Feb. 27, 1968 P. F. JETTINGHOFF 3,370,673

EXHAUST SYSTEM WITH SERIALLY-CONNECTED MUFFLERS

Original Filed Sept. 2, 1964 5 Sheets-Sheet 1

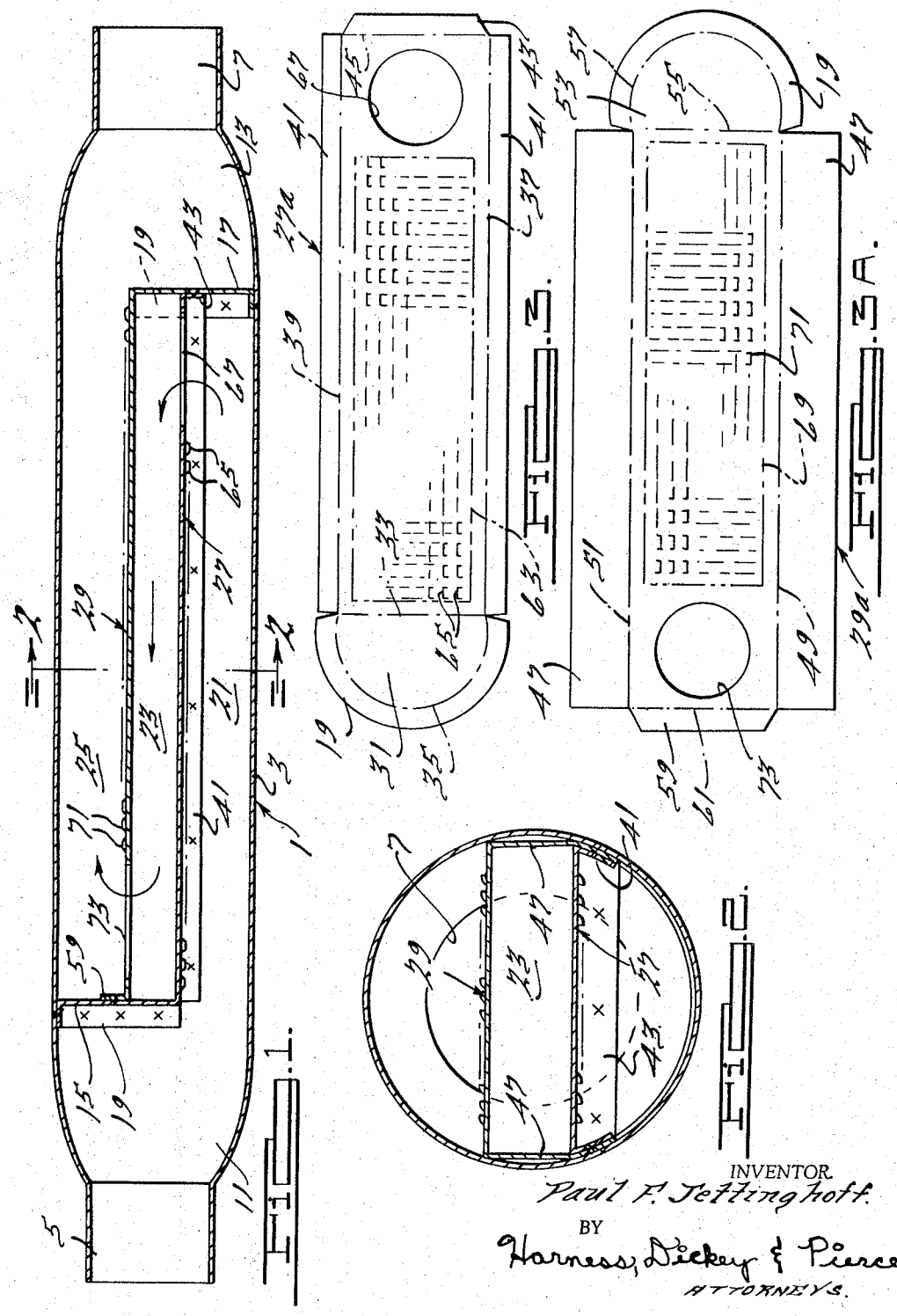


Fig. 1.

Fig. 2.

Fig. 3.

