Jan. 24, 1939. W. L. MANNING 2,144,725

SILENCER

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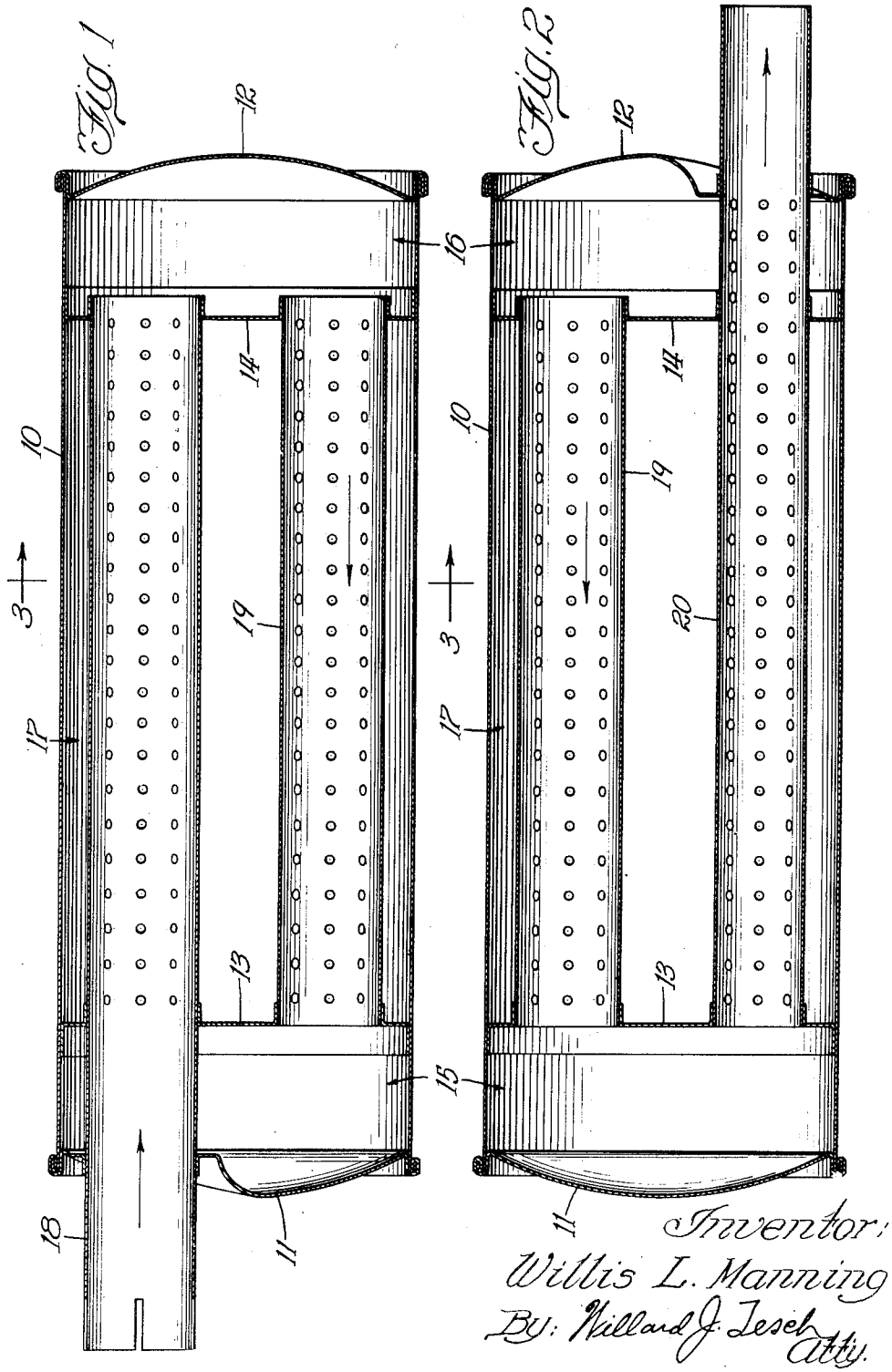

