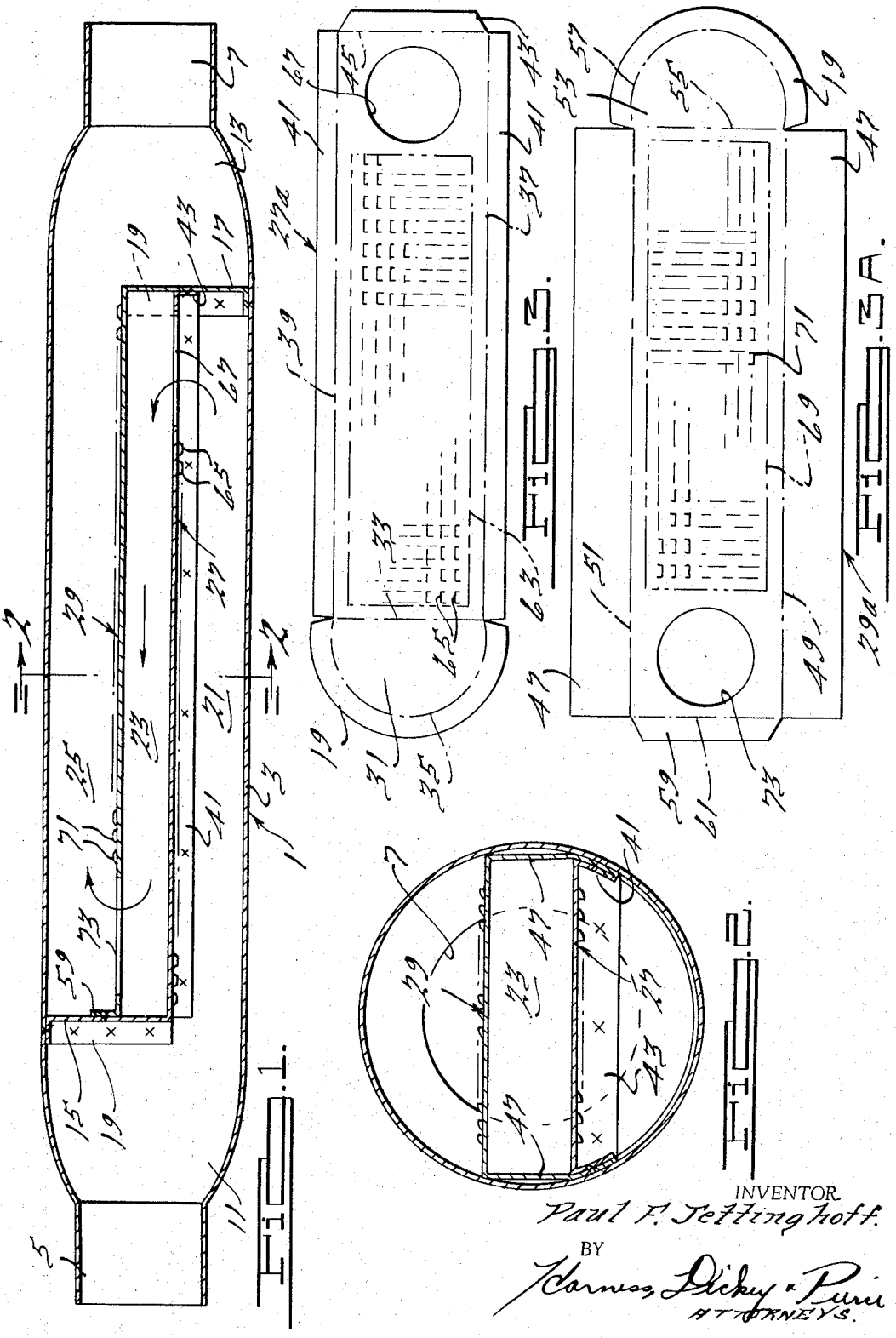
Feb. 27, 1968 P. F. JETTINGHOFF 3,370,674