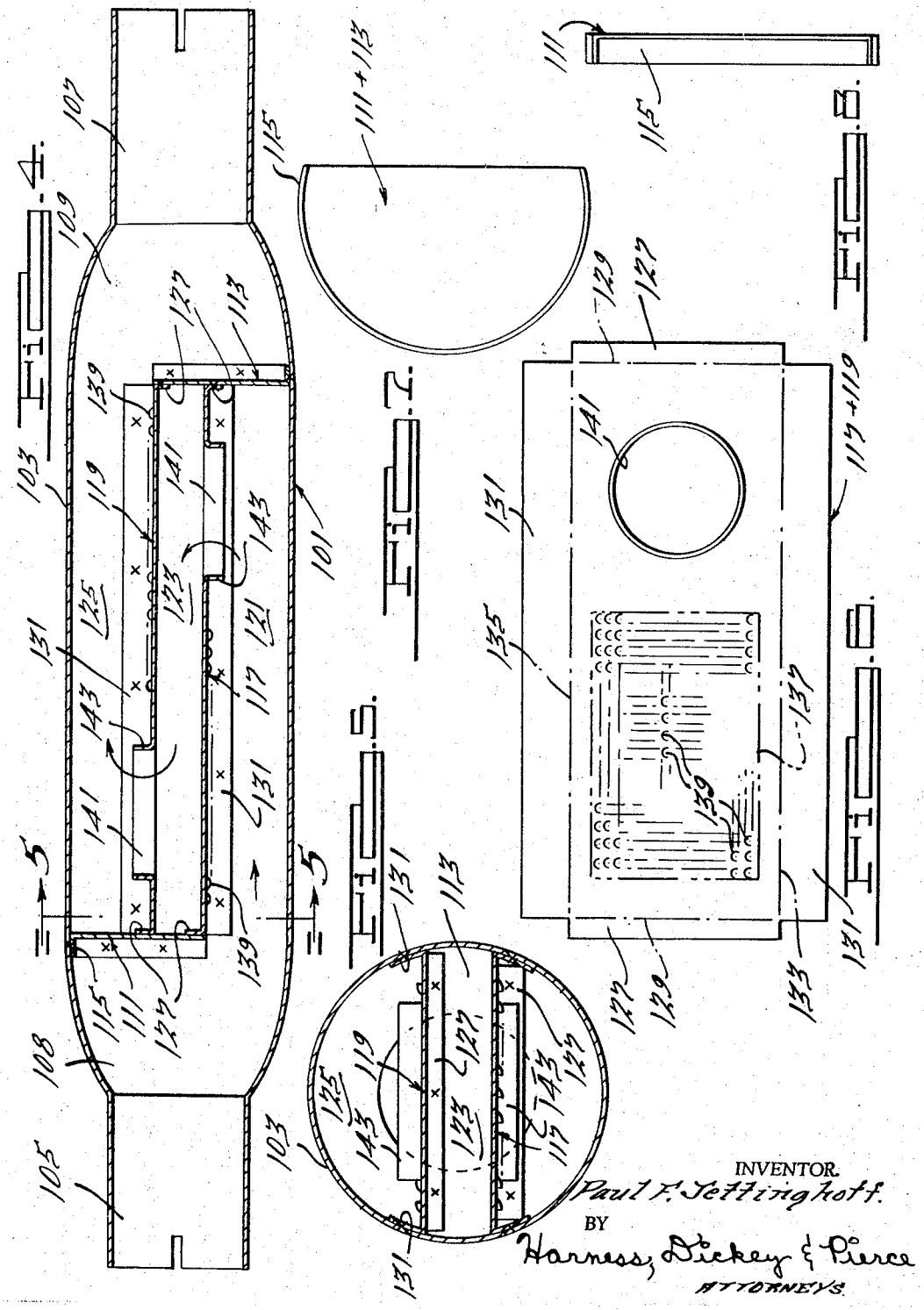
Fig. 3A.

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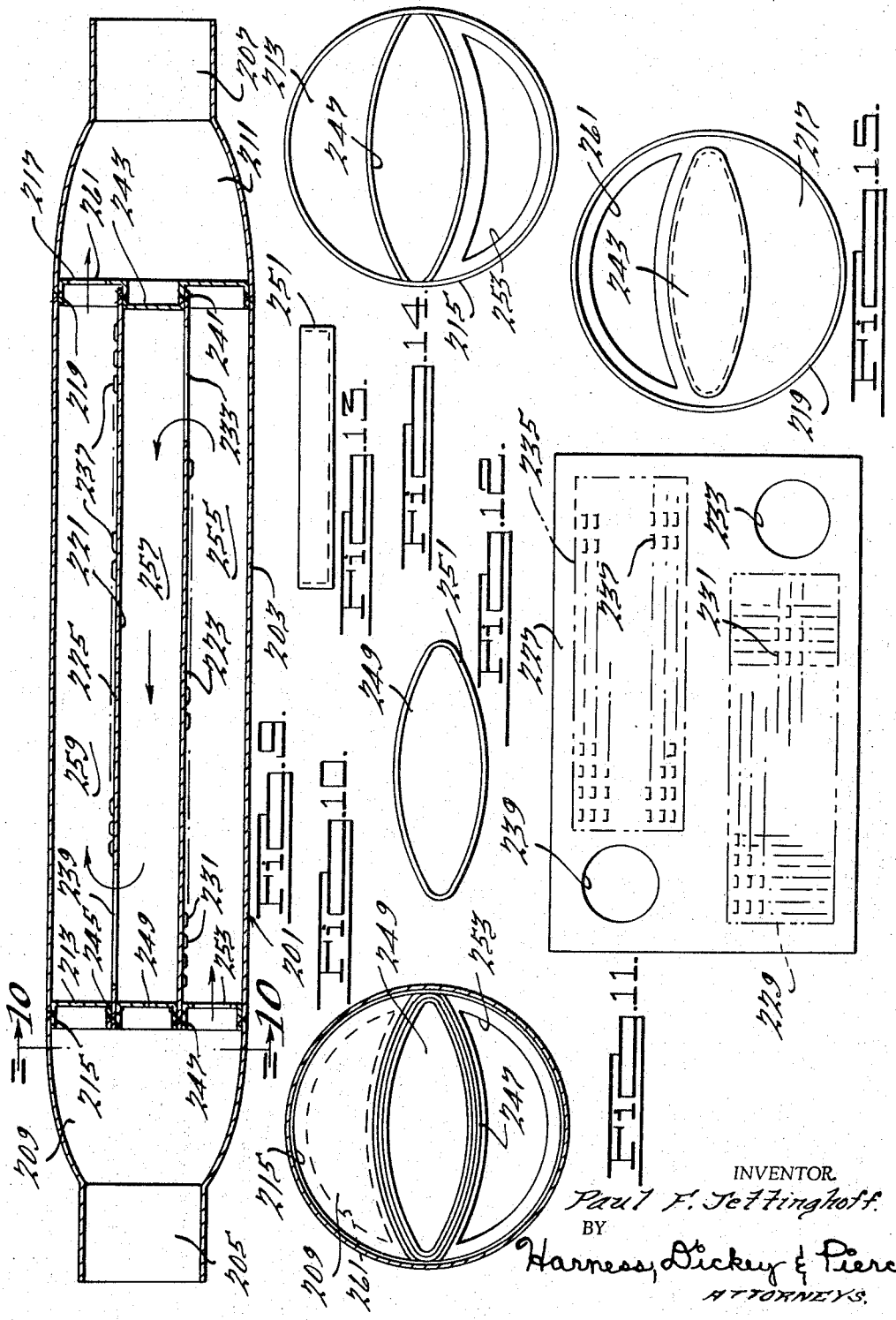
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EXHAUST SYSTEM WITH SERIALLY-CONNECTED MUFFLERS