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Fig. 6

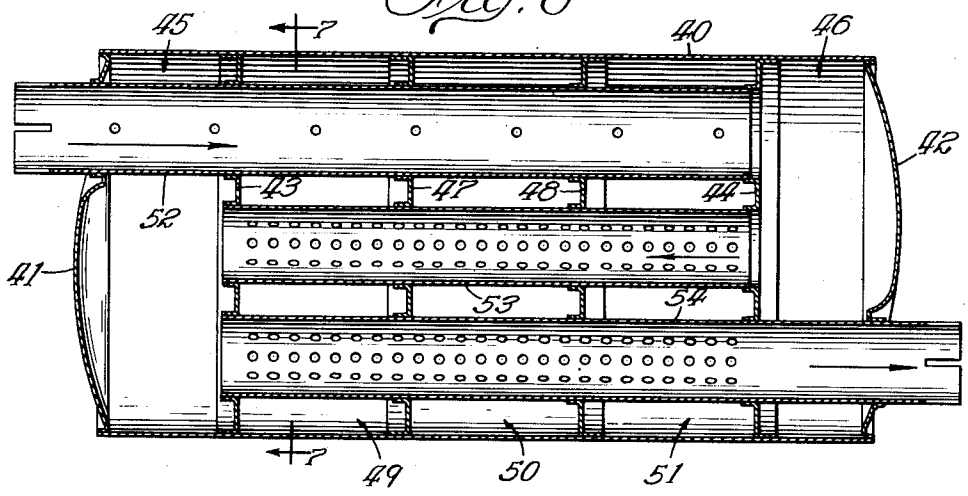


Fig. 7

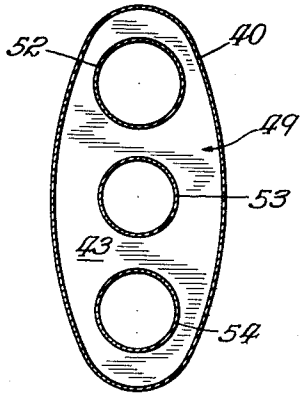
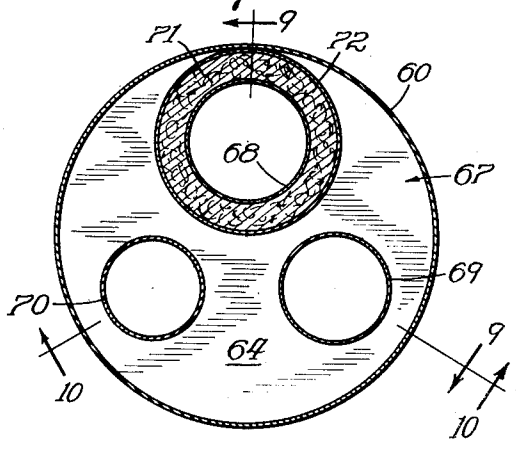


