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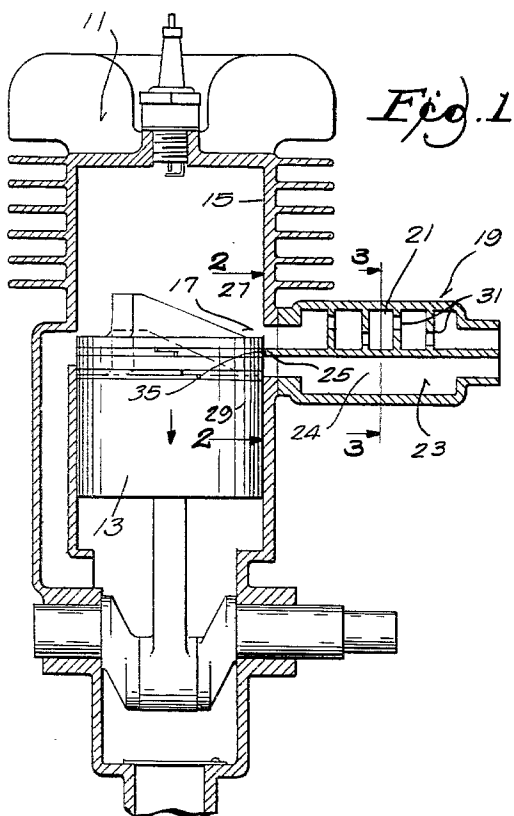


Fig. 1

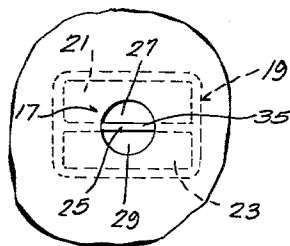


Fig. 2

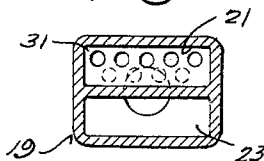


Fig. 3

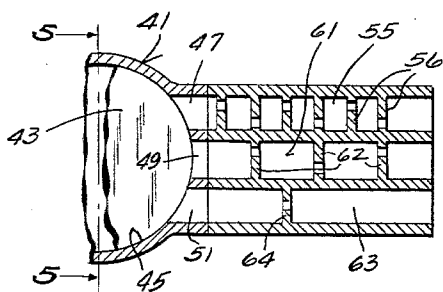


Fig. 4

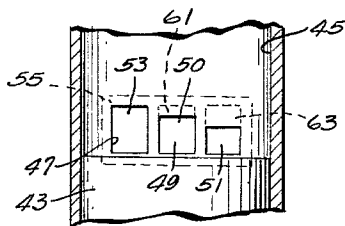


Fig. 5

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The invention relates generally to muffling methods and arrangements for piston ported internal combustion engines, such as engines of the two-stroke, four-stroke, and rotary type.

The invention provides methods and apparatus for obtaining improved muffling of piston ported engines and is based upon the discovery that the undesirable high noise level generally associated with gas flow from a piston ported engine is believed to be primarily due to high pressure gas flow occurring in response to initial opening by the piston of the otherwise closed cylinder. Relatively little noise is believed to be caused by exhaust of the lower pressure exhaust gases after initial release of the high pressure condition in the cylinder. Accordingly, the method provided by the invention comprises the steps of affording flow of the relatively high pressure gases present in the cylinder at the time of initial porting of the cylinder into a relatively efficient muffler and thereafter exhausting the relatively lower pressure exhaust gases either directly to the atmosphere or to a muffler which has a relatively lower noise suppressing efficiency and which affords relatively little restriction of gas flow to the atmosphere.

The invention also provides for the combination with a piston ported engine of a muffler having a portion with a high noise suppressing efficiency, the engine cylinder and the muffler having cooperating means successively affording, in response to piston movement, initial communication between the cylinder and the high noise suppressing efficiency portion of the muffler, and subsequent relatively unrestricted communication between the cylinder and the atmosphere.