Original Filed Sept. 2, 1964 5 Sheets-Sheet 3



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EXHAUST SYSTEM WITH SERIALLY-CONNECTED MUFFLERS

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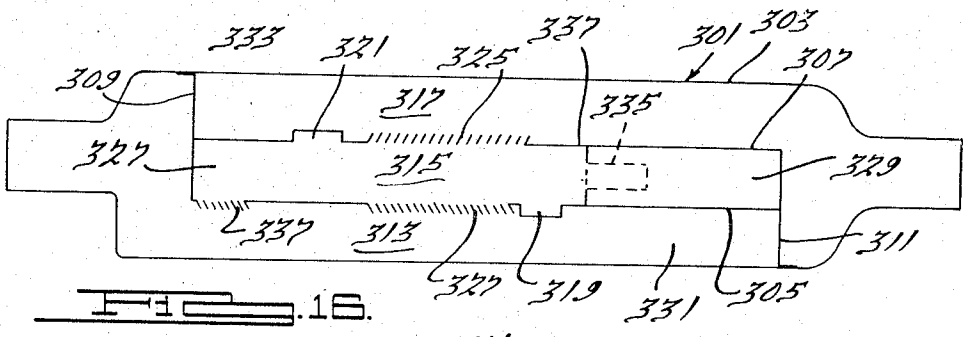
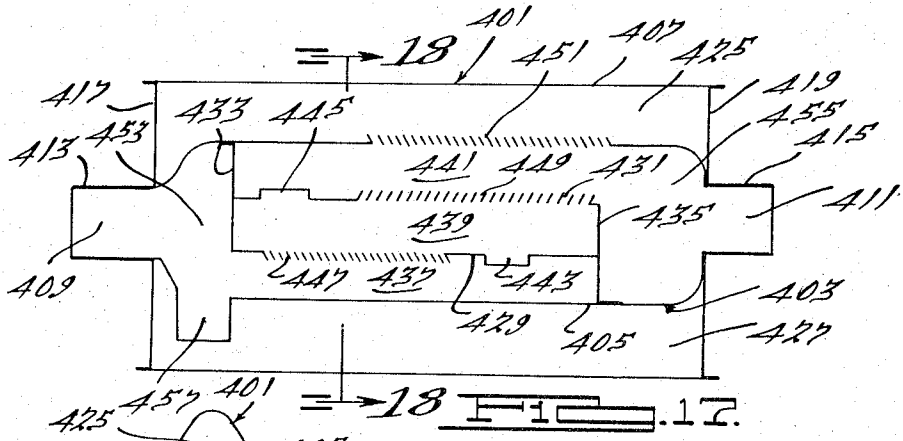


FIG. 16.



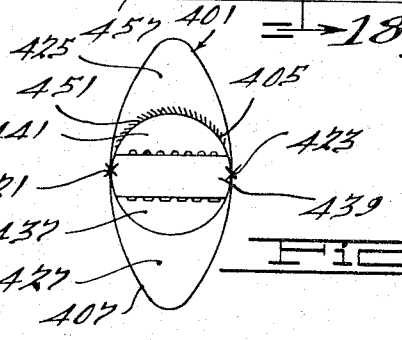
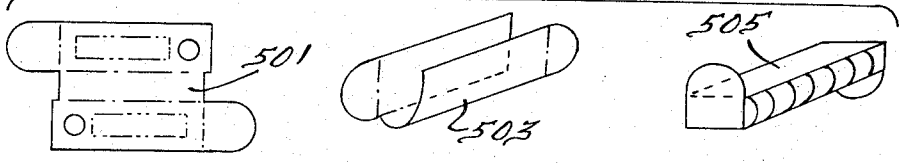


FIG. 17.

FIG. 18.

FIG. 19.