Fig. 8



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SILENCER

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Fig. 4

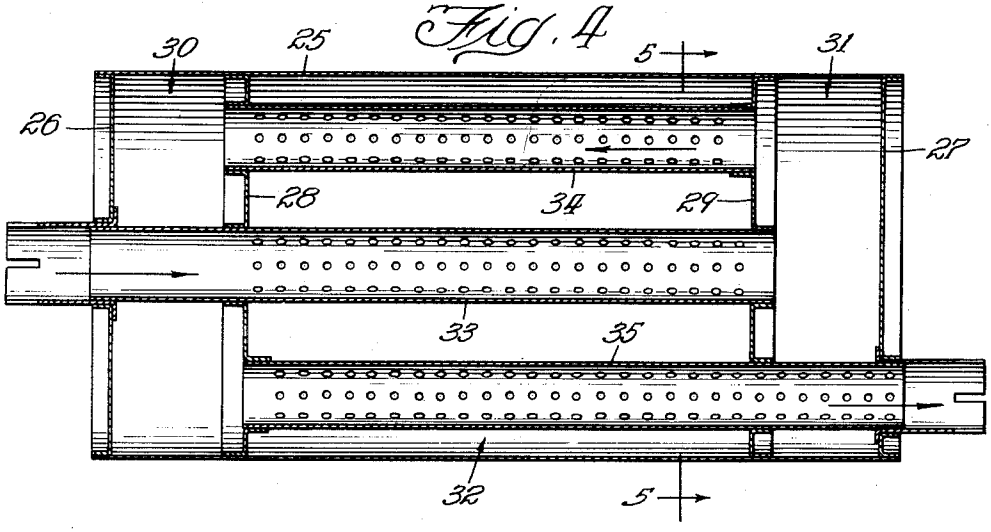


Fig. 5

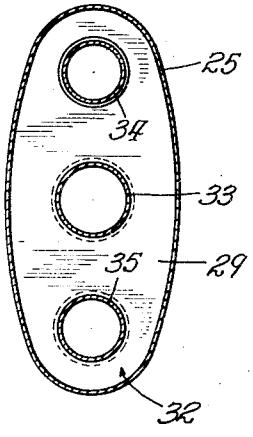
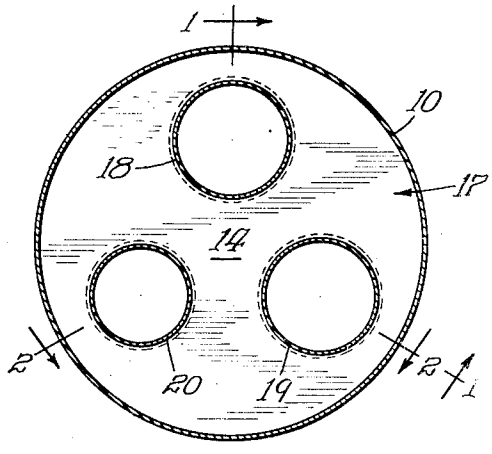


Fig. 3



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SILENCER

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Fig. 9

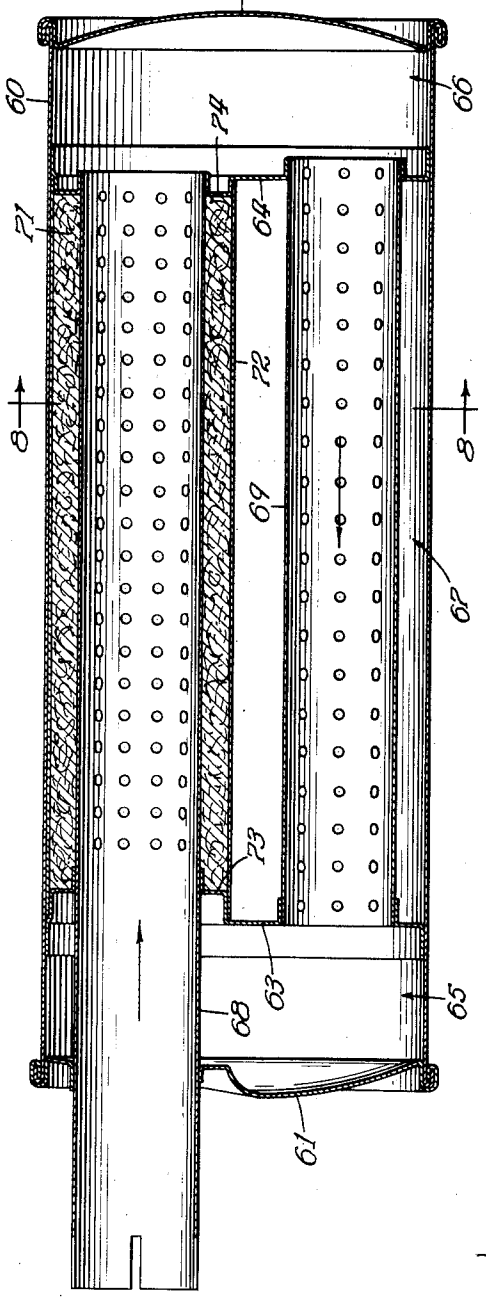
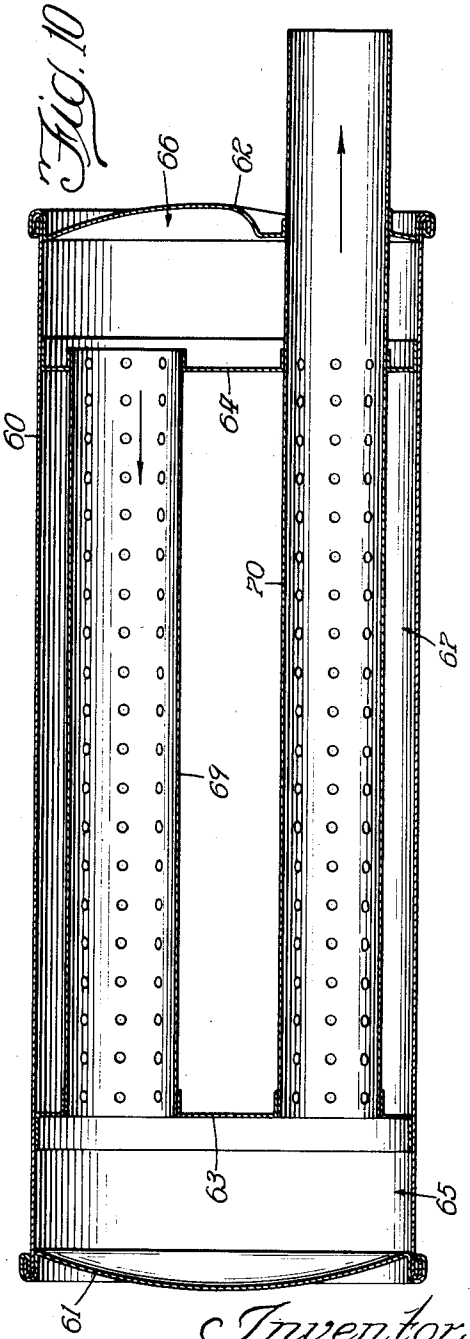


