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(54) COMPACT MUFFLER FOR SMALL TWO-STROKE INTERNAL COMBUSTION ENGINES

(76) Inventors: **Chris B. Harris**, Amity, OR (US); **Chris Pellegrino**, Yamhill, OR (US); **Gregory Stadeli**, Salem, OR (US); **Dean Glass**, Carlton, OR (US)

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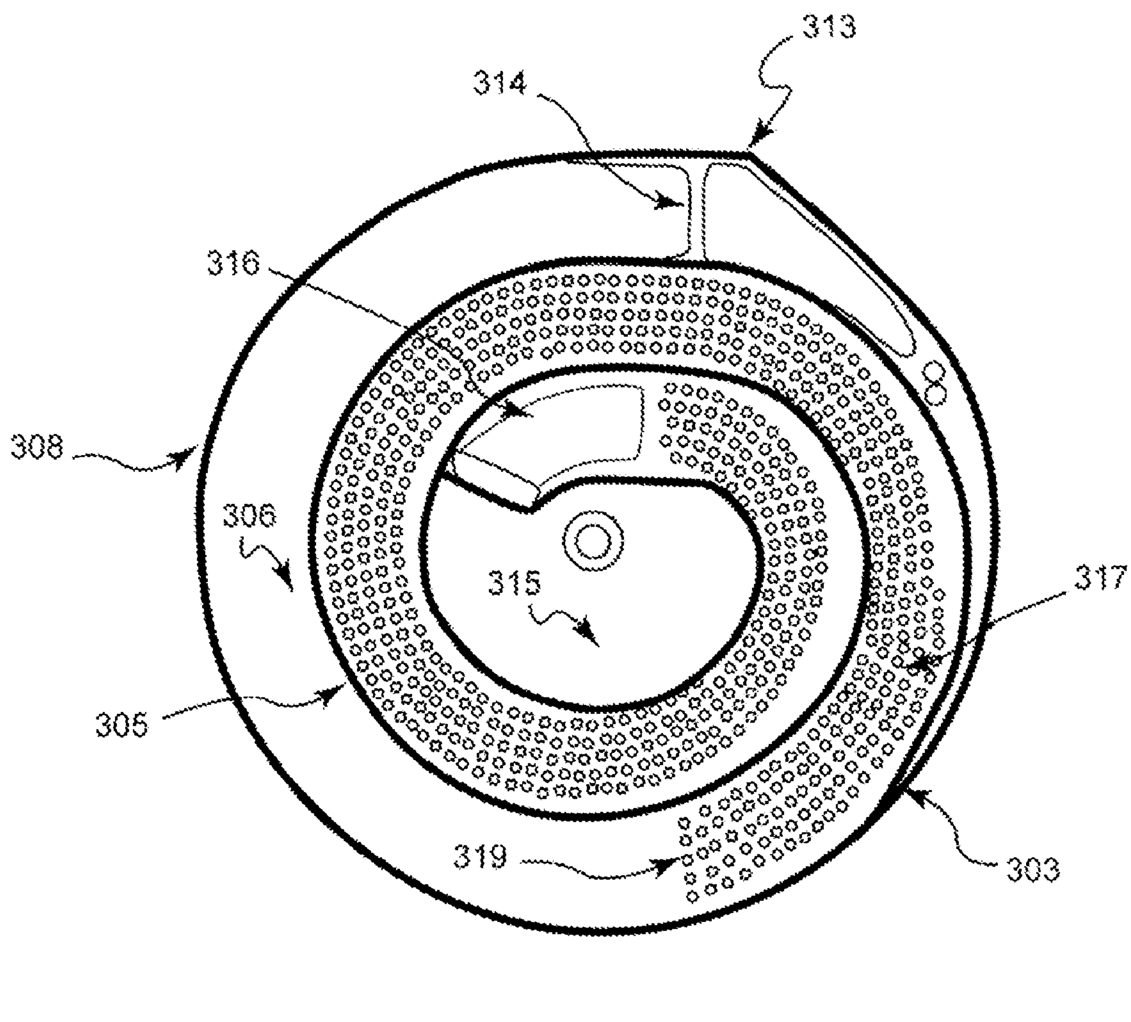
(57) **ABSTRACT**

A muffler providing a compact and low-profile form factor for small two-stroke engines is described, particularly useful for aerodynamic radio controlled aircraft. The muffler comprises a tuned internal header eliminating the need for an external header to mount the inventive muffler to the exhaust port of a two-stroke engine while maintaining enhanced engine performance, obviating the need for a conventional tuned-pipe exhaust.