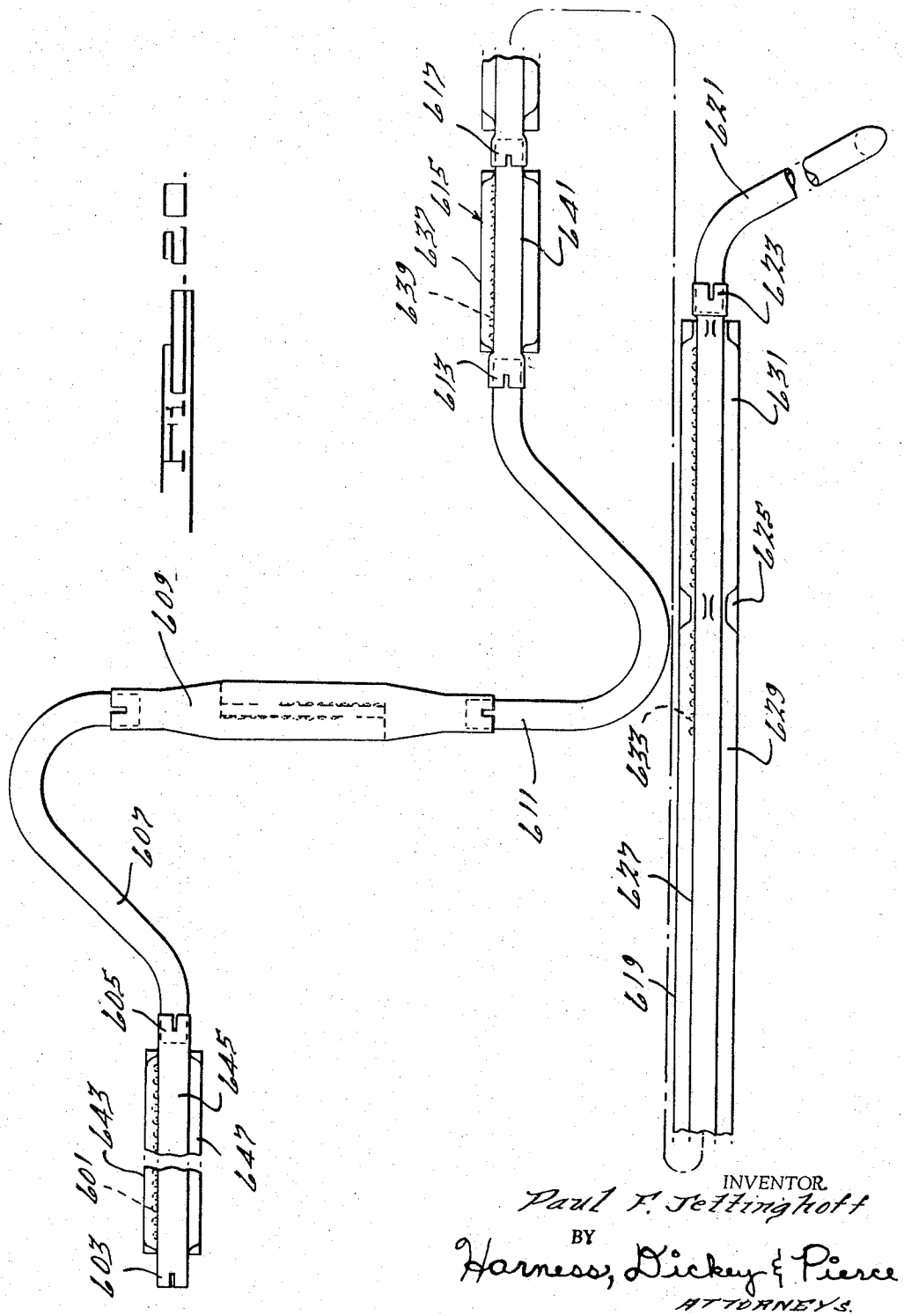
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EXHAUST SYSTEM WITH SERIALLY-CONNECTED MUFFLERS

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Fig. 2.



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3,370,673

EXHAUST SYSTEM WITH SERIALLY-CONNECTED MUFFLERS

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Original application Sept. 2, 1964, Ser. No. 393,864. Divided and this application Apr. 18, 1967, Ser. No. 631,825

1 Claim. (Cl. 181—35)

ABSTRACT OF THE DISCLOSURE

A small, highly effective exhaust muffler is provided by the use of three longitudinal partitions (which may be fabricated from a single piece of metal) that subdivide the interior of a housing into three series connected gas passages for main gas flow. The partitions are louvered for secondary gas flow across the gas passages and the resulting acoustic interference and turbulence acts with other attenuating effects in the muffler to silence a wide range of frequencies. A complete exhaust system using the muffler is disclosed.

Cross reference to related application

This application is a division Ser. No. 393,864 filed Sept. 2, 1964.

Summary of the invention

The invention relates to mufflers of the type that are used in the exhaust systems of internal combustion engines. It is an object of the invention to provide a muffler that is very small in width and thickness but which incorporates a tri-flow gas passage and to provide a tri-flow gas passage for mufflers which has improved sound attenuating characteristics. The invention accomplishes the foregoing and other objects by means of a construction in which a combination of longitudinal and transverse partitions act along with the side walls of the muffler casing to define three separate gas passages through which the gas flows successively from the inlet at one end to the outlet at the other end of the muffler. The partitions are preferably provided with banks of louvers so that the central gas passage acts not only as a flow passage but as the volume into which the louvers open and through which cross flow may occur to lower back pressure and attenuate sound by interference.

