June 14, 1960 L. H. BILLEY 2,940,538

SILENCER

Filed June 28, 1954 2 Sheets-Sheet 1

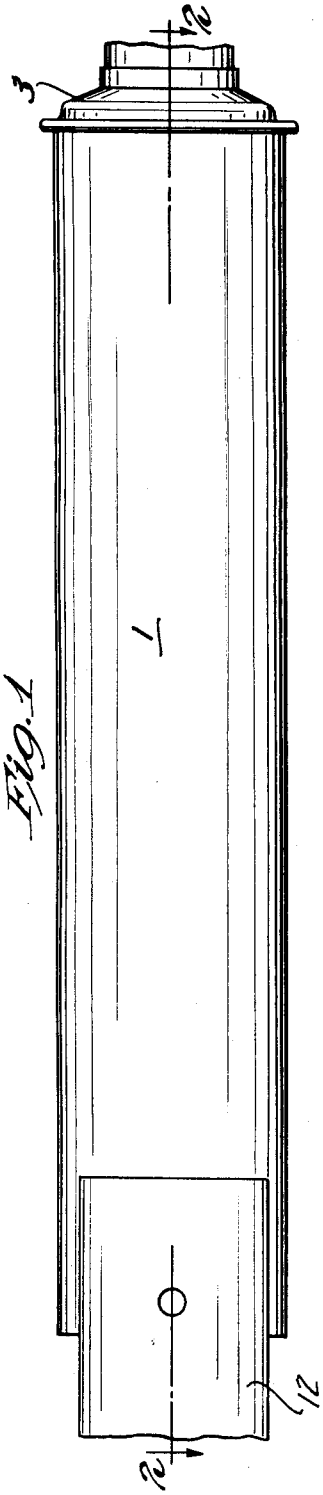


Fig. 1

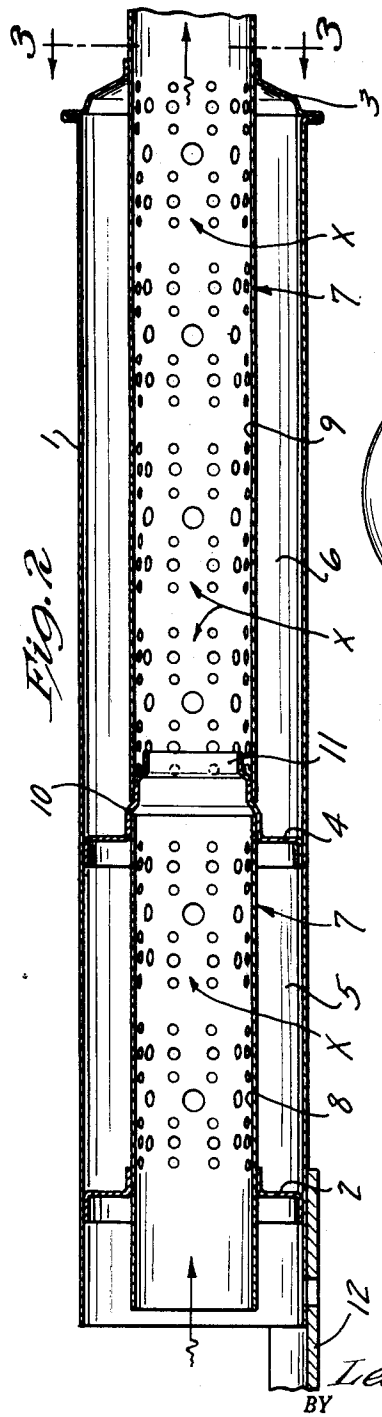


Fig. 2

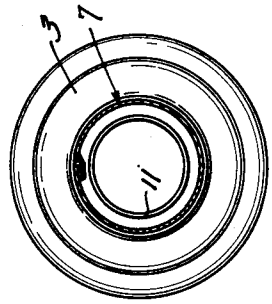


Fig. 3

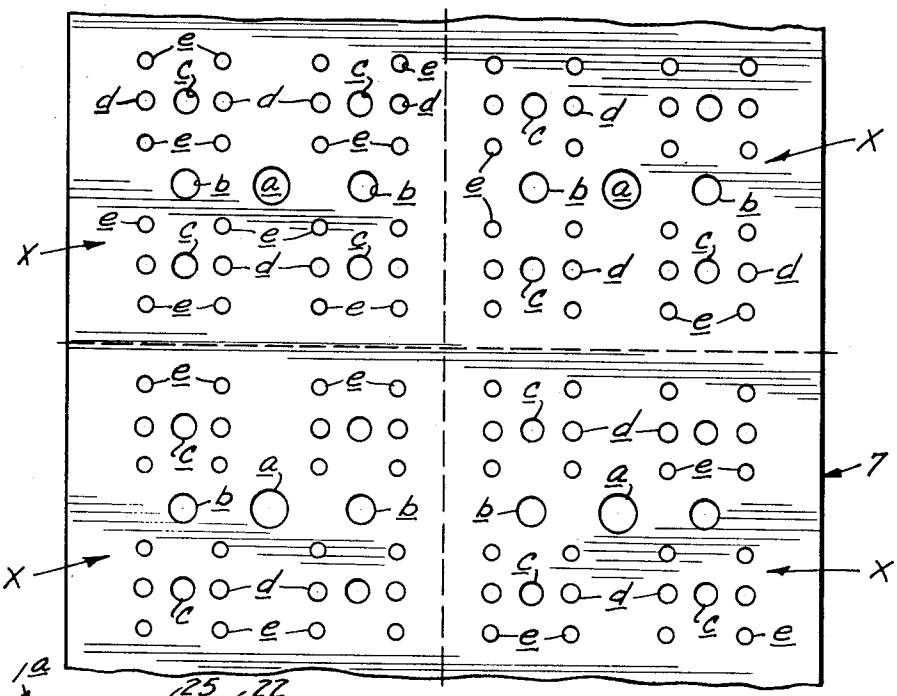
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Filed June 28, 1954 2 Sheets-Sheet 2

Fig. 4



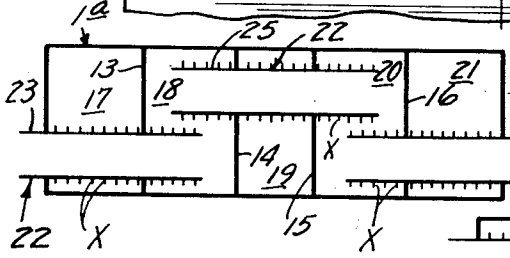


Fig. 5

Fig. 6

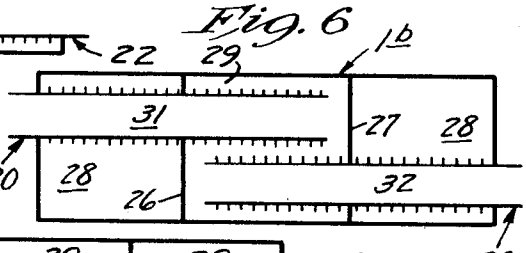


Fig. 7

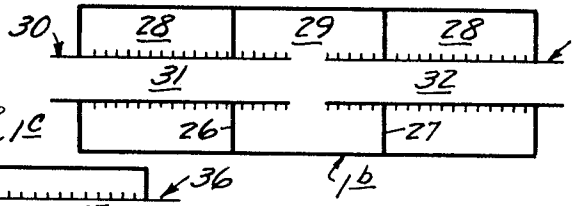
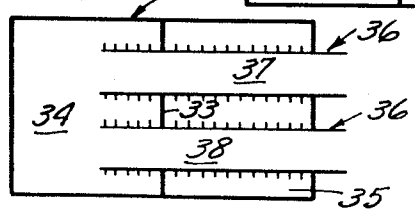


Fig. 8



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SILENCER

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7 Claims. (Cl. 181—63)

Generally stated, my present invention relates to improvements in the art of reducing or attenuating noises produced by gaseous medium subject to noise-producing pulsations of different pressures and frequencies.