RETROVERTED-FLOW MUFFLER WITH SIMPLIFIED PARTITION ARRANGEMENT

Filed Sept. 2, 1964 5 Sheets-Sheet 1



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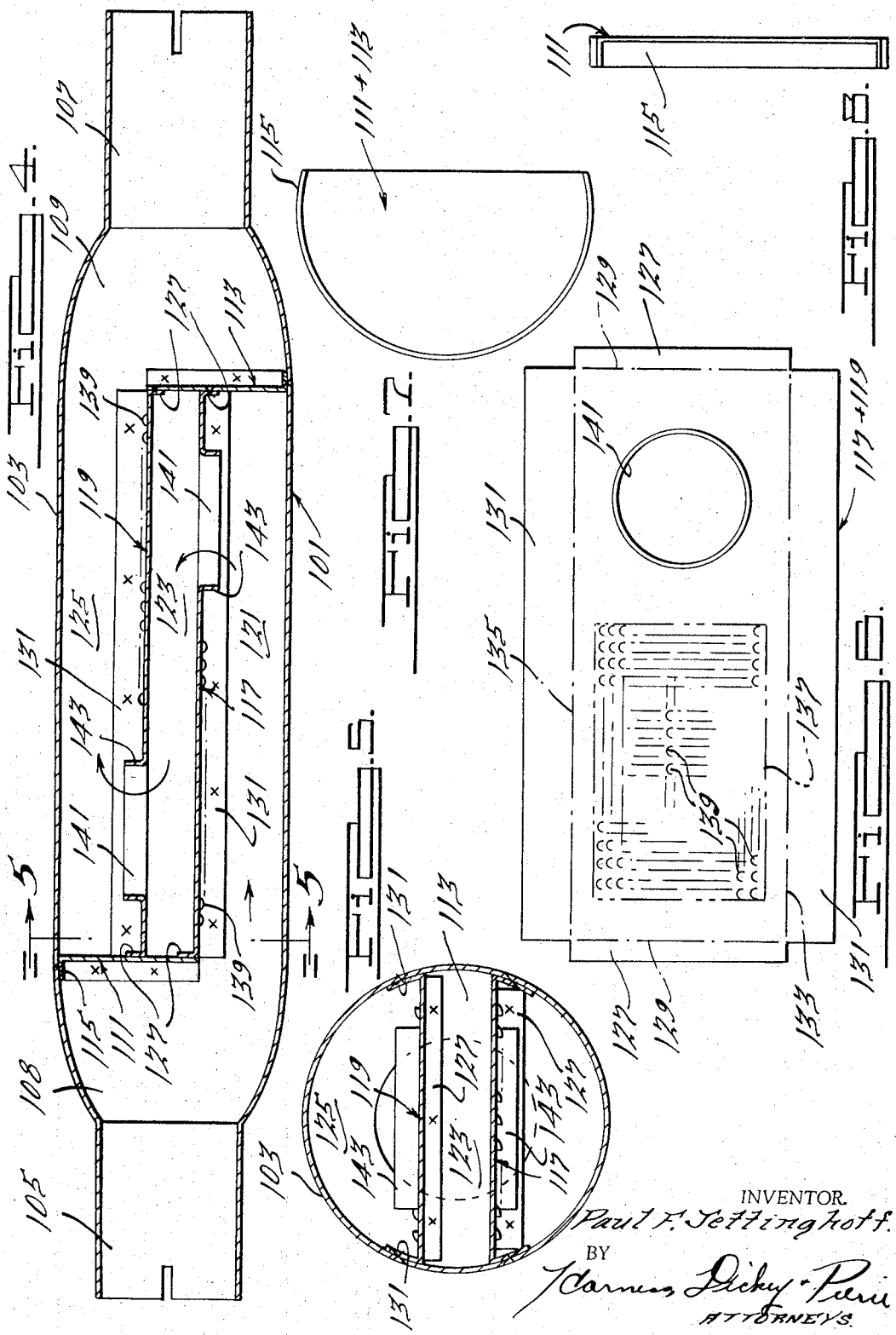
RETROVERTED-FLOW MUFFLER WITH SIMPLIFIED PARTITION ARRANGEMENT

