may, if desired, be replaced by an interruption in said pipe forming an annular opening. The transverse partitions 5, 6, 7 and 8 are secured at their outer peripheries to flanges of said cylindrical shells 2, 3 and 4 for holding said parts together. The left hand end of pipe 1 may be regarded as the inlet to the silencer and may be suitably attached to the apparatus to be silenced.

The structure as above described may be properly termed an acoustic filter of three sections in which the conduit 1 serves as the acoustic channel and the chambers 9, 10 and 11 as the side branches therefor acoustically coupled to said channels through the openings 12, 13 and 14. Inasmuch as the side branches or chambers 9, 10 and 11 are closed, this filter structure is of the low frequency pass type,—that is, only sound waves of very low frequency will be readily transmitted through said acoustic channel or pipe 1. The structure may be so designed that the cut off frequency, below which the acoustic waves will pass through the filter, will lie below the limit of audibility, which is in the neighborhood of sixteen cycles. The low pass type of filter is employed, not because of a desire to pass the lower frequencies, but because its physical requirements are suitable, and because the frequencies which are passed can be made so low as to be of no commercial consequence. However, such an acoustic filter structure requires for its proper operation either an infinite series of such sections as above described or the equivalent thereof in terminal impedance. Such an equivalent terminal impedance is sometimes called the "image impedance". The image impedance of any non-symmetrical structure is that impedance which can be substituted in the acoustic line at a junction point for the remaining structure without incurring reflection losses. When a structure is terminated in its image impedance, the impedance looking in either direction, toward the terminating impedance or back toward the structure (filter, in this case), is the same. In other words, when we make the impedances looking in either direction from a junction point identical, each section of a filter will function as though it were one section of an infinite number of similar sections, whereas it may be the only one of its kind in the system. For a theoretical discussion of acoustic filter structures, reference is made to an article by G. W. Stewart in "The Physical Review" of December, 1922, page 528.

A low frequency pass filter such as here provided will not pass waves of a frequency higher than that of the cut off frequency, which as before stated is chosen so that it is below the limit of audibility, except those frequencies corresponding to wave lengths of the same order of magnitude or less than the linear dimensions of a section, or harmonies thereof. Consequently, I have devised a terminal structure for the acoustic filter which will serve the purpose both of furnishing the terminal impedance for the effective operation of the three sections of the acoustic filter and also provide sufficient acoustic resistance to dissipate the waves of extremely high frequency which would otherwise pass through the silencer.

This terminal structure comprises a cylindrical shell 15 having mounted within the same a silencing unit or casing 18 which in turn has a central inlet opening at 27 in communication with the open end of the pipe 1. The shell 15 is preferably of the same diameter as shell 4 and is secured by flanges to the partition 8 at the end of shell 4, as shown. The outer end of shell 15 is closed by a header 16 having a central opening connected with the outlet pipe 17. The silencing unit 18 is made up of a plurality of inter-nested curved sheets 19 which are in superposed relation and radially spaced apart to provide a plurality of spiral passages in parallel leading from an interior chamber of said casing to an annular space at the exterior thereof, as more particularly shown in Fig. 2.

The superposed sheets 19 are held together in their spaced relation preferably by radial tie bolts 20 and spacing washers 21 between the sheets as shown. Preferably the sheets 19 are of equal length but are overlapped circumferentially in such a way as to provide circumferentially spaced inlets 22 and outlets 23 for the spiral passages formed by said sheets. The casing 18 is provided at one end with an annular header 26 abutting against the partition wall 8 and at its other end a cover plate 24 is secured for entirely covering the outer end of said casing and

the sides of the spiral passages. Suitable tie bolts 25 are provided for securing said casing to the partition 8 in a position so as to provide an annular passage between the outside of the casing 18 and said cylindrical shell 15 and an expansion chamber 28 between the header 24 and end wall 16. It will be understood that the spiral passages between the superposed sheets 19 are relatively shallow or of small depth as compared with their length and width so that the sound waves entering said casing are subdivided, each part thereof being compelled to take a circuitous course by the ever changing direction of each passage. The resistance offered by the comparatively large bounding surfaces of such passages and the reflections occurring from the ever changing direction of said passages very effectually dissipate and destroy sound waves of the higher frequencies.

The operation of the apparatus may be described as follows, assuming that the discharging exhaust of an internal combustion engine enters the left end of the conduit or pipe 1. The gases of said exhaust will flow freely through the straight passage of conduit 1 to the interior of said casing 18 and will there divide into a plurality of spirally directed streams with very little retardation as they flow to the annular space at the outside of said casing 18. From this point, the gases will continue to flow, in the direction of the arrows shown, out through the exit 17. The sound waves entering the pipe 1, except for those very high frequencies and the inaudible waves below the cut-off frequency, will be so greatly attenuated in passing through the several sections of the acoustic filter structure that practically no low frequency waves will pass into the terminal structure 18. The waves of higher frequency will be dissipated in passing outwardly through the spiral passages of the casing 18 by the action of frictional resistance and repeated reflection so that practically no sound waves of any magnitude will emerge from the outlet 17.

For some installations it may be desirable to combine the acoustic filter sections as above described with a terminal structure at each end thereof instead of only at one end as shown in Fig. 1. In this case, it would be merely necessary to place at the left hand end of the structure shown in Fig. 1 a duplicate of the terminal structure shown at the right of said figure. It may also be desirable in some cases to provide a filter in which the side chambers 9, 10 and 11 are progressively reduced in size from one end of the filter to the other.