Fig. 10



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Patented Jan. 24, 1939

2,144,725

UNITED STATES PATENT OFFICE

2,144,725

SILENCER

Willis L. Manning, Madison, Wis., assignor to Burgess Battery Company, Chicago, Ill., a corporation of Wisconsin

Application August 2, 1937, Serial No. 156,928

11 Claims. (Cl. 181—54)

This invention relates to silencers for internal combustion engines and particularly to silencers for the exhaust gases of such engines.

It is an object of the invention to provide a silencer of the retroverted passage type which is of simple and economical construction, but which is highly effective for silencing purposes. In furtherance of this object a silencer is provided in which the gas conducting tubes, or conduits, are so constructed and arranged that they co-operate with each other and with the space within the silencer casing to effect the silencing without the assistance of other silencing means.

Briefly, the invention provides a silencer containing at least three foraminous, or perforated, conduits through which the gases pass in succession, the conduits being arranged in laterally adjacent relation and without any partitions between them, whereby the interior of each conduit is in direct communication with the interiors of the other conduits through the perforations of the conduits and the space within the casing. As a modification, one form of the invention contains a layer of sound-absorbing and gas-pressure-absorbing material surrounding one of the gas conducting conduits.

In the drawings:

Figs. 1 and 2 are longitudinal sectional views of the silencer of this invention taken along lines 1—1 and 2—2 respectively of Fig. 3;

Fig. 3 is a transverse sectional view along line 3—3 of Fig. 1;

Fig. 4 is a longitudinal sectional view of a different modification of the invention;

Fig. 5 is a transverse sectional view along line 5—5 of Fig. 4;

Fig. 6 is a longitudinal sectional view of a further modification of the invention;

Fig. 7 is a transverse sectional view along line 7—7 of Fig. 6;

Fig. 8 is a transverse sectional view of a further modification of the invention, taken along line 8—8 of Fig. 9;

Figs. 9 and 10 are longitudinal sectional views along lines 9—9 and 10—10 of Fig. 8, respectively.

The silencer of Figs. 1, 2 and 3 comprises a substantially imperforate casing 10, which may be of cylindrical form, and which is closed at its ends by end walls 11 and 12. Spaced inwardly from the end walls are transverse bulkheads 13 and 14 which subdivide the casing into relatively small end chambers 15 and 16 and an intermediate main chamber 17. End wall 11 and bulkheads 13 and 14 have aligned openings therein within which is mounted an open ended entrance conduit 18, the said conduit terminating at its inner end at the said bulkhead 14. A return conduit 19 is mounted between a second pair of aligned openings in bulkheads 13 and 14, and an outlet conduit 20 is mounted in a third group of aligned openings in bulkheads 13 and 14 and end wall 12, the inner end of conduit 20 terminating at bulkhead 13. The conduits 18, 19 and 20 are foraminous at those portions which are located within the main chamber 17, and outlet conduit 20 is foraminous also at the portion thereof which is located in end chamber 16.