While the invention is adapted for a wide range of uses, it has been found particularly useful in silencing the exhausts and intakes of internal combustion engines and is herein illustrated in connection with mufflers or silencers for the exhausts of such engines.

As is well known, the gaseous medium discharged from the exhausts of internal combustion engines is subject to pressure pulsations of widely varying pressures and frequencies which produce objectionable noises unless some very effective attenuation, silencing or effective silencing is accomplished before the gaseous medium is discharged to atmosphere; such being generally accomplished by insertion of silencing devices, commonly referred to as mufflers, in the exhaust conduit of such engines. An ever-present problem confronting the industry is, of course, the provision of means for achieving a maximum degree of silencing or effective exhaust silencing, without producing objectionable power-consuming back-pressure, at the lowest possible cost and by devices utilizing a minimum of space and capable of giving long and trouble-free service. In practice, however, this ideal combination has been a difficult achievement for the reason that the frequency and pressure characteristics of the exhausts of each engine vary greatly with changes in engine speed and load, and because the frequency and pressure characteristics of the exhausts of engines or different specifications also vary widely, so that each engine presents its own particular problem to those responsible for the design of silencing equipment therefor.

At this point it may be said that an important object of the instant invention is the provision of an improved and novel concept of muffler or silencer design whereby the above-stated generally recognized objectives are achieved to a higher degree than has been hitherto possible; further objectives of the instant invention being as follows:

(A) The provision of an improved muffler or silencer design whereby the procedure of tailoring a muffler to any particular engine is greatly simplified and whereby a muffler tailor-designed for a particular engine will operate with a high degree of efficiency in connection with ther engines of different specifications within the volume handling capacity thereof; and

(B) The provision of simple and inexpensive means whereby an exceptionally wide range of frequencies may be attenuated, silenced or effectively silenced, with greater than usual uniformity throughout the range.

It should be appreciated that in the silencing art any modification of the sound resulting in audible improvement is generally considered and referred to as silencing, although, in some instances, what may be audibly evaluated as actual silencing or attenuation may, in fact, or as interpreted by sound level measuring instruments, be no more than a modification of the overall sound pattern

resulting in a more pleasant or less irritative sound, more acceptable to the ear and, hence, mentally evaluated as actual attenuation or actual silencing. Of course, the latter is effective silencing and is generally achieved by actual attenuation or silencing of certain irritating frequencies, but nevertheless not always producing actual attenuation of the overall noise pattern as seen by measuring instruments, which are non-discriminatory as to frequency. Hence, the term "silencing," as employed herein, is used in a broad and liberal sense to cover any modification of sound which would appear to the human ear as actual silencing or attenuation regardless of whether the effect be created by actual attenuation or silencing, or by a modification resulting in apparent but not actual attenuation or silencing.

There are, of course, many types of engine exhaust mufflers. In a general way, however, it may be said that the instant invention relates to that type of muffler or silencer wherein an exhaust conduit extends through a closed chamber usually afforded by an outer shell, and is provided within the closed chamber with a plurality of holes or passages through a wall thereof into the said closed chamber; the exhaust conduit sometimes extending completely through the closed chamber and, in other instances, being interrupted by a gap within the closed chamber. Some mufflers, in fact, employ a plurality of such closed chambers, which are generally of different volumetric capacities. Heretofore, however, the practice has been to make all of the holes or passages through the wall of the exhaust conduit into a given closed chamber of the same cross-sectional area, although where a plurality of chambers of different capacities have been employed in a common muffler, it has been common to utilize a different size and/or number of holes leading from the exhaust conduit into each such different chamber; chamber volume, uniform hole size and the number of holes to provide maximum attenuation at a desired frequency being generally arrived at by well-known formulae. Thus, with the plurality of chambers of different volumes each coupled wtih the exhaust conduit by a plurality of passages of uniform size or area, each chamber would attenuate a different but relatively narrow band of frequencies.