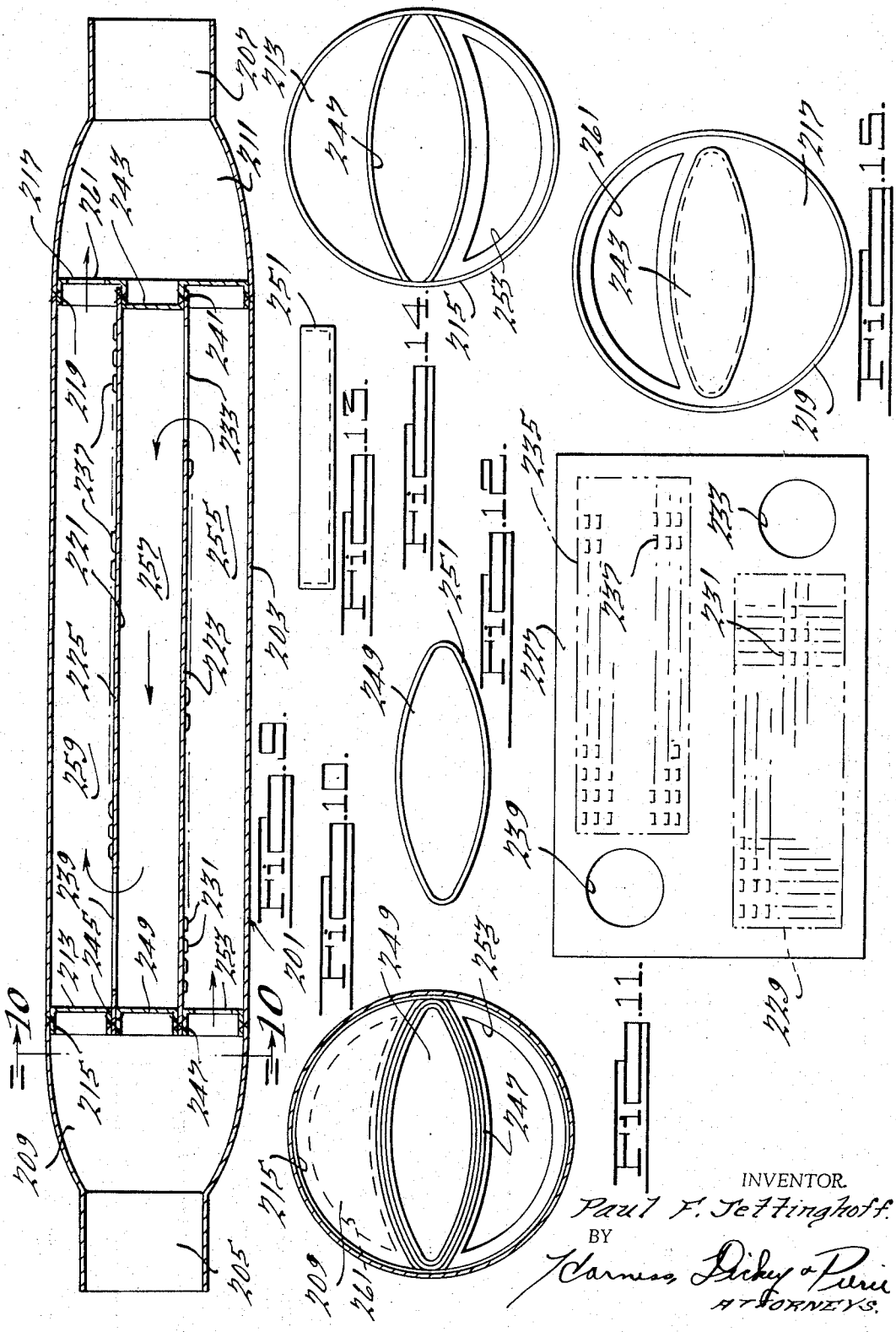
Filed Sept. 2, 1964 5 Sheets-Sheet 2



Feb. 27, 1968 P. F. JETTINGHOFF 3,370,674

RETROVERTED-FLOW MUFFLER WITH SIMPLIFIED PARTITION ARRANGEMENT

Filed Sept. 2, 1964 5 Sheets-Sheet 3



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RETROVERTED-FLOW MUFFLER WITH SIMPLIFIED PARTITION ARRANGEMENT

Filed Sept. 2, 1964 5 Sheets-Sheet 4

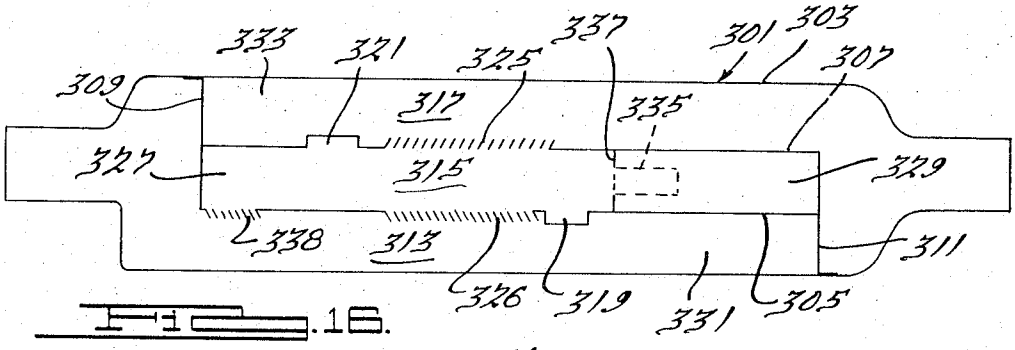


Fig. 16.

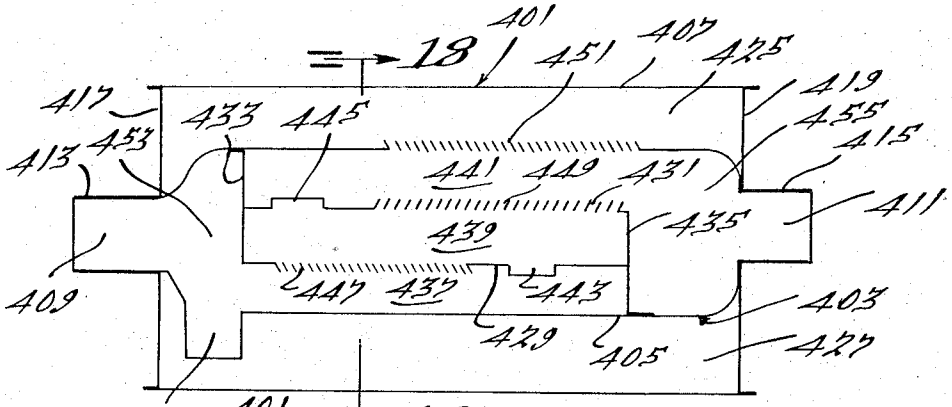


Fig. 17.