In one embodiment, the muffler is provided with a splitter or vane which extends into the exhaust port in the cylinder wall and into close proximity to the path of piston travel. The splitter serves to divide the exhaust port into two portions, one portion which is opened by piston travel before any opening of the other portion, said one portion of the port being in communication with a muffler portion having a high noise suppressing efficiency. The other portion of the exhaust port can be in communication with a muffler portion having a less efficient noise suppressing capacity and affording relatively free gas flow to the atmosphere.

In another embodiment, the piston ported engine includes a series of exhaust ports which are successively opened or ported in response to piston travel. The first port to be opened communicates with a relatively highly efficient muffling device, while the second port to be opened communicates with a less efficient muffling device. If a third port is employed, this port can be in communication with a muffling device which has a lesser muffling efficiency than the muffling device communicating with the second port. Alternatively, the third port can open directly to the atmosphere. The various muffling devices can either be independently constructed and mounted, or can be integrated in a unitary structure and unitarily mounted on the engine.

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Other objects and advantages of the invention will become known by reference to the following description and the accompanying drawings in which—

FIGURE 1 is an elevational view, partially in section, of one embodiment of an engine which includes a muffler and which embodies various of the features of the invention;

FIGURE 2 is a fragmentary elevational view taken generally along lines 2—2 of FIGURE 1;

FIGURE 3 is a sectional view taken generally along lines 3—3 of FIGURE 1;

FIGURE 4 is a fragmentary sectional plan view, taken transversely of the cylinder, of an engine which includes a muffler and which embodies various of the features of the invention; and

FIGURE 5 is a fragmentary view, partially in section, taken generally along lines 5—5 of FIGURE 4.

The engine muffling arrangement shown in FIGURES 1 through 3 comprises a piston ported engine 11 which is of the two-stroke reciprocating type and which has a piston 13 and a cylinder 15 within which the piston is reciprocable from top dead center to bottom dead center. Included in the cylinder 15 is an exhaust port 17 which is opened and closed in response to piston reciprocation. As thus disclosed, the engine 11 is conventionally constructed.

Connected to the cylinder 15 for communication with the exhaust port 17 is a muffler or noise suppressing device 19 including a first portion 21 which is a relatively efficient noise suppressor and a second portion 23 which is a relatively less efficient noise suppressor. Extending into the exhaust port 17 from the muffling device 19 is a splitter or partition 25 which extends into close proximity to the path of piston movement and which cooperates with the exhaust port 17 to provide means dividing the exhaust port 17 into first and second parts or portions 27 and 29, respectively. The first portion 27 is located closer to the head end of the cylinder 15 than the second portion 29 and is therefore substantially opened in response to piston travel from top dead center to bottom dead center before any opening of the second port portion 29.

The splitter 25 is also, at least in part, a part of the interior muffler construction which separates the relatively efficient noise suppressing portion 21 from the less efficient noise suppressing portion 23. In this regard, the muffler 19 is mounted so that the relatively efficient noise suppressing portion 21 is in communication with the first port portion 27 and so that the less efficient noise suppressing portion 23 is in communication with the second port portion 29. Thus, the splitter 25 can also be said to constitute, at least in part, means for affording communication in response to initial opening of the exhaust port 17, between the cylinder 15 and the relatively efficient noise suppressing or silencing portion 21, as well as the avoidance of effective direct communication between the cylinder 15 and the relatively less efficient noise silencing portion 23 during the initial opening of the exhaust port 17.

While a splitter could be provided in the port independently of the muffler, incorporation of the splitter as a part of the muffler advantageously permits substitution of the muffling arrangement herein disclosed for previously existing arrangements without reworking of the engine cylinder or exhaust port. Moreover, forming the splitter as a part of the muffler facilitates dimensional

control and finish of the splitter. In addition, formation of the splitter as a part of the muffler affords variance in the relative sizes of the port portions, in accordance with expected engine operating conditions, simply by substitution of one muffler for another. In general, the size of the port portion 21 as compared to the size of the port portion 23 should be increased with increased engine speed.