Referring to Fig. 3, which shows a modified form of the silencer, 30 indicates an outer cylindrical shell extending from one end to the other of said silencer and having at each end channel like headers 31 and 32. The header 31 has a central opening at 33 suitably coupled to an inlet or outlet pipe 34 and the header 32 has a central opening 35 suitably coupled to an inlet or outlet pipe 35. Attached to the header 31 by suitable tie bolts 37 is a casing or silencing unit 38 of the same construction as that of the casing 18 in Fig. 1. The casing 38 is spaced as shown from the outer shell 30 by the flanged periphery of the header 31 and the inner chamber 39 of said casing is in communication with the inlet pipe 34. A header 43 closes the end of said casing 38 opposite the inlet thereof. Similarly, to the header 32 is attached, by means of bolts 40, a casing or silencing unit 41 of the same construction as that of casing 18 in Fig. 1, and this casing is also spaced from the shell 30 by the peripheral flange of said header 32 with its inner chamber 42 in communication with the outlet pipe 35. A header 44 closes the end of casing 41 opposite the outlet thereof.

A series of acoustic filter sections are provided within the shell 30 between the terminal structures 38 and 41 and said acoustic sections are formed by an interior shell 45 which extends from the header 43 of the casing 38 to the header 44 of the casing 41. The interior shell 45 is divided at intervals throughout its length by partition walls 46 and 47, as shown, to provide a series of chambers 48, 49 and 50 which serve as acoustic side branches for the annular acoustic channel 51 formed between the shells 30 and 45. Circumferentially disposed openings 52, 53 and 54 are provided for said chambers 48, 49 and 50, respectively. In this way, the acoustic channel 51 is coupled acoustically to said side chambers 48, 49 and 50.

In the operation of this form of silencer, the gas entering at either end will be first directed outwardly through the casings 38 or 41 to the annular acoustic channel and will then flow longitudinally to the other end of the silencer and will then flow inwardly through the opposite casing to the exit of the silencer. The high frequency sound waves entering the silencer will be dissipated through the casings 38 and 41 and the lower frequency sound waves will be attenuated by the reactive forces set up by the side chambers along the acoustic channel as described. An advantage of this form of silencer is that sounds of high frequency entering at either end of said silencer are first dissipated by the spiral passages in the casings 38 or 41 before coming in contact with the outer shell 30, thus lessening the possibility of transmitting any sounds through said outer shell. A further advantage of this form lies in the fact that the annular channel 51 has relatively large bounding surfaces as compared with a pipe-like channel and therefore the dissipation of the sound wave energy by friction is materially increased.

It will be obvious that either end of this form of silencer may be used for attachment to apparatus to be silenced.

It will be understood that various other forms and modifications of the construction shown may be made to obtain equivalent and like results, and the invention should not be limited to the specific disclosures described, the scope of the invention being pointed out in the appended claims.

What I claim is:

1. A silencer comprising an acoustic conduit providing substantially unobstructed gas flow and possessing low acoustic resistance but high acoustic reactance, and a terminal structure through which the gas passes from the conduit, said terminal structure possessing low resistance to gas flow and high acoustic resistance and serving both as a terminal impedance for the acoustic conduit and as a high frequency silencer.

2. A silencer comprising a conduit providing substantially unobstructed gas flow, one or more side branch chambers coupled to the conduit acoustically only so as not to form part of the path traversed by the gas, said conduit and side branch chambers forming an acoustic unit presenting low resistance to gas flow and low acoustic resistance but a high acoustic reactance, and a terminal structure through which the gas passes from the conduit, said terminal structure possessing low resistance to gas flow and high acoustic resistance and serving both as a terminal impedance for the acoustic unit comprising the conduit and the side branch chambers and as a high frequency silencer.

3. A silencer comprising a conduit providing substantially unobstructed gas flow, one or more side branch chambers coupled to the conduit acoustically only so as not to form part of the path traversed by the gas, said conduit and side branch chambers forming an acoustic unit presenting low resistance to gas flow and low acoustic resistance but a high acoustic reactance, and a terminal structure through which the gas passes from the conduit, said terminal structure comprising a plurality of thin passageways arranged in multiple so as to provide a low resistance to flow of the gas but a high acoustic resistance.

4. A silencer comprising a casing divided transversely into chambers, a gas conduit within the casing passing by at least one of the chambers and coupled to it acoustically only so that said chamber does not form part of the path traversed by the gas, and serves as an acoustic side branch chamber to said conduit, said conduit opening into a chamber at one end of the casing, a plurality of closely spaced plates coiled within the latter chamber so as to provide a plurality of thin passageways arranged in multiple so as to present a high acoustic resistance and a low resistance to gas flow, and an outlet leading from said chamber positioned to vent the gas therefrom after it has passed through the passageways.

5. A silencer comprising a cylindrical casing, a partition dividing off a terminal chamber at one end of the casing, a pipe extending from the other end of the casing to the partition, a plurality of annular partitions surrounding the pipe and closing off the casing into a plurality of side branch chambers having no direct communication one with another, the pipe being formed with openings communicating with each of the side branch chambers, and a structure in the terminal chamber composed of a plurality of spirally wound plates and end closures therefor surrounding the opening of the pipe and forming a plurality of thin passageways arranged in multiple, and an outlet from the terminal chamber communicating with the outlet ends of said passageways.

6. A silencer comprising an outer casing, an inner casing spaced from the outer casing so as to provide an annular passageway between them, a plurality of partitions within the inner casing dividing it into a plurality of chambers having no direct communication one with another, the inner casing being formed with circumferentially arranged apertures joining each of the chambers with the annular passageway, a multiple spiral passage within the outer casing at each end of the inner casing leading from the annular passageway to a central space, and inlet and outlet conduits connected respectively to the central spaces of the multiple spiral passages.

In testimony whereof I have affixed my signature.

ROLAND B. BOURNE.