In operation, the exhaust gases enter the silencer by way of inlet conduit 18, the path of travel being indicated by the arrows. A large proportion of the gases pass through the conduit 18 into the chamber 16 where their direction is reversed and they pass forwardly into return conduit 19.

A large proportion of the gases which enter return conduit 19 pass through the same and enter the direction-reversing chamber 15, where their direction is again reversed and they enter outlet conduit 20 and pass through the said outlet conduit and out of the silencer. The end walls 11 and 12 of direction-reversing chambers 15 and 16 are curved outwardly, or convex. Such curvature facilitates and contributes to the silencing of the gases by reducing the noise caused by gas pressure impacts upon the end walls. It also facilitates the flow of the gas while the direction thereof is being reversed.

As is well known, the pressure of the exhaust gas pulses becomes progressively lower as the gases travel through the silencer so that there is a pressure differential between the different conduits. A proportion of the gases is discharged laterally through the perforations of the conduits from those conduits which are at higher pressure, and pass into the conduits which are at lower pressure, through the perforations of the latter. Thus there is a lateral passage of gases from conduit 18 to conduits 19 and 20, and from conduit 19 to conduit 20. There is no sound-absorbing material or walls or other obstructions in the chamber 17 to impede the transfer of the gases laterally between the conduits, and the openings in the walls of each conduit are in direct communication with the openings in the walls of the other conduits. The transfer is regulated by the area of the openings in the walls of the conduits. It has been found that satisfactory silencing is obtained when the openings occupy from about 0.5% to about 10% of the total area of the foraminous walls. As the proportion of

the area occupied by the openings is decreased within said range, the frequency range at which the silencer is effective becomes somewhat lower, and the opening area to be used in a given case is determined by the frequency characteristics of the noise which is to be silenced. Satisfactory silencing is accomplished in many instances with an opening area of approximately 4%, and, although this is not considered a preferred proportion, it is one which has been used for several applications with satisfactory results.

Some of the heat which is contained in the exhaust gases is dissipated during their passage through the silencer, with the result that the gases are cooled and the succeeding conduits in the path of the gases may be made progressively smaller. As is shown in Figs. 1, 2 and 3 each succeeding conduit is of slightly smaller diameter than the preceding conduit. Such reduction in size does not result in any increased resistance to the flow of gases through the silencer. In addition to the transfer of gases laterally between the conduits within chamber 17 the gases which are discharged from conduit 18 into direction-reversing chamber 16 are free to pass into outlet conduit 20 through the openings therein which are located in said direction-reversing chamber. The openings may be omitted from conduit 20 at this location but it has been found that such openings produce an improvement in the silencing function.

The action by which the silencer of this invention accomplishes the silencing function is not clearly understood. It is believed that there are three major factors involved. It is understood that in the exhaust of an internal combustion engine there is present both noise of a purely acoustical character, and gas pulsations of a purely mechanical nature and which consist of a series of separated slugs of exhaust gas at high pressure between which are areas of low pressure, which may be lower than atmospheric pressure. Both of these phenomena (acoustical and mechanical) consist of alternating pressure conditions in which the pressure varies alternately above and below a mean or average pressure. As the first factor, the large central chamber of the silencer constitutes an expansion space into which the high pressure pulses, both acoustical and mechanical, may freely expand through the perforations of the conduits and from which the minimum pressure condition may cause a suction into the conduits, with the result that both the maximum and minimum pressure conditions are attenuated.

A second factor is the lateral flow of gases from a conduit at higher pressure to one at lower pressure through the perforations of the conduits. The outward flow from the conduit at higher pressure is greatest during maximum pressure conditions with the result that the high pressures are reduced, and the inward flow into the conduit at lower pressure is greatest during minimum pressure conditions in the latter, with the result that the low pressures are increased and there is a general smoothing out of the pulsations. In other words, considering the laterally adjacent portions of any two conduits, the flow between the conduits at any instant depends upon the relative pressures in the said portions of the conduits and such flow will be greatest when the pressure difference is greatest, and consequently the high pressures in one and the low pressures in the other will be relieved, or attenuated, and a smoothing will be effected.

A third factor is the acoustic resonator action of the large chamber upon the sounds in the conduits. With respect to those sounds which travel within the conduits, the chamber represents the volume of a resonator and the perforations represent the connection or neck between each conduit and the said volume. The construction of this invention has a broad frequency response, that is, it attenuates a broad frequency range.