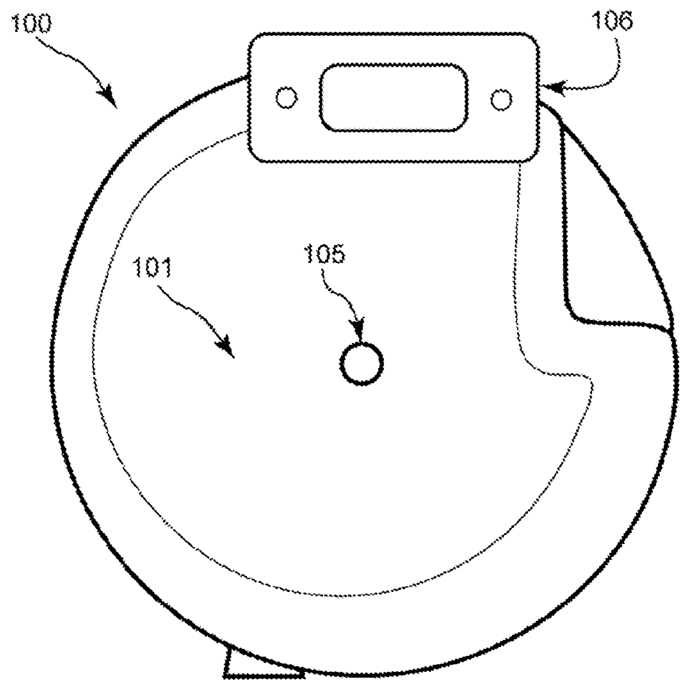


Fig 1a

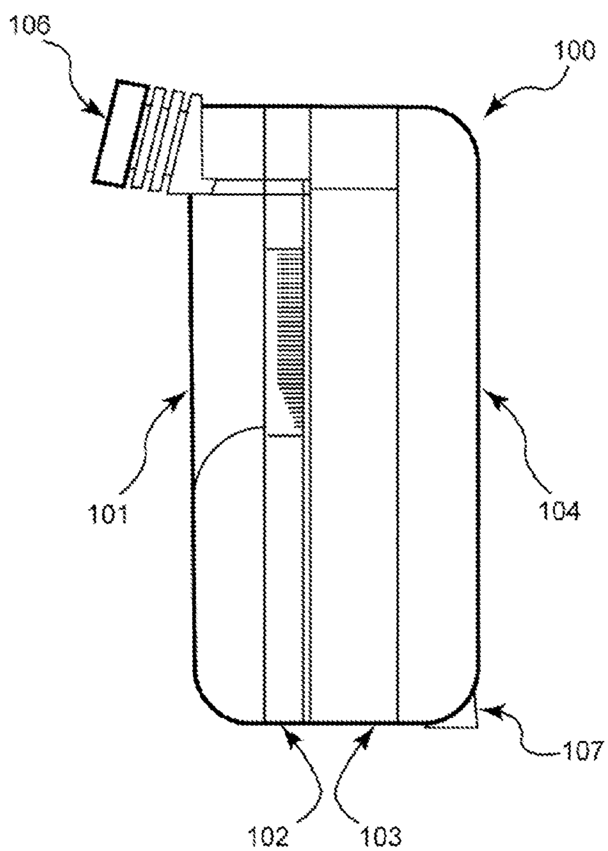


Fig 1b

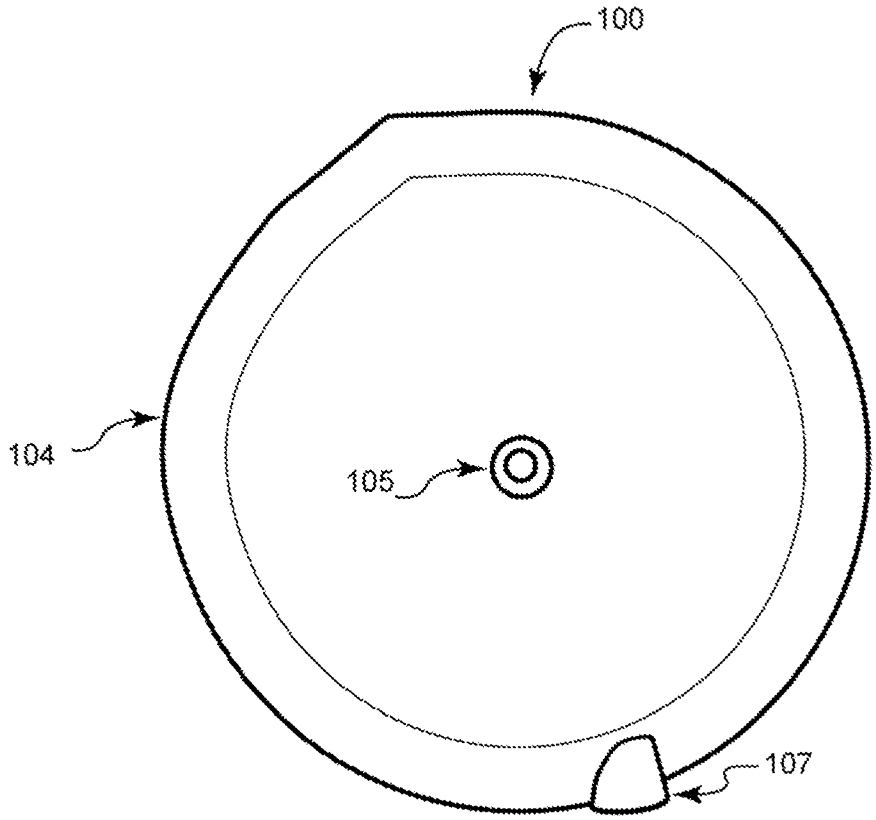


Fig. 1c

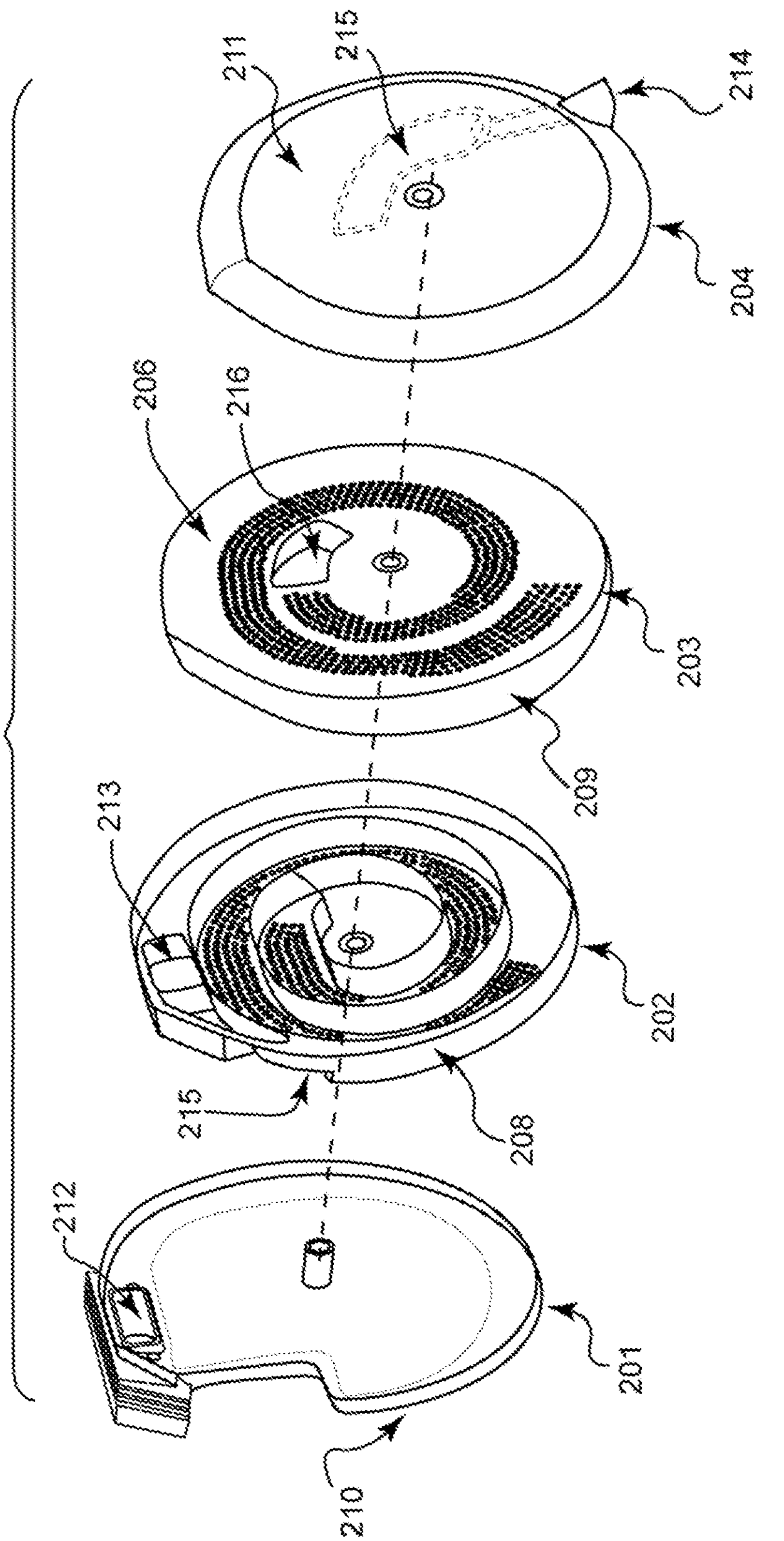


Fig. 2a

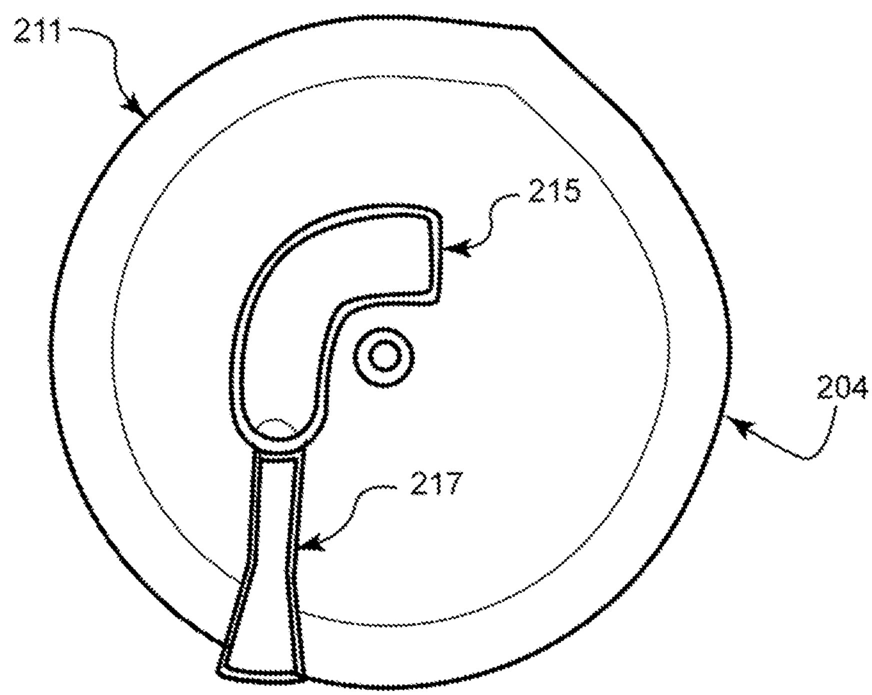


Fig. 2b

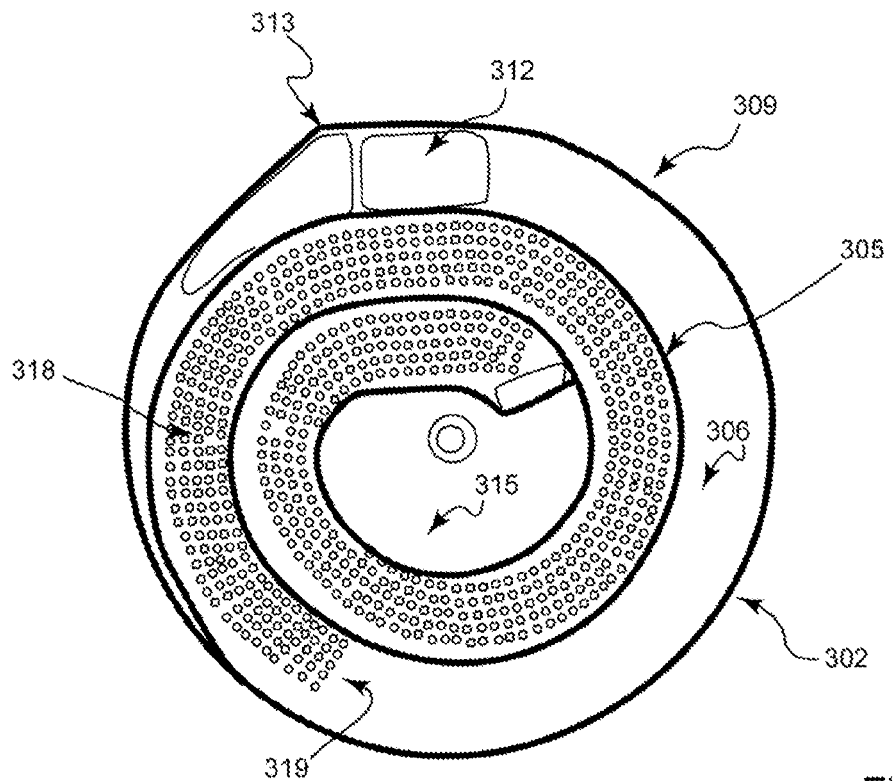
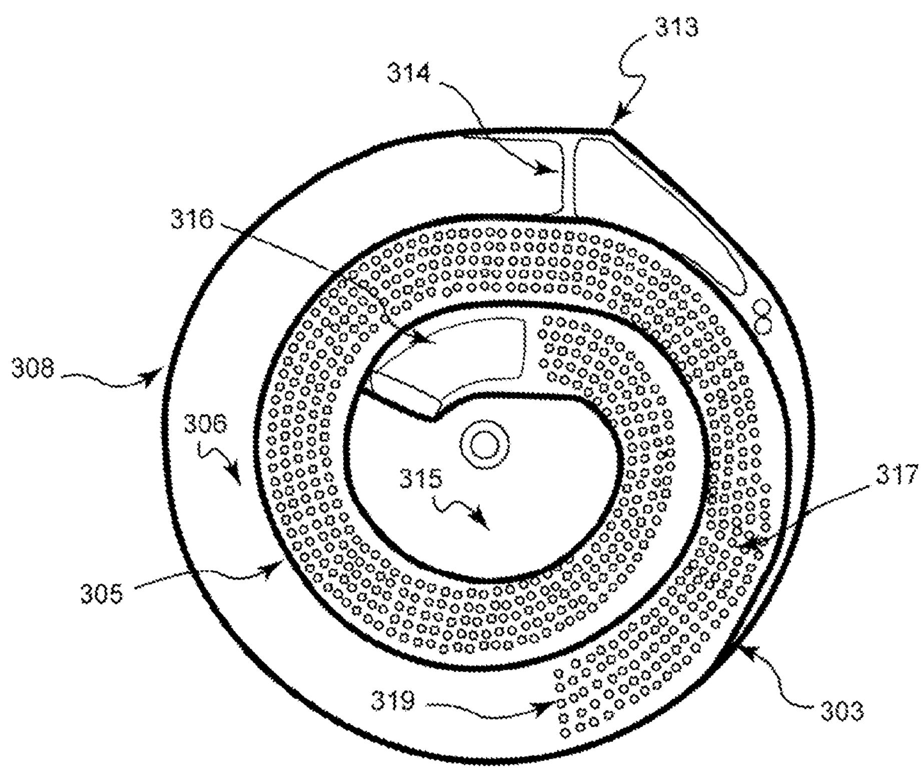

313
312
309
305
318
306
315
302
319

Fig 3a


313
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303

Fig 3b

COMPACT MUFFLER FOR SMALL TWO-STROKE INTERNAL COMBUSTION ENGINES

PRIORITY CLAIM

[0001] This application claims benefit to U.S. Provisional Application 61/515,156 filed on Aug. 4, 2011.

FIELD OF THE INVENTION