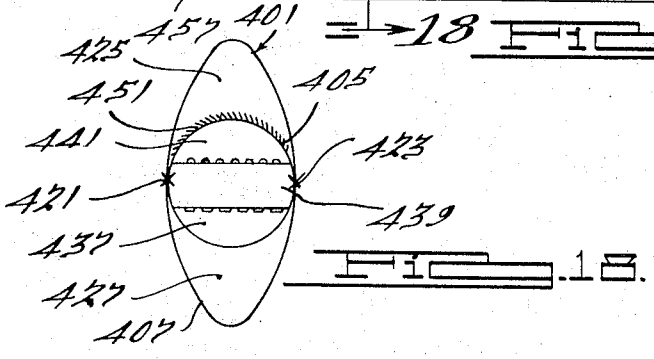
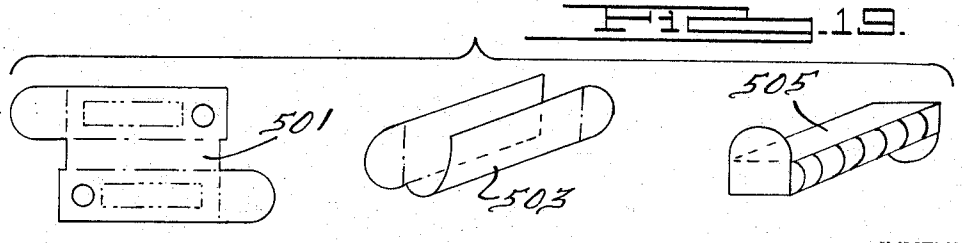


Fig. 18.

Fig. 19.



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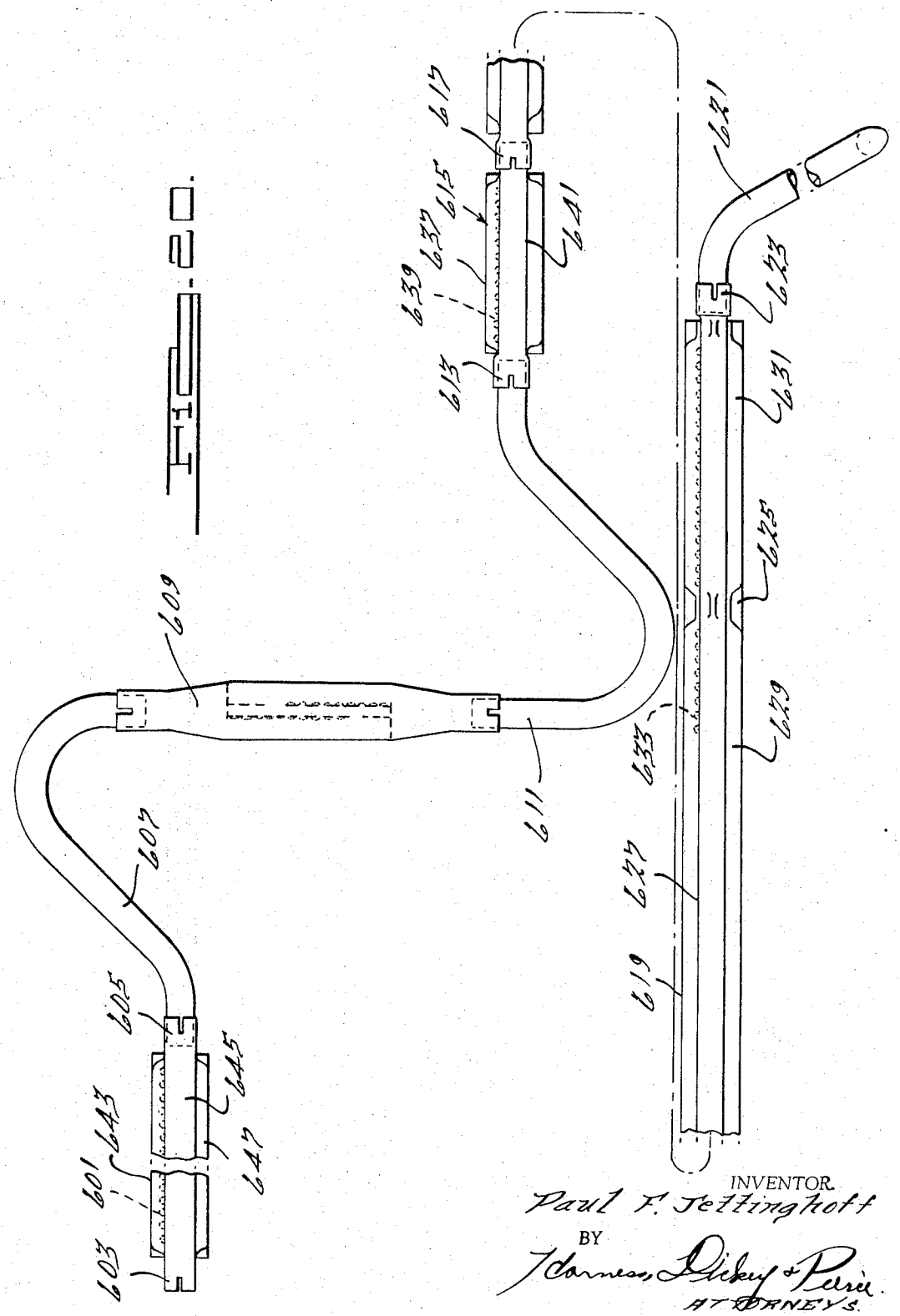
Feb. 27, 1968 P. F. JETTINGHOFF 3,370,674