Undoubtedly, there are additional minor factors which contribute to the silencing function, such as the expansion which takes place in the reversing chambers at the ends of the casing, and the cooling which occurs in the silencer.

Figs. 4 and 5 show a silencer which is similar to that of Figs. 1, 2 and 3, except that the casing 25 is oval in transverse shape and the gas conducting conduits are arranged in a row along the major transverse axis of the casing. The casing has two end walls 26 and 27, and two bulkheads 28 and 29 spaced interiorly from end walls 26 and 27, respectively, to form direction-reversing chambers 30 and 31 at the ends of the silencer and a main chamber 32 at the mid-portion of the casing. The end walls and the bulkheads have openings therein for the accommodation and the mounting of inlet conduit 33, return conduit 34 and outlet conduit 35. In this construction, inlet conduit 33 is located centrally of the casing and the other two conduits are located on opposite sides of the said inlet conduit.

The silencer of Figs. 6 and 7 is similar to that of Figs. 4 and 5. In this construction, however, the main chamber is sub-divided into a number of smaller chambers by transverse partitions, and the proportion of conduit wall area occupied by the openings is considerably smaller in the inlet conduit than in the other two. In this construction, also, the inlet conduit, rather than the outlet conduit, is perforated at the portion thereof which passes through one of the direction-reversing chambers. The casing 40 is of oval transverse shape and has end walls 41 and 42, which are curved outwardly. Transverse bulkheads 43 and 44 are spaced inwardly from end walls 41 and 42 respectively to form direction-reversing chambers 45 and 46. Transverse partitions 47 and 48 are located between bulkheads 43 and 44 and are spaced from said bulkheads and from each other to form intermediate chambers 49, 50 and 51. The end walls, bulkheads and partitions have openings therein for the accommodation and mounting of the gas-conducting conduits, the conduits being arranged in a row, the return conduit being located centrally and the inlet and outlet conduits being arranged on either side of the return conduit. The inlet conduit 52 is provided with perforations where it passes through direction-reversing chamber 45, these perforations permitting the entering gases, which are at the highest pressure within the silencer, to pass laterally from the inlet conduit 52 and through chamber 45 into the open end of outlet conduit 54. It has been found that these perforations and the presence of the partitions 47 and 48 result in increased silencing effectiveness for certain applications.

In Figs. 8, 9 and 10, a silencer is shown in which one of the conduits is surrounded with a relatively thick layer of porous sound-absorbing and gas-pressure-absorbing material. In this construction the layer of absorbing material is enclosed by a substantially imperforate wall which prevents lateral communication from the inlet conduit to the other conduits, such com-

munication being confined to the return conduit. In this construction the casing 60 may be of cylindrical shape and has curved end walls 61 and 62 and transverse bulkheads 63 and 64 spaced inwardly from said end walls to form direction-reversing chambers 65 and 66, and main chamber 67. The end walls and the bulkheads have openings therein for the accommodation and the mounting of the gas-conducting conduits comprising inlet conduit 68, return conduit 69 and outlet conduit 70. The foraminous inlet conduit is surrounded by a layer of porous sound-absorbing and gas-pressure-absorbing material, such as steel wool or other metallic wool, exfoliated vermiculite, asbestos fibers, rock wool, pumice or other loose ceramic aggregates, or aggregates bonded together with a suitable adhesive so as to provide inter-communicating pores and channels within the material. The absorbing material 71 is held in place by a substantially imperforate shell 72 which surrounds the said absorbing material. For supporting the shell 72, annular portions 73 and 74 are depressed inwardly upon bulkheads 63 and 64 to form shoulders upon which the said shell 72 is mounted.

In this construction the sounds and gas pulses have access through the perforations of the inlet conduit 68 to the absorbing material 71, which exerts the well-known silencing function of such a material, the silencing being particularly effective at the higher frequency range. All of the gases pass through conduit 68 and reversing chamber 66 into return conduit 69 where a portion passes through the conduit longitudinally and through the direction-reversing chamber 65 into the outlet conduit 70, and a second portion passes laterally through the perforations of conduit 69 into the chamber 67 and thence laterally through the perforations of conduit 70 and into said conduit, in the manner described heretofore in connection with the previous figures.