[0002] This invention relates to compact mufflers designed for small two-stroke engines used in radio controlled model aircraft, watercraft, hand held tools and the like.

BACKGROUND

[0003] Over the past several decades, muffler designs aiming at compactness and light weight have been introduced in order to accommodate the demands of modern vehicle designs. Being primarily directed to use with four-stroke engines in automobiles and motorcycles, prior art muffler designs have been focused on reducing the size of the muffler system and for enhancing engine efficiency by maintaining low back pressure while adequately reducing exhaust noise by different means. In these designs, the exhaust pipe is partially or wholly enclosed within the body of the muffler to accommodate a duct shaped in a "jellyroll" or spiral passageway enclosed in an outer shell comprising the muffler housing. The spiral passageway is of reduced cross section relative to the header pipe in which exhaust gases increase in velocity and reduced pressure in a gradual manner, thereby greatly reducing the noise associated with the expansion of these gases, while maintaining low pressure and forward flow within the muffler so as greatly lower the backpressure on the engine. Examples of such designs are described in U.S. Pat. No. 3,066,755 to Diehl, U.S. Pat. No. 3,692,142 to Stemp, U.S. Pat. No. 3,927,731 to Lancaster. Later, more elaborate methods of noise abatement were combined with the spiral flow passage, as exemplified in U.S. Pat. No. 4,579,195 to Nieri and U.S. Pat. No. 5,612,006 to Fisk.