RETROVERTED-FLOW MUFFLER WITH SIMPLIFIED PARTITION ARRANGEMENT

Filed Sept. 2, 1964 5 Sheets-Sheet 5

Fig. 20.



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3,370,674

RETROVERTED-FLOW MUFFLER WITH SIMPLIFIED PARTITION ARRANGEMENT

Paul F. Jettinghoff, Jackson, Mich., assignor to Walker Manufacturing Company, a corporation of Delaware

Filed Sept. 2, 1964, Ser. No. 393,864
28 Claims. (Cl. 181—54)

ABSTRACT OF THE DISCLOSURE

A small, highly effective exhaust muffler is provided by the use of two longitudinal partitions which 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. The partitions may be fabricated from a single piece of metal. A complete exhaust system using the muffler is also disclosed.

My invention relates to mufflers of the type that are used in the exhaust systems of internal combustion engines.

It is an object of my invention to provide a muffler that is very small in width and thickness but which incorporates a tri-flow gas passage.

It is also an object of my invention 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.

The invention is illustrated in the accompanying drawings in which:

FIGURE 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.

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 undercar 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 **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 minimum 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 forced 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 mid-section 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 flow 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 line **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 chamber 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 unit **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 sections, 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. If desired, the devices other than the tri-flow unit **609** may be flattened to reduced their width in one dimension and to give them a somewhat oval conformation.

The silencing device **619** has an outer casing which 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 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 spotwelded 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. In a tri-flow muffler, an elongated shell, and means providing a pair of transversely spaced longitudinal walls in said shell subdividing said shell into three series-connected coextensive longitudinal passages separated from each other only by said pair of walls, said means comprising a one piece part of sheet metal having two longitudinal side sections providing said walls and an intermediate section extending at an angle to said side sections and connecting them together.

2. The invention set forth in claim **1** wherein said walls have banks of openings providing for cross flow of gas across the central of the longitudinal passages.

3. The invention set forth in claim **1** wherein the one-piece part has an end section at the end of the side sections and extending at a right angle to it to provide a partition defining an end of a longitudinal passage.

4. A tri-flow muffler for use in internal combustion engine exhaust systems comprising

(a) an elongated casing extending in a longitudinal direction,

(b) said casing having an upstream end with an inlet to receive gas and a downstream end with an outlet to discharge gas,

(c) partition means including a first longitudinal partition in said casing extending across the width of the casing and longitudinally of the casing and acting with a wall of the casing to define a longitudinal inlet chamber,

(d) said partition means including a second longitudinal partition in said casing extending across the width of the casing and longitudinally of the casing and acting with a wall of the casing to define a longitudinal outlet chamber,

(e) said two longitudinal partitions acting together to define a central longitudinal chamber located between said inlet and outlet chambers,

(f) each of said longitudinal inlet and outlet chambers and partitions having an upstream end and a downstream end, the upstream end being located nearer to the casing inlet than to the casing outlet and the downstream end being located nearer to the casing outlet than to the casing inlet,

(g) said longitudinal inlet and outlet chambers each having apertures therein defining a gas flow inlet and a gas flow outlet and said inlets being located closer to the upstream ends of said chambers than are the outlets and the outlets being located closer to the downstream ends of said chambers than are the inlets,

(h) the gas flow outlet of said longitudinal inlet chamber opening into the central chamber and forming the gas flow inlet for said central chamber,

(i) the gas flow inlet of said longitudinal outlet chamber opening into the central chamber and forming the gas flow outlet for said central chamber,