The relatively efficient noise suppressing portion 21 of the muffler 19 can be constructed in various well-known ways to provide for highly effective noise silencing. For instance, the muffler portion 21 can comprise a series of slotted or apertured baffles 31 which will eventually accommodate gas flow therethrough but which are highly effective to suppress noise transmission. The portion 21 can also be essentially a closed chamber communicating solely with the port portion 27 except for the provision of means for slowly bleeding pressure from the closed chamber. Such pressure can be bled directly into the atmosphere, into a less efficient noise suppressing device such as the muffler portion 23, around the edge of the splitter 25 adjacent to the path of piston travel, or even back into the cylinder 15 for ultimate exhaust through the port portion 29. The exact details of the construction of the relatively efficient noise suppressing portion are not a part of the invention herein disclosed so long as the construction provides a highly effective noise silencer.

The less efficient noise suppressing portion 23 of the muffler 19 can be a duct or passageway extending directly from the port portion 29 to the atmosphere. If desired, the portion 23 can be a chamber 24 enlarged with respect to the port portion 29, or one or more baffles can be included. The exact details of the construction of the less efficient noise suppressing portion 23 are not a part of the invention disclosed herein so long as the construction affords relatively free, unrestricted gas flow to the atmosphere, thereby minimizing power loss.

It is desirable that the splitter 25 be constructed of material which is relatively thin to avoid power loss. Use of a splitter 25 having a thickness of .040 has been found to provide good results. In order to achieve various of the advantages of the invention, it is believed that the splitter 25 should have a thickness less than $\frac{1}{8}$ of an inch. As already noted, the splitter should desirably extend up to the path of piston travel. However, the inner end or edge 35 of the splitter, i.e., the edge 35 adjacent to the path of piston travel or reciprocation, can be spaced slightly from the path of piston travel and still obtain at least some of the advantages of the invention.

Specifically, such spacing is particularly desirable when using a highly efficient noise suppressing portion in the form of a closed chamber. Satisfactory results have been attained when the inner edge 35 of the splitter 25 was spaced .080 inch from the path of piston travel. It is believed that spacing of the inner edge 35 of the splitter 25 from the path of piston travel beyond $\frac{1}{8}$ of an inch will prevent the splitter 25 from effectively preventing direct communication between the less efficient noise suppressing portion 23 and the cylinder 15 upon initial opening of the exhaust port 17.

In addition, as shown best in FIG. 2, it is desirable that the splitter 25 divide the exhaust port 17 so that the portion 21 is at least as large as the portion 23. The arrangement can also be such that the splitter 25 divides the exhaust port 17 so that the first portion 21 has a length in the direction of piston travel at least as great as the length of the second exhaust port 23 in the direction of piston travel.

In the embodiment shown in FIGURES 4 and 5, there is shown an engine 41 including a piston 43 and a cylinder 45 in which the piston 41 is reciprocable in the well-known manner. Formed in the cylinder wall are a plurality of exhaust ports including ports 47, 49, and 51. The exhaust port 47 includes a portion 53 which is opened

in response to piston travel from top dead center to bottom dead center in advance of the opening of any part of the other ports 49 and 51. The exhaust port 49 includes a portion 50 which is opened in advance of any part of the remaining port 51.

Mounted on the cylinder 45 in communication with a port 47 is a first muffler or device 55 which is a highly efficient noise suppressor. The exact details of the construction of such a noise suppressor are not a part of the invention disclosed here so long as the device 55 is highly effective in suppressing noise. In the drawings, the device 55 is shown as including a series of apertured or slotted baffles 56.

The port 49 is in communication with a noise suppressor 61 which is relatively less efficient than the noise suppressing device 55. The exact details of the construction of the noise suppressing device 61 are not a part of the invention disclosed herein so long as the noise suppressing capability of the device 61 is less than that of the noise suppressing device 55. The device 61 can include, as shown in the drawings, a series of apertured baffles 62 to afford noise silencing. The noise suppressing devices 55 and 61 can be constructed and mounted independently of each other. Preferably, the noise suppressing devices 55 and 61 are integrated in a single unit or device.