[0004] More recently, streamlining muffler systems for two-stroke engines has been addressed. For a two-stroke engine, backpressure is an issue, but in the opposite sense in relation to four-stroke engines, and efforts have been made to design an exhaust system to maintain a certain level of backpressure so that the air/fuel mixture does not empty too quickly from the cylinder on the down-stroke of the piston. The quintessential exhaust processing system for a two-stroke engine has been the tuned straight pipe, adding to the passive backpressure control of the air/fuel charge in the cylinder by sending positive pressure pulses to the cylinder synchronized with the down-stroke to push fresh un-combusted air/fuel charge that had escaped into the exhaust system back into the cylinder just before the compression/combustion stroke of the piston. While the straight tuned pipe works well to enhance two-stroke engine efficiency, and reduce exhaust system noise, in the case of small vehicles and hand tools powered by small two-stroke engines, tuned pipes are in many instances longer and bulkier than the very vehicle or devices on which they are mounted, adding significant weight as well. For instance, radio controlled model aircraft are hampered by the presence of a tuned pipe exhaust because it is difficult to hide or streamline the tuned pipe for increasing aerodynamic efficiency. U.S. Pat. No. 6,684,633 to Jett addresses this issue and describes a compact muffler designed for radio controlled aircraft and small engine-powered tools. U.S. Pat. No. 6,959,782 to Brower et al. describes a muffler design based on similar principles for two-cylinder two-stroke motorcycle engines. Both designs comprise compact "tuned" exhaust systems, whereby the tuned exhaust pipe is rolled into a spiral passage leading to an expansion chamber. These mufflers are claimed to be effectively tuned pipes folded into a compact form factor, however fall short of a perfect tuned pipe exhaust because of the combination of the abrupt angles along the folded course of flow, and the rectangular cross section of the spiral passage itself, effectively frustrate the propagation of pressure waves, greatly detuning the system.

BRIEF DESCRIPTION OF THE INVENTION

[0005] While the latter prior designs address some of the problems mentioned in the Background section, the instant invention solves the problem of providing an effective compact muffler system without the need to have a conventional tuned pipe exhaust for good engine performance, yet still maintain or enhance engine performance, provide noise attenuation and very importantly provide a low-profile form-factor when mounted on an engine to allow for streamlined and aerodynamic vehicle design, such as for radio controlled aircraft and watercraft powered by small two-stroke engines. The inventors provide a lightweight highly compact muffler design for mounting on small two-stroke engines, providing the benefits of a tuned pipe exhaust system without the inconvenience of the extra weight and space requirements that a tuned pipe necessitates. This aspect of the instant invention is especially beneficial for radio controlled model aircraft and unmanned aerial vehicles (UAVs), where the ability to encase the muffler fully within the engine compartment of the fuselage does not engender drag that would normally be encountered by a more bulky exhaust system, and allows operation of the small aircraft with full aerodynamic efficiency, as intended by the aircraft's designers. The inventive muffler is mounted directly or almost directly on the engine, being connected to a shorted exhaust pipe from a manifold or header system, or directly to the engine exhaust port.

[0006] The preferred embodiment of the invention comprises a substantially cylindrical shell housing having a low aspect ratio and divided into at least four removable or separable cylindrical sections that shared a common axis and are assembled into a stack, fastened together by one or more bolts that extend through the muffler body parallel to the axis, when in use. The muffler can be readily disassembled for servicing by means of this design. The shell housing is divided internally into at least three chambers consisting of a middle chamber and two auxiliary outer chambers sharing a common axis and arranged in a stack. In the preferred embodiment, the outer chambers are arranged above and below the middle chamber and share common internal partitions with the middle chamber. An intake port flange is integrally formed in and on the body of the upper chamber delineated and partially enclosed by the first shell section, disposed near the edge thereof and penetrating through the interior of the upper chamber via an integrally formed duct to reach and communicate with the middle chamber. A stinger exhaust outlet is similarly integrally formed in and on the body, comprising a tube and conical diffuser section disposed within and outside of the lower chamber, delineated and enclosed partially by the fourth shell section. The stinger exhaust outlet port is integrally formed with the fourth shell section, and is partially disposed on the interior of the shell to reach and communicate with the middle chamber. The exhaust stinger tube section is aerodynamically designed for minimal disturbance to the flow path of the exiting exhaust gases to minimize overly high backpressure due to turbulence effects, and seamlessly diverges to form the conical diffuser section for efficient flow ejection to the atmosphere. The middle chamber in turn is composed of two half chambers delineated and encompassed by the second and third sections of the housing shell forming an outer wall, internally bounded by an upper partition plate separating the upper chamber from the top of the middle chamber and a lower partition plate separating the lower chamber from the bottom of the middle chamber, wherein a spiral inner wall spanning the middle chamber from the top partition plate to the bottom partition plate is formed integrally with the upper and lower partition plates, and has an origin that bifurcates inwardly from the outer wall, winding spirally towards the center of the middle chamber. The windings of the spiral wall delineate a spiral exhaust passage having a peripheral terminus disposed near the periphery of the middle chamber, and an inner terminus disposed near the center of the middle chamber. Enclosed within the spiral exhaust passage and disposed at the peripheral terminus is an entrance aperture in communication with the intake port, whereas an exit aperture in communication with the exhaust outlet port is also enclosed within the spiral passage and disposed at its inner terminus. The exhaust port further comprises a duct formed integrally with the shell section housing the lower chamber, leading to the stinger outlet. The stinger outlet further comprises a straight tubular duct of narrow bore, also formed integrally with the shell section housing of the lower chamber, leading to the exterior of the lower chamber, where an integrally formed flared outlet penetrates the shell section of the lower chamber to vent exhaust to the atmosphere.