Description of the drawings

FIG. 1 is a longitudinal cross section through one form of muffler embodying the invention;

FIG. 2 is a cross section along the line 2—2 of FIG. 1;

FIG. 3 is a blank layout of one of the longitudinal partitions used in the muffler of FIGS. 1 and 2;

FIG. 3A is a blank layout of the other longitudinal partition used in the muffler of FIGS. 1 and 2;

FIG. 4 is a longitudinal cross section through another form of muffler embodying the invention;

FIG. 5 is a cross section along the lines 5—5 of FIG. 4;

FIG. 6 is a blank layout of the longitudinal partitions used in the muffler of FIGS. 4 and 5;

FIG. 7 is a detail view of a transverse partition;

FIG. 8 is a side elevation of the transverse partition of FIG. 7;

FIG. 9 is a longitudinal cross section through another form of muffler embodying the invention;

FIG. 10 is a cross section along the line 10—10 of FIG. 9;

FIG. 11 is a blank layout of the longitudinal partition forming means (in this case a tube) used in the muffler of FIGS. 9 and 10;

FIG .12 is a side elevation of a partition used to close the end of the tube of FIG. 11;

FIG. 13 is a side elevation of the partition of FIG. 12;

FIG. 14 is a side elevation of the partition used at the inlet end of the gas passages;

FIG. 15 is a side view of the partition used at the outlet or downstream end of the tri-flow gas passages;

FIG. 16 is a schematic longitudinal cross section through a modification;

FIG. 17 is a schematic longitudinal cross section through another modified form of the invention;

FIG. 18 is a cross section along line 18—18 of FIG. 17;

FIG. 19 shows a method of forming the transverse and longitudinal passages from one piece of metal; and

FIG. 20 shows a side elevation of an exhaust system utilizing the muffler of this invention.

Detailed description

Referring now to the embodiment shown in FIGS. 1–3, the muffler **1** has a tubular sheet metal casing or housing **3** which is reduced in diameter at opposite ends to form an inlet bushing **5** and an outlet bushing **7**. The outer diameter of the casing **3** is preferably about 3 inches, thus enabling the muffler to be advantageously used in modern automobiles which have very little under-car space. Adjacent the inner end of the bushing **5** is an inlet chamber **11** and adjacent the inner end of the outlet bushing **7** is an outlet chamber **13**. The inner end of the inlet chamber **11** is defined by a transverse partition **15** and the inner end of the outlet bushing **13** is defined by a transverse partition **17**. The partitions **15** and **17** are partly circular and have flanges **19** which are spot-welded or otherwise attached to the wall of casing **3**.

Gas passing from the inlet chamber **11** to the outlet chamber **13** must travel the distance between the partitions in **15** and **17** three times. Thus, the muffler is a tri-flow unit. The gas follows a first or inlet passage **21** and then reverses its direction of flow to head back toward the inlet end in an intermediate or central passage **23** and then reverses its flow again to flow through an outlet passage **25** to the outlet chamber **13**.

The walls of the passages **21**, **23**, and **25** are defined by a pair of longitudinal partitions **27** and **29**. The partition **27** acts with the side wall of the casing **3** to define the inner side of the inlet passage **21**. The partition **29** acts along with the other side wall of the casing to define the outlet passage **25**. The two partitions **27** and **29** define together opposite sides of the central passage **23**.

The partition **27** is formed from an originally flat piece of metal **27***a* which is bent along the phantom lines that are shown in FIG. 3. It will be noted that the transverse partition **15** is formed by bending the partly circular section **31** at the left end of the blank **27***a* along the line **33** so that it is at right angles to the balance of the plate **27***a*. The flanges **19** are formed by bending the section **31** along the dotted line **35**. The sides of the plate **27***a* are bent along the lines **37** and **39** to form flanges **41** which extend longitudinally and are spotwelded to the wall of the casing **3** so that the partition **27** is held in the proper position. The end of the plate **27***a* has a reduced width flange **43** formed on it which is bent along the dotted line **45** at right angles to the plate.

The plate **29***a* of FIG. 3A, from which partition **29** is formed, is very similar to the plate **27***a* except that the parts are reversed so that one is left-handed and the other is right-handed and it is somewhat wider than plate **27***a* so that the side flanges **47** which are formed by bending it longitudinally along the dotted lines **49** and **51** are wider than the corresponding flanges **41**. The plate **29***a* has

a partly circular section 53 which is bent along the dotted line 55 at right angles to the plate 29*a* so as to form the partition 17. The outer periphery of the section 53 is bent along dotted line 57 to form the flange 19 which may be spotwelded or otherwise suitably attached to the wall 3. The opposite end of the plate 29*a* has a reduced width flange 59 which is bent normal to the plate along the line 61. The flange 59 is spotwelded to the transverse partition 15 whereas the corresponding flange 43 of the plate 27*a* is spotwelded to the partition 17.

The partition 27 has a relatively large area or bank 63 of fine flat louvers 65 formed therein along with an opening 67 which forms a means of interconnecting the passages 21 and 23 adjacent to the partition 17. Similarly, the partition 29 has a bank 69 of fine flat louvers 71 formed therein and an opening 73 which is located adjacent to the partition 15 so that the gas from passage 23 can flow into the passage 25.

In operation, the exhaust gas entering the inlet bushing 5 flows into the inlet chamber 11 and from there into the longitudinal inlet passage 21. The mainstream of gas reverses direction as it flows through hole 67 and flows back toward the inlet through the central passage 23. It reverses direction again as it flows through the opening 73 into the outlet passage 25 through which it flows to the outlet chamber 13 and then out of the muffler through the outlet bushing 7. In addition to the mainstream of gas flow through the three longitudinal passages, there is a substantial transverse or cross flow of gas due to the open areas provided by the louver banks 63 and 69.

FIGS. 4 to 8 show a modified form of the muffler which is similar in most respects to the embodiment shown in FIGS. 1 to 4, the principal difference being that the transverse partitions are formed as separate parts and the two longitudinal partitions are identical in construction to each other.