The port 51 can open directly to the atmosphere or can be in communication with a muffler or device 63 which is less effective than either of the noise suppressing devices 55 and 61 and which offers relatively little resistance to exhaust gas flow. The exact details of the construction of the device 63 are not a part of the invention disclosed herein so long as exhaust gas can be discharged relatively freely from the cylinder 43. The device 63 can comprise a gas passage having one or more slotted or apertured baffles, as shown at 64 in the drawings. Although the device 63 can be independently mounted on the cylinder 43, preferably the device 63 is integrated with the noise suppressing devices 55 and 61 in a unitary muffler or device.

As used herein, the term "piston ported engine" refers to any internal combustion engine wherein piston movement, or in the case of an engine of the rotary type, vane movement, relative to a port in a cylinder wall serves to open and close the port.

The terms "muffler," "noise silencing device," and "noise suppressing device" are used herein in their normal sense, i.e., in reference to any device which primarily serves the purpose of absorbing or damping noise emissions without attempting to recover energy from the exhaust gas. The terms "muffler," "noise silencing device," and "noise suppressing device" are exclusive of any device which absorbs or damps noise emissions incidental to the employment of exhaust of gas flow to perform work, as in arrangements wherein exhaust gas from a ported engine is fed to a turbine to convert the energy therein to useful work.

As used herein, the terms "relatively efficient" and "relatively inefficient" or "relatively less efficient," when employed with respect to a noise suppressor or noise suppressing or silencing device or portion, are used in their normal sense, and when used in comparison to each other, refer to a pair of muffling devices, one of which is more efficient than the other.

Various of the features of the invention are set forth in the following claims.

What is claimed is:

1. A method of muffling a piston ported engine comprising the steps of affording flow of the relatively high pressure exhaust gases present in the cylinder at the time of initial porting of the cylinder into a first relatively efficient muffling device, affording flow of the intermediate pressure exhaust gases present in the cylinder after the initial porting of the cylinder into a second muffler having a lesser muffling efficiency than the first muffler, and affording relatively unrestricted flow to the atmo-

sphere of the remaining relatively low pressure exhaust gases present in the cylinder subsequent to the time when flow of exhaust gases into the second muffler is afforded.

2. The combination of a muffler including a first portion having a high noise suppressing efficiency and a second portion having a lesser noise suppressing efficiency, a cylinder having an exhaust port, a piston movable in said cylinder, and a partition extending into said exhaust port to divide said port into first and second parts to successively afford, in response to piston movement from the head end of said cylinder, initial communication between said first part of said exhaust port and said first muffler portion, and subsequent communication between said second part of said exhaust port and said second muffler portion.

3. The combination in an engine of a piston, a cylinder in which said piston is movable, said cylinder including an exhaust port which is opened and closed by piston movement, and a muffler mounted on said engine, said muffler having a relatively efficient noise silencing portion, having a relatively less efficient noise silencing portion, and having means extending into said port in proximate relation to the path of piston movement to afford, in response to initial opening of said port, communication between said cylinder and said relatively efficient noise silencing portion and the avoidance of effective direct communication between said cylinder and said relatively efficient noise silencing portion during said initial opening of said port.

4. A combination in accordance with claim 3 wherein said means extending into said port has a thickness adjacent the path of piston travel of less than about one-eighth of an inch.

5. A combination in accordance with claim 3 wherein said means extending into said port terminates adjacent the path of piston movement, along an edge spaced from said path at a distance less than about one-eighth of an inch.

6. The combination in an engine of a piston, a cylinder in which said piston is movable, said cylinder including an exhaust port which is opened and closed by piston movement, and a muffler mounted on said engine, said muffler having a first, relatively efficient noise silencing portion, having a second noise silencing portion offering less resistance to exhaust gas passage than said first silencing portion, and having means extending into said port in proximate relation to the path of piston movement to afford, in response to initial opening of said port, communication between said cylinder substantially solely with said first silencing portion, and to afford, in response to further opening of said port, communication between said cylinder and said second noise silencing portion.