[0007] Disposed on both the upper and lower partition plates of the middle chamber is a plurality of perforations arranged in a pattern following the contours of the spiral passage. The perforations occupy only a portion of the spiral chamber defined as the aft-portion, whereby an initial segment extending from the aperture at the peripheral terminus to a point along the spiral passage, defined as the fore-portion, is not perforated. The fore-portion of the spiral exhaust passage forms an internal header. An adjustment of the length of the internal header is performed empirically to yield maximum engine performance for a particular engine. The plurality of perforations in the aft-portion of the spiral exhaust passage allow communication between the passage and the interior of the upper and lower auxiliary chambers, wherein a sound dampening material packing is enclosed. Gases passing through the spiral exhaust passage follow the internal header to the aft-portion wherein the gases enter the auxiliary chambers through the perforations and interact with the sound absorbent packing where the sound energy that they carry is dissipated. The gases then re-enter the spiral chamber to be exhausted to the atmosphere through the stinger outlet. In an aspect of the present invention, the gases do not pass through the sound dampening material, extending the service life of the material.

[0008] The inventive muffler thus provides a simple and highly compact form factor and construction for low profile mounting on small two-stroke engines, while at the same time yielding enhanced performance, obviating the need for an unwieldy conventional tuned pipe exhaust that adds unnecessary bulk and weight to light-weight aerodynamic vehicles and small apparatuses powered by small two-stoke engines, such as radio controlled aircraft, watercraft and UAVs. The inventive muffler provides this enhancement by maintaining adequate backpressure on the cylinder to which it is mounted, reducing the potential for gases to escape too rapidly during the scavenging phase on the down-stroke of the piston.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1***a*. A frontal (top) view of the invention

[0010] FIG. **1***b*. Side view of the inventive muffler assembled, showing the profile of the intake port flange, and the four removable sections.

[0011] FIG. **1***c*. Inventive muffler—rear (bottom) view showing stinger exhaust port.

[0012] FIG. **2***a*. Exploded view of the inventive muffler, showing some details of the internal components.

[0013] FIG. **2***b*. Plan view of the interior of bottom outer chamber exposing details of stinger exhaust outlet port.

[0014] FIG. **3***a*. Plan view of the interior of the top half section of middle chamber, exposing details of entrance aperture, the top half of the spiral exhaust duct with its perforation pattern.

[0015] FIG. **3***b*. Plan view of the interior of the bottom half section of middle chamber, exposing details of exit aperture, the bottom half of the spiral exhaust duct, and perforation pattern.

DETAILED DESCRIPTION

[0016] Details of the preferred embodiment of the invention will now be described.

[0017] Referring to FIGS. **1***a* and **1***b*, the inventive muffler body comprises a substantially cylindrical housing shell **100** characterized by a low aspect ratio, whereby the diameter of the housing is larger than its axial length. Housing shell **100** is further subdivided into four removable sections **101**-**104**, described in greater detail below, designed to lock together in a stack formation when assembled. Passage hole **105** is traverses the four sections to allow securing the assembled muffler sections together by a bolt or screw. An exhaust intake port flange **106** is disposed near the edge of the top section for mounting to an exhaust port of a small two-cycle engine. On the reverse side of the housing shell **100**, a conical stinger exhaust outlet port **107** is disposed along the edge of the housing shell. It will be appreciated by persons skilled in the art that the exterior positioning of the exhaust intake and outlet ports is not critical to the operation of the muffler, and that other embodiments may incorporate such variations of the placement of these ports without departing from the scope and spirit of the invention.

[0018] Referring now to FIGS. **2***a* and **2***b*, the interior of housing shell **200** is partitioned into three adjacent chambers along a first and second plane that are both normal to its axis, forming a stack consisting of a middle chamber and two auxiliary outer chambers positioned above and below the middle chamber. FIG. **2***a* shows an exploded view of the sandwich arrangement of the interior chambers. Outer chambers **201** ad **204** comprise the first and forth removable sections of housing shell **200**, and cap the middle chamber, which is divided into two half sections **202** and **203**. The half sections **202** and **203** of the middle chamber are bounded axially by two parallel partitions, or plates **205** and **206**, while being bound radially by the second **208** and third **209** removable segments of the muffle housing shell extending between the two partitions, forming an outer wall. The partition plates **205** and **206** are also shared in common with the two outer chambers **201** and **204**. The outer chambers are in turn bounded internally the planar partitions **205** and **206** and by upper **210** and lower **211** sections, or first and fourth removable sections, respectively, of the removable muffler housing shell segments extending from the partitions to the end extremities of the shell.

[0019] Continuing to refer to FIG. **2***a*, the intake port **212** disposed near the outer edge of the surface of the top chamber and is extended exteriorly from the muffler housing shell by a finned flange for connection to the cylinder's exhaust port. The port **212** penetrates interiorly through the top chamber **201** to the middle chamber half **202** with which it is in communication via an entrance aperture **213** in the partition plate **205** dividing the middle and top chambers. In this way, the interior of top chamber **201** is isolated from the raw exhaust gas entering the muffler body. Similarly, outlet **214** is disposed on the interior of outer chamber **204**. Referring to FIG. **2***b*, a view of the interior of chamber **204** is shown. The exhaust port comprises a straight tube **217** whose cross section is narrower than that of the duct **215** leading to it, forming a constriction. Toward the distal end of the port, the tube is flared in a divergent acute angle **214**, the combination of the straight tube and flared port forming a stinger. Flared port **214** penetrates through the wall of chamber **204** and connects with one end of duct **215**. The opposite extremity of duct **215** covers exit aperture **216** (shown in FIG. **2***a*), which is formed in partition plate **206**, thus facilitating communication between the middle chamber and the atmosphere for removal of exhaust gases. Duct **215** and stinger tube **217** are partially formed and integral with the shell section **211** wherein the interior of the duct is exposed when the muffler housing is disassembled. When assembled, the duct and stinger tube seals against partition plate **206**, and covering aperture **216**. The stinger constriction inhibits the flow rate of escaping gases, thereby increasing the backpressure within the passageway of the muffler, inhibiting the loss of fuel/air mixture charge therein, thereby increasing engine performance, as is well known in the art.