In the muffler 101 of FIGS. 4–8, there is an outer shell or casing 103 which is reduced in diameter at opposite ends to form an inlet bushing 105 and an outlet bushing 107. Adjacent the inlet end of the inlet bushing 105 is an inlet chamber 108 and adjacent the inner end of the outlet bushing 107 is an outlet chamber 109. The inside ends of the chambers 108 and 109 are defined by transverse partitions 111 and 113, respectively, which are shown in detail in FIGS. 7 and 8. It will be seen that these are partly circular plates that have transverse flanges 115 formed around their outer periphery whereby they may be spotwelded or otherwise suitably attached to the shell 103.

A pair of longitudinal partitions 117 and 119 divide the space between the partitions 111 and 113 into three longitudinal passages through which the gas must flow. There is the inlet passage 121 which receives gases from the inlet chamber 108, a return flow or intermediate passage 123, and an outlet passage 125 which delivers gases to the outlet chamber 109. The partitions 117 and 119 are preferably identical in construction and formed from originally flat blanks such as shown in FIG. 6. Thus, the partitions have flanges 127 formed at opposite ends which are bent around dotted lines 129 to positions at right angles to the body of the partition, and these are preferably spotwelded to the transverse partitions 111 and 113. Longitudinal flanges 131 are formed on opposite sides of the partitions 117, 119 by bending the outer portions about the lines 133 and 135. The flanges 131 are spotwelded to the shell 103. The partitions 117, 119 have banks or patches 137 of louvers 139, preferably round, therein and each partition has an opening 141 which may be provided with a neck 143.

When the parts are assembled, as shown in FIG. 4, it will be seen that the operation of the muffler is substantially the same as that previously described. The addition of the necks 143 about the openings 141 will provide some tuning effect that helps to attenuate certain of the intermediate and low frequencies.

The embodiment shown in FIGS. 9–15 differs from the previous two embodiments mainly in the structure for providing the two longitudinal partitions. In this embodiment the partitions are formed by one piece which is rolled up into a tubular form and then attached to the transverse partitions at opposite ends.

The muffler 201 of FIGS. 9–15 has an outer shell 203 which is reduced in diameter at opposite ends to form an inlet bushing 205 and an outlet bushing 207. Adjacent the inner end of the inlet bushing 205 is an inlet chamber 209 and adjacent the inner end of the outlet bushing 207 is an outlet chamber 211.

At the inner end of the inlet chamber 209 is a transverse partition 213 of the configuration shown in FIG. 14 and which has a peripheral flange 215 that is spotwelded to the outer shell 203. At the inner end of the outlet chamber 211 is a transverse partition 217 of the configuration shown in FIG. 15 which also has an outer peripheral flange 219 that is spotwelded to the outer shell 203.

Extending between and secured to the partitions 213 and 217 is a tube 221 of relatively flat elliptical cross section so that it has a bottom section 223 and a top section 225. As can be seen from FIG. 11, the tube 221 is formed from an originally flat metal blank 227 which is rolled into the elliptical configuration. The blank 227 is substantially a composite of the two partitions used in the preceding embodiments with the attaching flanges removed. Thus, the bottom section of the blank 227 has a bank 229 of fine flat louvers 231 and also an opening 233. The top section of the blank 227 has a bank 235 of fine flat louvers 237 and an opening 239 in it. When the blank 227 is rolled into tubular form, the downstream end 241 fits on and is spotwelded to an elliptically shaped depression 243 that is formed in the partition 217. The upstream end 245 of the tube 221 fits inside of an elliptically shaped neck 247 formed in the partition 213. It is closed by an elliptically shaped partition 249 (FIGS. 12 and 13) which has a peripheral flange 251 whereby it may be spotwelded inside the end 245 of the tube 221 and to the neck 247.

In operation of the muffler 201, exhaust gas enters the inlet bushing 205 and flows into inlet chamber 209 from which it flows through opening 253 in partition 213 into the longitudinal inlet passage 255. A main stream of the gas reverses direction at the end of passage 255 as it flows through the opening 233 into the central longitudinal passage 257. It then reverses direction at the end of passage 257 as it flows through opening 239 into the longitudinal outlet passage 259, from which it flows into outlet chamber 211 through opening 261 in partition 217 and then into the outlet bushing 207. A cross flow of gas cuts across the longitudinal passages, especially passage 257, due to the open areas provided by the louver banks 229 and 235 in combination with those provided by the openings 233 and 239.

In the several embodiments of the invention described above, sound energy is effectively removed from the gas by various means contained in a minimnm size muffler. Energy is abstracted from the gases as they enter and leave the inlet and outlet chambers due to the abrupt changes in cross section of the areas through which the gas flows. While the banks of louvers could in the broad purview of the invention be replaced by mere perforations, louvers are preferred since they act as short tuning necks to attenuate high frequency sounds in the gases flowing by them. The relatively long length of the gas passage due to the tri-flow construction also provides for maximum sound attenuation.

Of major importance in the sound removal capabilities of mufflers embodying the invention is the substantial cross flow of gas from the inlet passage to the outlet passage across the intermediate passage. Due to the confining effect of the outer housing and the common perforated walls shared by the three passages, all gas that attempts during favorable pressure pulse conditions to by-pass from the inlet passage is formed to enter or cut entirely across

the intermediate passage. This cross flow causes enough acoustic interference to collapse troublesome notes or waves. Preferably, the louver banks extend across substantially the entire width of the partitions and along a large portion of their lengths as shown in the three embodiments. Excellent results have been obtained when the total open area of each louver bank was the same and this area was substantially the same as the cross-sectional area of the inlet passage. The louver bank area, especially the one opening into the inlet passage, is preferably about 35–60% of the cross-sectional area of the inlet passage. Preferably, the muffler is positioned in the exhaust system so that the louver bank in the inlet passage is located adjacent a pressure peak or antinode of any special frequency it is desired to have the muffler attenuate.