In accordance with the instant invention, I accomplish the above and other important objectives, greatly simplify muffler or silencer design procedure and provide a simple and improved muffler or silencer construction, all without added construction or material cost and without adding, and in many cases reducing, the power-consuming back-pressure. In accordance with the invention, these and other highly important objectives and advantages are accomplished by the simple expedient of departing from hitherto accepted practice to the extent of providing a plurality of different size or area holes or passages leading through the exhaust conduit into each or any chamber of given volume; this is in contrast to the hitherto accepted practice of limiting communication between each chamber and the exhaust conduit to a plurality of holes of uniform size or area. By means of this simple expedient, each chamber serves to more uniformly attenuate a wider range of frequencies than was heretofore considered possible. A possible explanation of this hitherto long-standing void in the art may have been the absence of formulae whereby the frequency of maximum attenuation, resulting from a chamber of given volume in communication with the exhaust conduit through holes of different sizes or areas, could be calculated. In any event, the great advancement in the art achieved by this simple expedient, coupled with its apparent absence in the art, clearly indicates its elusive nature insofar as previous workers in the art were concerned.

It should be appreciated that the invention hereof,

while perhaps finding its widest application in mufflers or silencers for the exhaust systems of internal combustion engines and the like, may also be advantageously employed in silencers for the intake systems of internal combustion engines, pumps, compressors and other devices creating a noise-producing pulsating flow of air or other gaseous medium.

The above and other important objects and advantages of the invention will be made apparent or further emphasized in the following specification, claims and appended drawings.

Referring to the drawings:

Fig. 1 is a view in side elevation, with some parts broken away, of one form of muffler embodying the invention;

Fig. 2 is an axial sectional view taken on the line 2—2 of Fig. 1;

Fig. 3 is a view, partly in section and partly in end elevation, taken on the line 3—3 of Fig. 2 or from a corresponding position on Fig. 1;

Fig. 4 is a fragmentary plan view of a section of flat sheet metal to be formed, before bending to tubular formation to form a tubular exhaust conduit for the muffler of Figs. 1 and 2, but after perforation to provide a plurality of holes or passages therethrough of different sizes or areas; and

Fig. 5 through 8 are views in line diagram corresponding generally to Fig. 2, but each showing the invention embodied in a muffler of somewhat different design or configuration.

The muffler or silencer of Figs. 1–4 is of the general variety generally referred to in the industry as the "straight-through" type and comprises an elongated tubular outer shell **1**, end walls **2** and **3** and partition wall **4**, dividing the interior of the outer shell or casing **1** into a plurality of closed chambers indicated by **5** and **6** respectively, and an axial exhaust conduit **7** projecting completely through the closed chambers **5** and **6**. The axial exhaust conduit **7** is shown as being made up of a primary section **8** and a secondary section **9** and an intermediate coupling section **10**, the latter of which is integrally formed with the partition **4** and defines a restricted throat **11**. The preferred direction of flow through the muffler is indicated by flow arrows on Fig. 2, and it will be understood that the projecting ends of the axial exhaust conduit **7** are adapted to be coupled in and as a section of the exhaust pipe of an engine's exhaust system. A bracket for use in mounting the muffler to a suitable support is indicated by **12**.