Modifications of the invention may be made in addition to those described herein. For example, the construction of Figs. 6 and 7 is illustrative of the principle that the proportion of opening area of the conduit walls need not be uniform in the different conduits. Any combination of opening area in the different conduits may be used, within the range recited heretofore to suit particular applications.

In this construction, the number of partitions between the bulkheads may be varied. In the constructions of Figs. 5 and 7, the casings may be of other than oval shape, and may be of any shape in which one transverse dimension is greater than the other and the conduits are arranged substantially in a row along the greater transverse dimension. In the silencer of Figs. 8, 9 and 10, the layer of absorbing material may be arranged about the return conduit or the outlet conduit, instead of about the inlet conduit as shown. Other variations may be made, and it is understood that the invention is limited only by the scope of the appended claims.

I claim:

1. A silencer of the retroverted passage type comprising a substantially closed chamber, a plurality of open-ended conduits arranged longitudinally within said chamber and in laterally adjacent relation to each other, each of said conduits being directly exposed to the others, means connecting the open ends of said conduits for conducting the sounds and gases to be silenced to said conduits in succession, the walls of said conduits being foraminous and the openings in the walls of each of said conduits being in direct and unrestricted communication with the openings in the walls of the others of said conduits through the space within said chamber, the openings in said foraminous conduit walls occupying about 0.5% to 10% of the total area of said foraminous conduit walls.

2. The silencer of claim 1 in which the openings in the foraminous conduit walls occupy approximately 4% of the total area of said foraminous conduit walls.

3. The silencer of claim 1 in which there are three conduits in the chamber and the conduits are arranged in substantially parallel, laterally adjacent, spaced relation.

4. The silencer of claim 1 in which the conduits are foraminous through substantially their length within said chamber.

5. The silencer of claim 1 in which each successive conduit in the path of the sounds and gases is of smaller diameter than the preceding conduit.

6. The silencer of claim 1 in which the chamber is sub-divided into two or more smaller chambers by one or more transverse partitions and the conduits pass through said partitions.

7. A silencer of the retroverted passage type comprising a substantially closed chamber, a plurality of open-ended conduits arranged longitudinally within said chamber and in laterally adjacent relation to each other, each of said conduits being directly exposed to the others, means connecting the open ends of said conduits for conducting the sounds and gases to be silenced to said conduits in succession, the walls of said conduits being foraminous and the openings in the walls of each of said conduits being in direct and unrestricted communication with the openings in the walls of the others of said conduits through the space within said chamber, the openings in said foraminous conduit walls occupying about 0.5% to 10% of the total area of said foraminous conduit walls and an additional length of foraminous conduit connected in the path of said sounds and gases, said additional length of foraminous conduit being surrounded by porous sound-absorbing and gas-pressure-absorbing material.

8. A silencer of the retroverted passage type comprising a substantially imperforate casing having inlet and outlet openings in the end walls thereof, transverse bulkheads within said casing and spaced from said end walls respectively to form a direction-reversing chamber at each end of said silencer and a main chamber between said bulkheads, an inlet conduit, an outlet conduit and a return conduit passing longitudinally through said main chamber and said bulkheads, said conduits being laterally adjacent and directly exposed to one another within said main chamber, said inlet conduit passing through the direction-reversing chamber at the inlet end of said casing and connecting said inlet opening with the direction-reversing chamber at the outlet end of said casing and said outlet conduit passing through the direction-reversing chamber at the outlet end of said casing and connecting the direction-reversing chamber at the inlet end of said casing with said outlet opening, said return conduit connecting the two direction-reversing chambers together, the walls of said conduits within said main chamber being foraminous, the openings in the walls of each of said conduits being in direct and unrestricted communication with the openings in the walls of the

others of said conduits through the space within said main chamber, the openings in said foraminous conduit walls occupying about 0.5% to 10% of the total area of said foraminous conduit walls.

9. The silencer of claim 8 in which one of the conduits comprising the inlet and outlet conduits is foraminous within the direction-reversing chamber through which it passes.

10. The silencer of claim 8 in which one transverse dimension of the casing is greater than the other and the conduits are arranged in a row substantially parallel to the greater of said dimensions.

11. The silencer of claim 8 in which the end walls of the casing are curved outwardly.

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