While the heights of the three passages seen along a diameter of the casing may be of the proportions shown, it is feasible to reduce the height (decrease the area) of the central passage because of the cross flow direct from the inlet to the outlet passage. Preferably, however, the cross-sectional area of the central passage is substantially larger, e.g., two or three times, than that of the inlet passage and preferably also substantially larger than that of the outlet passage. When this relationship is used, the velocity of gas flow through the central passage is materially less than it is in the smaller area passages and materially less than that of the cross flow gases, thus promoting maximum interference and turbulent effects. It can be seen that by locating the central passage along the midsection of the casing (which could be oval as well as round) the central passage will have a much larger width and area than the inlet and outlet passages even though its height is the same or even somewhat less thereby facilitating cross flow of gases from the inlet passage all the way to the outlet passage and promoting maximum attenuation.

In addition to the sound attenuation caused by cross currents of gas flow into and/or through the main flow stream along the central passage, sound attenuation occurs because the central passage acts as a volume into which the louvers open so that sound waves from the main stream can enter it and be trapped or dissipated. The central passage therefore acts in a plurality of distinctly different acoustic ways to attenuate sound.

Additional acoustic uses of the central passage are possible as seen schematically in the muffler **301** of FIG. 16. This muffler has an outer casing **303** which acts with the longitudinal partitions **305** and **307** and the transverse partitions **309** and **311** to define the longitudinal inlet passage **313**, the central passage **315**, and the outlet passage **317**. The partitions **305** and **307** have mainstream flow openings **319** and **321** and louver banks **325** and **326** all as described in the preceding embodiments. It will be noted, however, that in this embodiment the openings **319** and **321** are located a substantial distance inwardly of the ends of the central passage **315** thereby providing dead end chambers **327** and **329** at opposite ends of the central passage. Corresponding dead end chambers **331** and **333** are formed at the downstream and upstream ends, respectively, of the inlet and outlet passages **313** and **317**.

In operation of the muffler **301** of FIG. 16, the gas flow and sound attenuation occurs as in the preceding embodiments. Additionally, the chambers **327**, **329**, **331** and **333** act as sound absorbing dead chambers which, if of the proper volume and/or length, act to attenuate certain notes in the exhaust gas sound spectrum. If desired, a tuning neck **335** may be attached to a partition **337** placed in the central passage **315** to serve as a means acting with the chamber **329** to tune it to a desired frequency. Also, if desired, the partition **305** may be provided with a bank of louvers **338** that open into the chamber **327**. Thus, the dead chamber **327** will act in conjunction with these louvers to some extent as a spit chamber for removing high and medium frequency sounds.

FIGS. 17 and 18 show a modification in which a muffler similar to the muffler **1** is used inside of an outer casing. The space between this muffler and the outer casing is then used as additional silencing means.

Thus, the muffler **401** of FIG. 17 has an internal triflow muffler **403**. The casing **405** of the muffler **403**, which may be the same as the casings of the mufflers previously described, is disposed inside of the casing **407** and the inlet and outlet bushings **409** and **411** may be disposed inside of and spotwelded to one or both of the inlet and outlet bushings **413** and **415** in the inlet and outlet headers **417** and **419** attached to the ends of the casing **407** in a conventional manner. As seen in FIG. 18, the casing **407** may be elliptical and tangent to the top and the bottom of the casing **405**, as indicated at the lines **421** and **423**. The inner and outer casings **405** and **407** may be welded together along these longitudinal lines of contact to divide the space between them into two transversely separated, longitudinally extending chambers **425** and **427**. These two chambers may, if desired, be additionally subdivided by transverse partitions into longitudinally separated chambers as, for example, by a partition (not shown) located on the section line **18—18**. Inside of the casing **405** are a pair of longitudinal partitions **429** and **431** and a pair of transverse partitions **433** and **435** which divide the space inside of the casing **405** into an inlet passage **437**, a central passage **439**, and an outlet passage **441**, all as previously described in connection with the other embodiments of the invention. The opening **443** permits gases to flow in a main stream from the inlet passage **437** to the intermediate passage **439** while the opening **445** in partition **431** permits gases to flow in a mainstream from the central chamber **439** to the outlet chamber **441**. The louver patches **447** and **449** in the longitudinal partitions **429** and **431** permit the cross-flow of gases as previously described. The wall of the casing **405** is provided with a louver patch **451** which opens into the outlet passage **441** and connects it with the longitudinal chamber **425**. Thus, the chamber **425** acts as a large spit chamber or untuned resonator to attenuate a broad spectrum of intermediate and high frequencies remaining in the gases as they pass through the passage **441**. It will be noted that the louver patch **451** could be provided if desired to open into one or more of the three longitudinal passages, either alone or in combination. The illustrated design however is preferable to preserve maximum cross-flow across the central passage.

The muffler **403** has an inlet chamber **453** and an outlet chamber **455** as in the preceding embodiments and in accordance with this embodiment one or the other of these chambers, such as chamber **453**, is provided with a tuning neck **457** which forms the only inlet and outlet to the chamber **427**. By proper sizing of the length and area of the neck **457** in combination with the volume of the chamber **427** the two can be used to tune to a desired medium or low frequency.