(j) the gas flow inlet of said central chamber being located closer to the downstream end of said chamber than is its gas flow outlet and the gas flow outlet of said central chamber being located closer to the upstream end of said chamber than is its gas flow inlet,

(k) the gas flow inlet of said longitudinal inlet chamber being in gas flow communication with the casing inlet and the gas flow outlet of said longitudinal outlet chamber being in gas flow communication with the casing outlet,

(l) said gas flow inlets and outlets defining a tri-flow passage for gas flow consecutively through said longitudinal inlet, central, and outlet chambers,

(m) first closure means closing the upstream ends of the longitudinal central and outlet chambers, and

(n) second closure means closing the downstream ends of the longitudinal central and inlet chambers,

(o) the full cross sectional areas of said two longitudinal chambers and said central chamber being open and unobstructed and forming said tri-flow passage and said tri-flow passage having the full

cross sectional areas of said longitudinal and central chambers.

5. The invention set forth in claim 4 including an outer shell surrounding said casing and acting with it to form an outer sound attenuating chamber, and means forming at least one opening in said casing communicating the space inside said casing with said outer sound attenuating chamber.

6. The invention set forth in claim 4 including means comprising perforations in said partition means providing for cross flow of gas at an angle to said tri-flow passage and from said longitudinal inlet chamber into said longitudinal central chamber.

7. The invention set forth in claim 6 wherein said perforations are in said first longitudinal partition.

8. The invention set forth in claim 7 wherein said perforations are in both said first and second longitudinal partitions and are located between the gas inlet and gas outlet openings of the longitudinal central chamber whereby said cross flow intersects the tri-flow passage of gas through said longitudinal central chamber.

9. The invention set forth in claim 8 wherein the perforations in at least one of said longitudinal partitions are formed by louvers.

10. The invention set forth in claim 4 including acoustic opening means formed in said partition means and acoustically connecting at least one of the longitudinal inlet and outlet chambers to the longitudinal central chamber to attenuate sound in the gas flowing in said tri-flow passage.

11. The invention set forth in claim 10 wherein said acoustic opening means is formed in at least said first longitudinal partition and provides additionally for a diversion and cross flow of gas out of said tri-flow passage and from said longitudinal inlet chamber to said longitudinal central chamber.

12. The invention set forth in claim 11 including an outer shell surrounding said casing and means forming an acoustic opening in said casing connecting the inside of the casing with the space between the casing and shell.

13. The invention set forth in claim 4 wherein the relative cross-sectional areas of the longitudinal inlet and central chambers are such that gas in said tri-flow passage flows at a substantially lower velocity through said central chamber and including perforation means in said partition means providing for cross flow of gases from said inlet chamber at an angle to said tri-flow passage and through said longitudinal central chamber whereby cross flow gas and tri-flow gas flow at different velocities and directions and are intermingled in said central chamber.

14. The invention set forth in claim 4 wherein said first longitudinal partition has a bank of perforations formed therein extending in length substantially from the upstream end of the partition to the gas flow outlet of the longitudinal inlet chamber, said perforations opening into the longitudinal central chamber and providing for cross flow of gas from the longitudinal inlet to the longitudinal central chamber and for acoustic connection of gas in the longitudinal inlet chamber portion of said tri-flow passage with said central chamber.

15. The invention set forth in claim 14 wherein said bank of perforations has a total area of about 35–60% of the cross-sectional area of the inlet chamber.

16. The invention set forth in claim 15 wherein the second longitudinal partition has a bank of perforations extending in length substantially from the gas flow inlet of the longitudinal outlet chamber to the downstream end of the partition and opening into the longitudinal central chamber providing for cross flow of gas and for acoustic connection of gas in the longitudinal outlet chamber portion of said tri-flow passage with said central chamber.

17. The invention set forth in claim 16 wherein the relative areas of the longitudinal inlet and central chambers are such that the velocity of gas flow in the central chamber is substantially less than that in the inlet chamber and that of said cross flow gas.

18. The invention set forth in claim 4 wherein said casing is substantially round in cross section and said longitudinal central chamber is located on a diametral midplane of said casing and therefore is as wide as said casing and substantially wider than the longitudinal inlet and outlet chambers, the height of said central chamber being substantially less than the heights of said longitudinal inlet and outlet chambers, said longitudinal partitions including banks of perforations providing for cross flow of gas at an angle to said tri-flow gas passage and across said central chamber.

19. The invention set forth in claim 4 wherein said first and second longitudinal partitions comprise opposite sides of an elongated oval tube and said first and second closure means comprises transverse partitions secured to said casing and to said tube and supporting said tube in said casing.

20. The invention set forth in claim 4 wherein said first and second longitudinal partitions and said first and second closure means are provided by a single part folded from a flat piece of metal into a tube having flanges closing opposite ends of the tube and extending in opposite directions at each end thereof to be secured to the casing.