[0020] Referring now to FIGS. **3***a* and **3***b*, the interior space of the middle chamber, comprising half sections **302** and **303**, is further divided by an interior wall **305** that bifurcates from the outer walls **308** and **309** of each half section, respectively, and spirals inwardly towards the center of the chamber, segmenting the interior space of the middle chamber into a spiral labyrinth. When the muffler is assembled, the spiral contours of the interior wall extend axially, between the first and second partitions (**205** and **206** in FIG. **2***a*), forming a spiral duct **306** of constant rectangular cross section that directs exhaust gases entering the muffler from the entrance aperture **312** towards the center of the muffler, wherefrom the exit aperture **316** opens into duct **215** (FIG. **2***b*) leading to the atmosphere via exhaust port stinger **214** (FIG. **2***b*). Upper and lower halves of interior spiral wall **305** are integral with the top and bottom partition plates (**205** and **206** of FIG. **2***a*), as well as with the outer wall at the point of bifurcation, respectively. The upper and lower halves of the spiral wall **305** mesh together when assembled, forming a contiguous structure spanning the height of the middle chamber.

[0021] Continuing to refer to FIGS. **3***a* and **3***b*, the outer wall **308** and **309** of the middle chamber sections is substantially circular, but in the preferred embodiment has a deformation at a point along its perimeter that forms an obtuse vertex **313** subtended by straight segments of the wall that gradually blend with the greater circular segment arc. The bifurcation of the interior wall **305** from the outer wall occurs near this vertex **313**, allowing the cross section of the spiral duct **306** to remain constant along its entire length. The inner wall bifurcates near the vertex **313** at a point approximately coinciding with the convergence of the straight wall segment subtending the vertex with the greater circular arc, initially forming an acute divergence angle with the outer wall, then flattens to become parallel with the straight segment subtending the vertex angle but on the opposite side of the vertex, becoming rounded once more to maintain parallelism with the contour of the outer wall. At this same point a partition wall **314** extends perpendicularly from the outer wall and spans the gap between the inner and outer walls, forming a cul-de-sac and demarking the peripheral terminus of the spiral duct. Aperture **312** leading to the intake port is located at this terminus, thereby defining the peripheral terminus as the entrance to the spiral duct. The inner spirals follow the same pattern to maintain the distance between successive spiral contours equal until the spiral duct terminates in the central portion of the chamber. The inner spiral wall terminates by joining itself along the final spiral segment forming a cul-de-sac and demarking the inner terminus of the spiral duct, also forming an enclosure around an inner space **315** as a consequence. The enclosed inner space **315** serves no function. The exit aperture **316** leading to the exhaust port is located in the cul-de-sac of the inner terminus. Again, a constant rectangular cross section of the spiral duct is maintained by this scheme. Materials of construction for all structural components of the present invention can be metals such as alloys of aluminum, steel, and high temperature plastics such as Torlon® or Zytel HTN®.

[0022] In an aspect of the preferred embodiment, the upper and lower plates, comprising the top and bottom of spiral duct **306**, are perforated in patterns **317** and **318**, respectively, that provide a plurality of perforations that are constrained to occupy the top and bottom of the spiral exhaust passage within the confines of the spiral duct **306**, that is, the perforation pattern follows the spiral contours of the duct, thereby allowing communication between the middle chamber and the top and bottom chambers through the plurality of perforations. Exhaust gases can eventually escape into the spaces of the outer chambers through the perforations, which are packed with sound absorbing materials for noise attenuation, such as non-woven glass fiber mat. In one aspect of the preferred embodiment, the degree to which the perforation grouping fills the spiral duct has been found to be essential to the performance of the muffler for engine efficiency. In other words, it is desirable that the perforations do not occupy the total length of the duct, and more specifically do not occupy the fore-portion of the duct between the intake port at the duct entrance and a point **319** downstream, but begin at a distance substantially downstream of the duct entrance and terminate at the duct exit.

[0023] Placement of the perforation pattern within the spiral duct in this manner has been found by the inventors to allow exhaust gases entering the muffler to maintain the exit velocity from the engine cylinder for a distance within the duct before encountering the perforations in the duct floor and ceiling, whereby the fore-portion of the spiral exhaust duct functions as a straight header pipe. Thus, the fore-portion of the duct functions as an internal header pipe. The main advantage of this aspect of the invention is that an external header necessary for connecting the muffler to a small two-stroke engine is eliminated, allowing for a more compact mounting of the inventive muffler to the engine and maintaining a smaller engine footprint overall in accordance with the spirit of the invention.

[0024] Engine performance is maintained or enhanced relative to a tuned pipe because the header function of the fore-portion of the duct prevents premature dissipation of the exhaust gas energy caused when gases disperse through the perforations to interact with the sound absorbing material, also creating turbulence, as would be the case if the perforations began at the entrance to the duct, thereby minimizing flow resistance within the spiral duct. In light of this discussion, the inventors have found that the length of the internal header is critical for engine performance, and have developed empirical methods to determine the optimal length. The exact placement of the perforation pattern, and hence the length of the internal header, is therefore optimized to produce maximum performance of the particular two-stroke engines to which the inventive muffler is intended to be attached. The following example demonstrates one optimization procedure developed by the inventors for determining the length of the internal header.

Example 1

Procedure for Optimizing the Length of Internal Header

[0025] An external straight header pipe of a given length is attached to the exhaust port of a particular small two-stroke engine. The length of the external header is determined empirically by finding the relationship between the engine performance and the length of the header. The optimum external header length required to achieve the maximum engine performance is then determined and used for the optimization of the internal header length. A prototype of the inventive muffler having perforations occupying the entire length of the spiral duct is mounted on the end of the external header. The engine performance is then measured in terms of rpm achieved (or other performance metric) with a given air/fuel mixture. The header pipe is incrementally reduced in length, and engine performance is measured, yielding an inferior result in comparison with the performance observed using the optimal external header length. Subsequently, short segments of the perforated fore-portion of the spiral duct are incrementally covered to compensate for the loss of external header until the maximum engine performance is recovered. This procedure is repeated until the external header is completely removed, resulting in the determination of the maximum length of internal header. Thus, the internal header length is shorter than the external header length giving maximum engine performance, and is optimized for the particular type of engine used for the procedure.