FIG. 19 shows how a one-piece stamping **501** may be rolled up as indicated at **503** into the construction **505** which will provide both the longitudinal and transverse partitions to form the three longitudinal passages as described above.

It will be noted that what have been referred to as the longitudinal "passages" formed by the longitudinal partitions serve more broadly as longitudinal sound attenuating chambers through which the mainstream of gas follows a tri-flow passage through the muffler. The gas in each passage of the mainstream, however, is in acoustic connection through the banks of louvers with the adjacent chamber which acts to attenuate sound in the mainstream gas. The banks of louvers also act as openings to permit cross-flow of the gas that does not remain in the main gas stream following the tri-flow passage.

FIG. 20 shows the muffler of this invention incorporated into an actual exhaust system, the illustrated system being one designed to silence the exhaust of a 1965 Citroen DS–19. The exhaust system shown in FIG. 20 comprises a relatively long broad banded, resonator cham-

ber unit 601 having an inlet end 603. At the outlet end 605 a connecting pipe 607 is attached and this is bent as indicated in the drawings and its downstream end is attached to the inlet end of a muffler 609 which may be any one of the mufflers previously described but is preferably the muffler 101 shown in FIGS. 4–8. At the outlet end of the muffler 609 there is a connecting pipe 611 which is bent as shown and attached to the inlet end 613 of a spit chamber unit 615. The outlet end of the 615 is inserted in the inlet bushing 617 of a tuned silencer 619 and a tailpipe section 621 attached to the outlet 623 of the silencer 619 carries the gases to atmosphere. The various conduits or pipe scetions, such as 607 and 611, are one and one-half inch in outer diameter while the various silencing devices are of three inch outer diameter. It desired, the devices other than the tri-flow unit 609 may be flattened to reduce their width in one dimension and to give them a somewhat oval conformation.

The silencing device 619 has an outer casing while is preferably pinched down at 625 to the inner pipe 627 so as to divide the casing into a relatively long chamber 629 and a somewhat shorter chamber 631. The pipe 627 is louvered along the length of the chamber 631 so that it forms an untuned resonator chamber. The louvers extend along preferably about 12¼ inches of the pipe and the full length of the chamber. The pipe section 627 in the chamber 629 has a louver patch 633 which is preferably located as indicated and about 5$\frac{5}{16}$ inches long. The balance of the chamber 629 upstream from the louver patch 633 is preferably 34 inches long. The louver patch 633 is preferably located 35 inches from the downstream end of the tailpipe section 631. This is the anti-node of a 125 cycle standing wave to which the chamber 629 is tuned.

The spit chamber 615 has a housing 637 which provides a chamber 639 around the inner pipe 641 which is louvered along substantially its full length, approximately 7⅞ inches, so that the chamber 639 will act as a spit chamber or untuned resonator to attenuate medium and high frequencies.

The action of the muffler 609 has already been described in connection with the various embodiments of the invention and in this particular exhaust system it acts, without imposing undue back pressure, to substantially lower the sound level and to substantially attenuate standing waves occurring at 75 and 175 cycles. The unit 609 is preferably about 14 inches long exclusive of the inlet and outlet bushings, and the longitudinal tri-flow passages are preferably about 7¼ inches long.

The untuned resonator unit 601 has a housing 643 around the interior pipe 645 to provide a chamber 647. Louvers extend along the full length of the chamber or about 10¼ inches of the pipe 645 to open into chamber 647 which acts, therefore, as a spit chamber and untuned resonator to attenuate medium and high frequencies.

It will be noted in the exhaust system of FIG. 20 that the muffler 609, which itself is of relatively simple construction, does such a substantial job of sound attenuation that it is possible to make the rest of the system of extremely simple construction and of very small outer dimension.

The tri-flow mufflers illustrated herein embody a variety of effective silencing principles and techniques in a small, economical construction that has low back pressure. In manufacture the metal partition means which subdivides the interior of the casing into the various chambers may be inserted into an open ended metal tube and spot-welded to it and then the ends of the tube swaged down to form the actual casing having the inlet and outlet bushings illustrated.

Modifications may be made in the structure illustrated without departing from the spirit and scope of the invention.

I claim:

1. An exhaust system for silencing the exhaust gases of an internal combustion engine and having standing waves of substantially 75, 125, and 175 cycles per second comprising in succession going from the upstream end of the system to the downstream end of the system: an untuned resonator and spit chamber unit, a first conduit connected to and receiving gas from said unit, a tri-flow muffler connected to and receiving gas from said first conduit, said tri-flow muffler having a casing with a pair of internal partitions subdividing the casing into three laterally adjacent and tri-flow connected gas flow chambers and being perforated to provide for cross flow between the chambers, said tri-flow muffler lowering the sound level in said system and attenuating said 75 and 175 cycle waves, a second conduit connected to receive gas from said tri-flow muffler, a second untuned resonator and spit chamber connected to and receiving gas from said second conduit, a tuned silencer connected to and receiving gas from said second untuned resonator and tuned to attenuate said 125 cycle wave, said tuned silencer including a center tube and a casing providing a chamber around said center tube and said chamber being closed except for a bank of louvers provided in said center tube and which is located substantially at an anti-node of said 125 cycle wave, a third untuned resonator and spit chamber receiving gas from said tuned silencer, and a tailpipe conduit receiving gas from said third untuned resonator and discharging it to atmosphere.

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