21. A tri-flow muffler for use in internal combustion engine exhaust systems comprising an elongated casing extending in a longitudinal direction, said casing having an upstream end with an inlet to receive gas and a downstream end with an outlet to discharge gas, partition means including a first longitudinal partition in said casing extending across the width of the casing and longitudinally of the casing and acting with a wall of the casing to define a longitudinal inlet chamber, said partition means including a second longitudinal partition in said casing extending across the width of the casing and longitudinally of the casing and acting with a wall of the casing to define a longitudinal outlet chamber, said two longitudinal partitions acting together to define a central longitudinal chamber located between said inlet and outlet chambers, each of said longitudinal inlet and outlet chambers and partitions having an upstream end and a downstream end, the upstream end being located nearer to the casing inlet than to the casing outlet and the downstream end being located nearer to the casing outlet than to the casing inlet, said longitudinal inlet and outlet chambers each having a gas flow inlet and a gas flow outlet and said inlets being located closer to the upstream ends of said chambers than are the outlets and the outlets being located closer to the downstream ends of said chambers than are the inlets, the gas flow outlet of said longitudinal inlet chamber opening into the central chamber and forming the gas flow inlet for said central chamber, the gas flow inlet of said longitudinal outlet chamber opening into the central chamber and forming the gas flow outlet for said central chamber, the gas flow inlet of said central chamber being located closer to the downstream end of said chamber than is its gas flow outlet and the gas flow outlet of said central chamber being located closer to the upstream end of said chamber than is its gas flow inlet, the gas flow inlet of said longitudinal inlet chamber being in gas flow communication with the casing inlet and the gas flow outlet of said longitudinal outlet chamber being in gas flow communication with the casing outlet, said gas flow inlets and outlets defining a tri-flow passage for gas flow consecutively through said longitudinal inlet, central, and outlet chambers, first closure means closing the upstream ends of the longitudinal central and outlet chambers, and second closure means closing the downstream ends of the longitudinal central and inlet chambers, at least one of said longitudinal chambers having a dead chamber portion of substantial length and volume acting to attenuate sound and located outside the

portion of said one chamber included between its gas flow inlet and gas flow outlet.

22. The invention set forth in claim 21 wherein said dead chamber portion is located in said longitudinal central chamber.

23. The invention set forth in claim 22 wherein said first longitudinal partition includes a bank of perforations opening into said longitudinal central chamber and located between the gas flow inlet and the gas flow outlet of said central chamber and providing for cross flow of gas into said central chamber.

24. The invention set forth in claim 23 wherein said partition means includes perforations providing an acoustic connection with said dead chamber portion of said longitudinal central chamber.

25. A tri-flow muffler for use in internal combustion engine exhaust systems comprising an elongated casing extending in a longitudinal direction, said casing having an upstream end with an inlet to receive gas and a downstream end with an outlet to discharge gas, partition means including a first longitudinal partition in said casing extending across the width of the casing and longitudinally of the casing and acting with a wall of the casing to define a longitudinal inlet chamber, said partition means including a second longitudinal partition in said casing extending across the width of the casing and longitudinally of the casing and acting with a wall of the casing to define a longitudinal outlet chamber, said two longitudinal partitions acting together to define a central longitudinal chamber located between said inlet and outlet chambers, each of said longitudinal inlet and outlet chambers and partitions having an upstream end and a downstream end, the upstream end being located nearer to the casing inlet than to the casing outlet and the downstream end being located nearer to the casing outlet than to the casing inlet, said longitudinal inlet and outlet chambers each having a gas flow inlet and a gas flow outlet and said inlets being located closer to the upstream ends of said chambers than are the outlets and the outlets being located closer to the downstream ends of said chambers than are the inlets, the gas flow outlet of said longitudinal inlet chamber opening into the central chamber and forming the gas flow inlet for said central chamber, the gas flow inlet of said longitudinal outlet chamber opening into the central chamber and forming the gas flow outlet for said central chamber, the gas flow inlet of said central chamber being located closer to the downstream end of said chamber than is its gas flow outlet and the gas flow outlet of said central chamber being located closer to the upstream end of said chamber than is its gas flow inlet, the gas flow inlet of said longitudinal inlet chamber being in gas flow communication with the casing inlet and the gas flow outlet of said longitudinal outlet chamber being in gas flow communication with the casing outlet, said gas flow inlets and outlets defining a tri-flow passage for gas flow consecutively through said longitudinal inlet, central, and outlet chambers, first closure means closing the upstream ends of the longitudinal central and outlet chambers, and second closure means closing the downstream ends of the longitudinal central and inlet chambers, said first longitudinal partition comprising a plate having longitudinal side flanges secured to the casing and a right angle portion at its upstream end secured to said casing and forming said first closure means, said second longitudinal partition comprising a plate having longitudinal side flanges secured to the casing and a right angle portion at its downstream end secured to said casing and forming said second closure means.