[0026] At the same time, a degree of exhaust gas backpressure is maintained within the muffler, mitigating the rate at which the air/fuel charge in the engine cylinder is sucked out of the cylinder before the compression stroke. While the inventive muffler is not a tuned pipe exhaust system as is claimed in a similar muffler design for two-stroke engines disclosed in U.S. Pat. No. 6,684,633, by maintaining a relatively high backpressure for an extended period of time within the duct, the inventive muffler mimics the supercharging action of a two-stroke tuned pipe without creating a reflected pressure wave. However, the backpressure within the inventive muffler is not so high as to inhibit fuel scavenging on the down-stroke of the piston, nor work against the compression stroke.

Noise Reduction

[0027] As mentioned above, the outer chambers serve to hold sound dampening material packings, which serve to attenuate low and high frequency noise. Materials such as non-woven glass fiber mat has been used for this purpose, and functions in ways understood in the art. Communication with the exhaust gases flowing in the spiral duct of the middle chamber is accomplished via the perforations decorating the upper and lower partition plates. Gases entering the auxiliary outer chambers via the plurality of perforations undergo expansion and lose pressure and velocity. The sound dampening packing dissipates the sound energy carried by the exhaust gases entering the auxiliary chambers, and the spent exhaust gases re-enter the spiral exhaust chamber to exit to the atmosphere through the stinger.

[0028] It will be appreciated by persons skilled in the art that the embodiment described herein is meant to be exemplary for illustrative purposes only, and that other embodiments and configurations are possible without deviating from the scope and spirit of the invention.

We claim:

1. A compact muffler for small two-stroke engines, comprising:

(a) A substantially cylindrical shell having an axial dimension and a radial dimension, wherein the radial dimension is substantially greater than the axial dimension, the shell housing divided into at least four removable axial sections, wherein the interior is partitioned into three adjacent substantially cylindrical chambers disposed along the axial dimension, the three adjacent chambers comprising a middle chamber axially bounded by an upper partition plate and a lower partition plate, and radially bounded by an outer wall disposed along the perimeter of the middle chamber and extending between the upper partition plate and lower partition plate, the middle chamber further subdivided into an upper half bounded exteriorly by the second housing shell section and a lower half bounded exteriorly by the third housing shell section, a top auxiliary chamber and a bottom auxiliary chamber, the top and bottom auxiliary chambers disposed axially on opposite sides of the middle chamber, the exterior boundary of each auxiliary chamber coinciding with the first and fourth housing shell sections, the interior boundary of each auxiliary chamber coinciding with the upper and lower plates of the middle chamber;

(b) An interior wall initiating as a bifurcation from said outer wall and extending axially from the upper plate to the lower plate, and radially into the interior of said central chamber by following a spiral trajectory along the radial dimension towards the center portion of said central chamber and terminating by joining itself at a point along its innermost spiral forming an enclosed space within said center portion, whereby a spiral exhaust passage of constant cross section is formed and is radially bound between the successive spiral windings of said interior wall and axially bound by the upper and lower plates, said spiral exhaust passage having a fore-portion and an aft-portion, wherein a peripheral terminus disposed near the outer wall demarks the beginning of the fore-portion and a point between the termini of said spiral exhaust passage demarks the boundary between the fore-portion and the aft-portion, said aft-portion continuing to extend along the spiral exhaust passage to an interior terminus disposed within the center portion of said central chamber, thereby demarking the end of the aft-portion;

(c) an inlet port disposed along the periphery of the shell of the top auxiliary chamber wherein said inlet port extends through the top auxiliary chamber to communicate with said spiral passage via an aperture disposed at the peripheral terminus in the fore-portion of said spiral passage;

(d) an exhaust port disposed along the outer surface of the bottom auxiliary chamber wherein said exhaust port extends through the bottom auxiliary chamber to communicate with said spiral passage via an aperture disposed at the interior terminus of said passage;

(e) A plurality of perforations disposed on said top plate and said bottom plate of the central chamber whereby the central chamber communicates with both auxiliary chambers through the plurality of perforations, said plurality of perforations being substantially confined within contours of the aft-portion of the spiral exhaust passage;

(f) An internal header coinciding with the non-perforated fore-portion of the spiral exhaust passage; and

(g) A packing of sound dampening material enclosed within each of the two auxiliary chambers for attenuation of sound energy carried by exhaust gases entering within, wherein auxiliary chambers communicate with the spiral exhaust passage through the perforations disposed on the upper and lower partition plates of the middle chamber, whereby the exhaust gases do not pass through the sound absorbent material to the atmosphere.

2. The compact muffler of claim **1**, wherein the inlet port is integrally formed with the shell housing of the top auxiliary chamber.

3. The compact muffler of claim **1**, wherein the exhaust port is integrally formed with the shell housing of the bottom auxiliary chamber

4. The compact muffler of claim **1**, wherein the shell housing is made from aluminum alloys, steel alloys or high temperature plastic materials.

5. The compact muffler of claim **1**, wherein the upper and lower partition plates are manufactured from aluminum alloys, steel alloys or high temperature plastic materials.

6. The compact muffler of claim **1**, wherein the interior wall is manufactured from aluminum alloys, steel alloys or high temperature plastic materials.

7. The compact muffler of claim **1**, wherein the sound-dampening packing is non-woven glass fiber mat.

* * * * *