By reference to Figs. 2 and 4, it will be seen that the portion of sections **8** and **9** of the exhaust conduit **7** respectively located within chambers **5** and **6** are perforated to provide holes or passages of different sizes or areas leading therethrough into said chambers. In the preferred arrangement illustrated in the longitudinal sectional view of Fig. 2, these holes are arranged as a plurality of adjacent pattern groups X of closely arranged apertures *a*, *b*, *c*, *d* and *e* with said pattern groups X extending both longitudinally and circumferentially of said conduit **7**, and the apertures of each pattern group varying markedly in cross-sectional area from relatively large to relatively small diameter apertures as hereinafter more fully described and shown in Fig. 4. In this said flat plan section of the apertured sheet from which the tubular exhaust conduit **7** is formed the like hole patterns of which there are four in the flat fragmentary section of Fig. 4, are separated by broken lines on said figure. While these holes could be of any shape, they are round, as shown. By reference particularly to Fig. 4, it will be seen that each of these like hole patterns comprises holes *a*, *b*, *c*, *d* and *e* of progressively reduced diameter and area; there being in each patteern illustrated one relatively large hole *a*, two slightly smaller holes *b*, four still smaller holes *c*, eight yet smaller holes *d* and sixteen quite small holes *e*. In accordance with the preferred example give, holes *a* have a diameter of .281 in., holes *b* have a diameter of .218 in.; holes *c* have a diameter of .156 in.; holes *d* have a diameter of .125 in.; and holes *e* a diameter of .093. These like hole patterns, each indicated by X and the hole diameters given, have proven suitable for a wide range of overlapping bands or ranges of pulsations of different pressures and frequencies longitudinally of the exhaust conduit **7**, simply by using a greater or lesser number of such patterns to suit different chamber volumes and other variables. The muffler of Figs. 1–4, which is of the "straight-through" variety, is equally well adapted for use in connection with an unusually wide variety of engines, due to the provision of holes or passages of different sizes or areas leading therethrough into the closed chambers **5** and **6**. The pertinent specifications of this particular muffler are as follows:

Inside diameter of sections **8** and **9**, conduit **7**: 1.750 in.
Wall thickness conduit sections **8** and **9**: .036 in.
Diameter chambers **5** and **6**: 3.250 in.
Cubic capacity chamber **5**: 28½ cu. in.
Cubic capacity chamber **6**: 61½ cu. in.

It should be understood that the specifications are not nearly as critical as in similarly designed mufflers utilizing a plurality of uniform size holes for each chamber of given area, and that the specifications given are merely set forth for the purpose of example.

It should be further understood that the chambers **5** and **6**, being of different capacities and being in communication with the exhaust conduit through different numbers of different sized holes will each provide exceptionally smooth and uniform attenuation of a different, although overlapping, band of noise frequencies.

The muffler of Fig. 5 comprises a tubular shell **1***a* having internal partitions **13**, **14**, **15** and **16**, dividing the interior thereof into closed chambers **17**, **18**, **19**, **20** and **21**. In this design, the exhaust conduit, indicated as an entirety by **22**, comprises end sections **23** and **24** and an intermediate section **25**. All portions of the conduit sections **23** through **25** within the muffler shell are provided with a pluarity of hole patterns X, such as shown in Figs. 2 and 4, but indicated only digrammatically in Fig. 5 and succeeding figures. It will be noted that the conduit sections **23**, **24** and **25**, respectively, pass completely through chambers **17**, **21** and **19**, in the manner of Fig. 2, but that the adjacent ends of sections **23** and **25** extend into a common chamber **18** and are spaced and offset therein to provide what is known as an S gap therebetween, and that the adjacent ends of conduit sections **24** and **25** are spaced and offset in chamber **20** to provide a similar S gap. It may be assumed that the several chambers (**17**, **18**, **19**, **20** and **21**) of the muffler of Fig. 5 are of different volumes and are in communication with their respective sections of the exhaust conduit **22**, through a different number of holes, openings or passages, so that each of the chambers will effectively attenuate or silence a different but overlapping band of noise frequencies.

In Fig. 6, the elongated muffler shell **1***b* is provided with internal partitions **26** and **27**, dividing the same into end chambers **28** and an intermediate chamber **29**. Here again the chambers may be assumed to be of different capacities and to be in communication with their respective sections of the exhaust conduit **30** through a different number and size of holes *a* through *e*. In this case, the exhaust conduit sections **31** and **32** extend straight through the chambers **28** and into the common intermediate chamber **29**, where the ends thereof are spaced and offset to provide a S gap. Here again, of course, each of the chambers **28** and **29** will effectively attenuate or silence a different, but preferably overlapping, band of noise frequencies.