26. A tri-flow muffler for use in internal combustion engine exhaust systems comprising an elongated casing extending in a longitudinal direction, said casing having an upstream end with an inlet to receive gas and a downstream end with an outlet to discharge gas, partition means including a first longitudinal partition in said casing extending across the width of the casing and longitudinally of the casing and acting with a wall of the casing to define a longitudinal inlet chamber, said partition means including a second longitudinal partition in said casing extending across the width of the casing and longitudinally of the casing and acting with a wall of the casing to define a longitudinal outlet chamber, said two longitudinal partitions acting together to define a central longitudinal chamber located between said inlet and outlet chambers, each of said longitudinal inlet and outlet chambers and partitions having an upstream end and a downstream end, the upstream end being located nearer to the casing inlet than to the casing outlet and the downstream end being located nearer to the casing outlet than to the casing inlet, said longitudinal inlet and outlet chambers each having a gas flow inlet and a gas flow outlet and said inlets being located closer to the upstream ends of said chambers than are the outlets and the outlets being located closer to the downstream ends of said chambers than are the inlets, the gas flow outlet of said longitudinal inlet chamber opening into the central chamber and forming the gas flow inlet for said central chamber, the gas flow inlet of said longitudinal outlet chamber opening into the central chamber and forming the gas flow outlet for said central chamber, the gas flow inlet of said central chamber being located closer to the downstream end of said chamber than is its gas flow outlet and the gas flow outlet of said central chamber being located closer to the upstream end of said chamber than is its gas flow inlet, the gas flow inlet of said longitudinal inlet chamber being in gas flow communication with the casing inlet and the gas flow outlet of said longitudinal outlet chamber being in gas flow communication with the casing outlet, said gas flow inlets and outlets defining a tri-flow passage for gas flow consecutively through said longitudinal inlet, central, and outlet chambers, first closure means closing the upstream ends of the longitudinal central and outlet chambers, and second closure means closing the downstream ends of the longitudinal central and inlet chambers, said first and second partitions being substantially identical and comprising plates having longitudinal side flanges secured to the casing, said first and second closure means being substantially identical and comprising transverse partitions secured to the ends of the longitudinal partitions and to the casing.

27. A tri-flow muffler for use in internal combustion engine exhaust systems comprising an elongated casing extending in a longitudinal direction, said casing having an upstream end with an inlet to receive gas and a downstream end with an outlet to discharge gas, partition means including a first longitudinal partition in said casing extending across the width of the casing and longitudinally of the casing and acting with a wall of the casing to define a longitudinal inlet chamber, said partition means including a second longitudinal partition in said casing extending across the width of the casing and longitudinally of the casing and acting with a wall of the casing to define a longitudinal outlet chamber, said two longitudinal partitions acting together to define a central longitudinal chamber located between said inlet and outlet chambers, each of said longitudinal inlet and outlet chambers and partitions having an upstream end and a downstream end, the upstream end being located nearer to the casing inlet than to the casing outlet and the downstream end being located nearer to the casing outlet than to the casing inlet, said longitudinal inlet and outlet chambers each having a gas flow inlet and a gas flow outlet and said inlets being located closer to the upstream ends of said chambers than are the outlets and the outlets being located closer to the downstream ends of said chambers than are the inlets, the gas flow outlet of said longitudinal inlet chamber opening into the central chamber and forming the gas flow inlet for said central chamber, the gas flow inlet of said longitudinal outlet chamber opening into the central chamber and forming the gas flow

outlet for said central chamber, the gas flow inlet of said central chamber being located closer to the downstream end of said chamber than is its gas flow outlet and the gas flow outlet of said central chamber being located closer to the upstream end of said chamber than is its gas flow inlet, the gas flow inlet of said longitudinal inlet chamber being in gas flow communication with the casing inlet and the gas flow outlet of said longitudinal outlet chamber being in gas flow communication with the casing outlet, said gas flow inlets and outlets defining a tri-flow passage for gas flow consecutively through said longitudinal inlet, central, and outlet chambers, first closure means closing the upstream ends of the longitudinal central and outlet chambers, second closure means closing the downstream ends of the longitudinal central and inlet chambers, and an inlet chamber extending across said casing and located upstream of said longitudinal chambers and receiving gas from said casing inlet and an outlet chamber extending across said casing and located downstream of said longitudinal chambers and discharging gas into said casing outlet, the gas flow inlet of said longitudinal inlet chamber opening into said inlet chamber and the gas flow outlet of said longitudinal outlet chamber opening into said outlet chamber.

28. The invention set forth in claim **27** wherein the relative areas of the longitudinal inlet and central chambers are such that the velocity of gas flow in the central chamber is substantially less than that in the longitudinal inlet chamber and means forming banks of perforations in said first and second longitudinal partition providing a multiplicity of acoustic and cross gas flow connections of said longitudinal inlet and outlet chambers with said longitudinal central chamber.

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