7. The combination in an engine of a piston, a cylinder in which said piston is movable, said cylinder including an exhaust port which is opened and closed by piston movement, and a muffler mounted on said engine, said muffler having a relatively efficient noise silencing portion, and having a splitter extending into said port in proximate relation to the path of piston movement to divide said port into first and second parts, said first part having a portion located more closely to the head end of said cylinder than any portion of said second part, said first part being solely in communication with said highly efficient noise silencing portion and said second part communicating with said atmosphere for relatively free exhaust gas flow thereto, whereby, in response to initial opening of said port by said piston, exhaust gas flow through said first port part between said cylinder and said relatively efficient silencing portion is afforded and exhaust gas flow to the atmosphere through said second port part is avoided.

8. The combination in an engine of a highly efficient muffling device, a less efficient muffling device, a piston,

and a cylinder within which said piston is movable, said cylinder having therein first and second exhaust ports, said first exhaust port having a portion which, in response to piston travel, is opened prior to any opening of said second port, and communicates with said highly efficient muffling device, said second port communicating with said less efficient muffling device, said first exhaust port being at least as large as said second exhaust port.

9. The combination in an engine of a piston, a cylinder within which said piston is movable, said cylinder having therein a plurality of exhaust ports, a highly efficient muffling device, a less efficient muffling device, a first of said exhaust ports having a portion which, in response to piston travel, is opened prior to any opening of the other of said exhaust ports and communicates with said highly efficient muffling device, a second of said exhaust ports having a portion which, in response to piston travel, is opened subsequent to opening of said portion of said first exhaust port and prior to opening of any other exhaust ports, and communicates with said less efficient muffling device, and a third of said exhaust ports communicating with the atmosphere for relatively free exhaust gas flow to the atmosphere.

10. The combination in an engine of a piston, a cylinder within which said piston is movable, said cylinder having therein a plurality of exhaust ports, a first highly efficient muffling device, a second muffling device which is less efficient than said first muffling device, a third device having a lesser muffling efficiency than said second muffling device, a first of said exhaust ports having a portion which, in response to piston travel, is opened prior to any opening of the other of said exhaust ports and communicates with said first highly efficient muffling device, a second of said exhaust ports having a portion which, in response to piston travel, is opened subsequent to opening of said portion of said first exhaust port and prior to opening of any other exhaust ports, and communicates with said second less efficient muffling device, and a third of said exhaust ports communicating with said third device.

11. The combination in an engine of a piston, a cylinder within which said piston is movable, said cylinder having therein first, second, and third exhaust ports opened and closed in response to piston reciprocation, said first exhaust port having a portion which, in response to piston travel, is opened prior to any opening of the other of said exhaust ports, said second exhaust port having a portion which, in response to piston travel, is opened subsequent to opening of said portion of said first exhaust port and prior to any opening of said third exhaust port, and a muffler mounted on said cylinder and including a highly efficient muffling portion in communication with said first exhaust port, a less efficient muffling portion in communication with said second exhaust port, and an additional gas passage communicating with said third exhaust port and affording relatively free gas flow from said cylinder to the atmosphere.

12. The combination in an engine of a piston, a cylinder in which said piston is movable, said cylinder including an exhaust port which is opened and closed by piston movement, a muffler mounted on said engine, said muffler having a relatively efficient noise silencing portion, and a relatively less efficient noise silencing portion, and a partition extending in said port in proximate relation to the path of piston movement and dividing said exhaust port into first and second portions, said first portion being at least as large as said second portion and being opened prior to said second portion in response to piston movement to afford communication between said cylinder and said silencing portions.

13. A combination in accordance with claim 12 wherein said partition is a part of said muffler.

14. The combination in an engine of a highly efficient muffling device, a less efficient muffling device, a piston,

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a cylinder within which said piston is movable, and means on said cylinder and on one of said cylinder and said muffling devices defining first and second exhaust ports, said first exhaust port having a portion which, in response to piston travel, is opened prior to any opening of said second port, and communicates with said highly efficient muffling device, said second port communicating with said less efficient muffling device, said first exhaust port having a length in the direction of piston travel at least as great as the length of said second exhaust port in the direction of piston travel.

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