The muffler of Fig. 7 corresponds so closely to Fig. 6 that identical numerals are applied thereto; the only difference between the structures of Figs. 6 and 7 being that

in Fig. 7 the adjacent ends of the exhaust conduit **30** within the intermediate chamber **29** are axially aligned so as to provide a straight gap rather than a **S** gap.

In Fig. 8, the tubular outer shell **1***c* is provided with a single partition **33** to divided the interior thereof into chambers **34** and **35**. In this case, the exhaust conduit **36** comprises laterally spaced parallel sections **37** and **38**, each passing completely through the chamber **35** and into the chamber **34** with their adjacent ends being spaced in said chamber **34** to provide what is known as a **C** gap. Also in this design the chambers **34** and **35** will usually be of different capacities and will be in communication with their respective conduit portions through a different number of perforations or holes *a* through *e*; the latter requirement being generally achieved by utilizing different numbers of hole patterns X, as shown best in Fig. 4, so that each chamber attenuates or silences a different but overlapping band or range of noise frequencies.

The muffler of Figs. 1–4 should preferably be connected into the exhaust pipe of an engine so that the direction of flow therethrough is from left to right with respect to Fig. 2, and in which case a left-hand end of the muffler's conduit **7** will be the intake or receiving end and the right-hand end thereof will be the outlet or exhaust end. The mufflers of Figures 5 through 8 are not critical as to direction of flow therethrough, so that either end of the exhaust conduit may become the intake end or the outlet or discharge end.

My invention has been thoroughly tested and found to be completely satisfactory for the accomplishment of the objectives set forth; and while I have shown certain preferred designs, it will be understood that the same is capable of modification without departure from the scope and spirit of the invention as defined in the claims.

What I claim is:

1. In a silencer for pulsating gaseous medium of different pressure and frequencies, comprising an unobstructed conduit means connected at one end to a source of pulsating gaseous medium and having its opposite end portion open to the atmosphere, said conduit means having an intermediate annular wall portion thereof provided with a plurality of adjacent pattern groups of closely arranged apertures with said pattern groups extending both longitudinally and circumferentially of said conduit, and the apertures of each pattern group varying markedly in cross-sectional area from relatively large to relatively small diameter apertures, and a casing surrounding said intermediate portion of said conduit means in circumferential spaced relation thereto and being connected therewith beyond said adjacent pattern groups of apertures to provide an enclosing chamber, into which chamber pulsating gaseous medium flowing longitudinally and unobstructedly through said conduit means from the exhaust of an engine or the like may expand in such varying degrees both longitudinally of its travel as well as transversely and circumferentially thereof that a minimum of back pressure results with maximum efficiency in effective noise silencing.

2. The structure as defined in claim 1, in which said conduit means is sectional, wall structure in said casing defining a plurality of closed chambers, a plurality of sections of said conduit projecting into and partially through one of said closed chambers with their inner ends spaced to provide a gap therebetween in said one chamber, one of said sections of said conduit extending completely through another of said chambers.

3. The structure defined in claim 1 in which said adjacent pattern groups comprise apertures of at least four different cross-sectional areas leading through said conduit structure to said chamber space, and in which there are a plurality of apertures of each area.

4. The structure defined in claim 1 in which said adjacent pattern groups comprise apertures of at least five different cross-sectional areas leading through said conduit structure to said chamber space, and in which there are a plurality of apertures of each area.

5. The structure defined in claim 2 in which there are apertures of at least four different cross-sectional areas leading from said conduit to each of said chambers, and in which there are a plurality of apertures of each area.

6. The structure defined in claim 2 in which there are apertures of at least five different cross-sectional areas leading from said conduit to each of said chambers, and in which there are a plurality of apertures of each area.

7. The structure defined in claim 2 in which the portion of each conduit section within each said chamber is provided with a plurality of aperture patterns each of which pattern comprises a plurality of apertures of each of at least four different areas, the aperture patterns in each chamber being repetitions of the aperture patterns in other chambers, the chambers being of different volumes and there being a different number of aperture patterns for each chamber.

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