## **United States Patent**

### Tenney

### [54] MULTIPLE RPM RANGE TUNED EXHAUST PIPE AND SILENCER FOR TWO-CYCLE ENGINE

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  [58] Field of Search ......181/35 R, 33 R, 33 D, 36 R, 181/36 D, 47 A, 64 R, 64 B, 65; 60/312, 314,

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### UNITED STATES PATENTS

1,483,354	2/1924	Kopper	
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### FOREIGN PATENTS OR APPLICATIONS

656,983	1/1929	France
278,857	10/1927	Great Britain181/65

# [15] 3,703,937 [45] Nov. 28, 1972

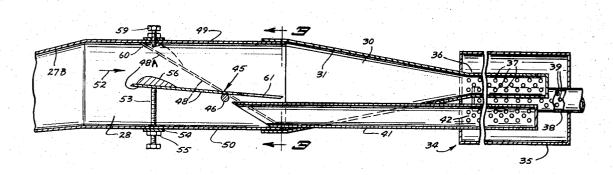
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Primary Examiner—Robert S. Ward, Jr. Attorney—Dugger, Peterson, Johnson & Westman

### [57] ABSTRACT

An expansion chamber exhaust system operative to obtain high power output from two-cycle engines at more than one engine rpm range. The exhaust system includes automatic or manual means to change the effective range of engine rpm at which it is providing power increase. At least one valve member is provided, which is open in a low speed position, to permit substantially unrestricted passage of the exhaust gases and exhaust gas pressure waves past the valve member, and which closes at higher engine rpm to provide a pressure wave reflecting surface so positioned to reflect a positive pressure wave to arrive at the exhaust port of the two-cycle engine just before the port closes, at the desired higher rpm range of the engine. The exhaust systems can be made with a fixed positive wave reflecting surface downstream from the valve member, or they may open directly to atmosphere downstream from the valve member, and they may include a silencing muffler, is desired.

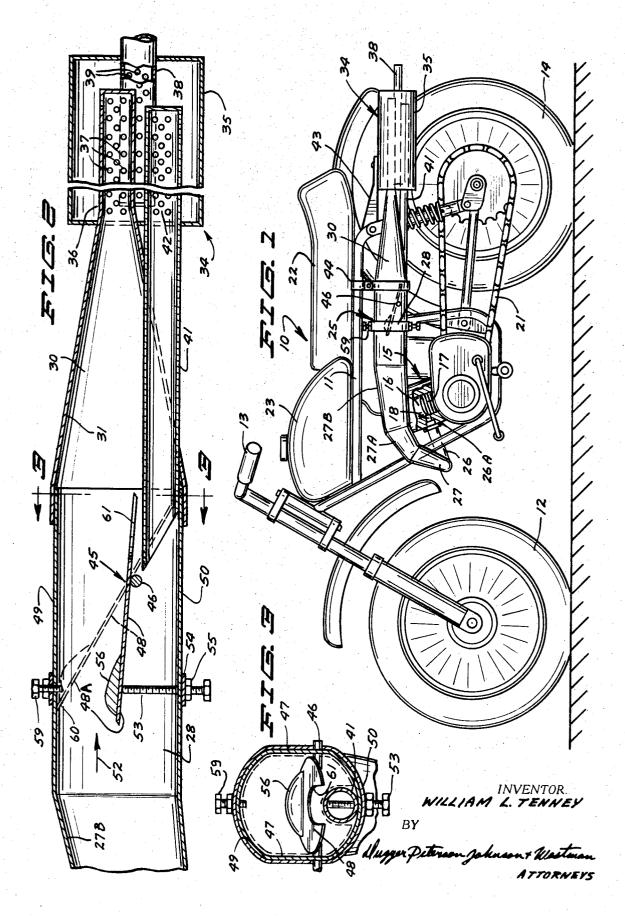
### 34 Claims, 22 Drawing Figures



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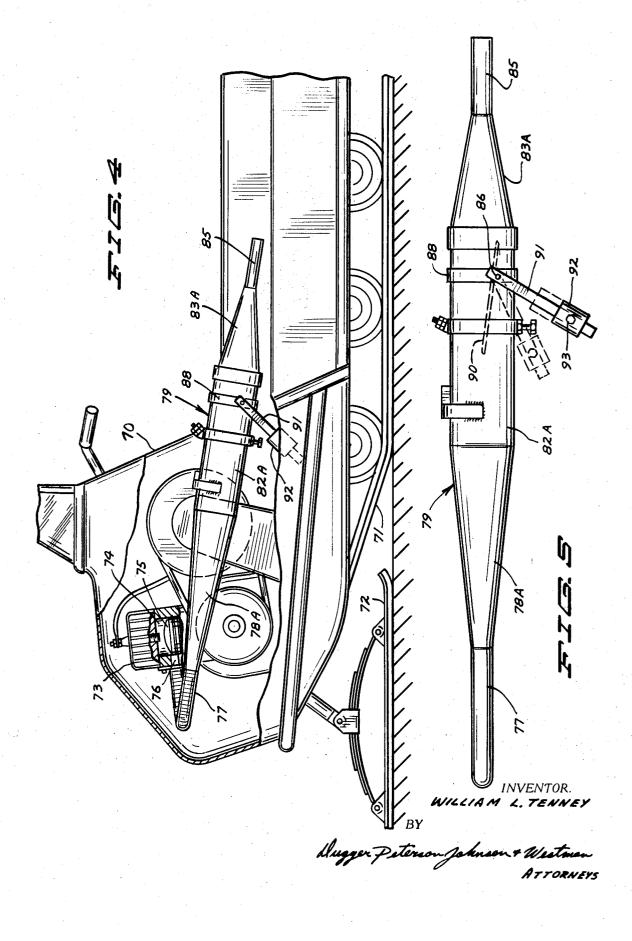
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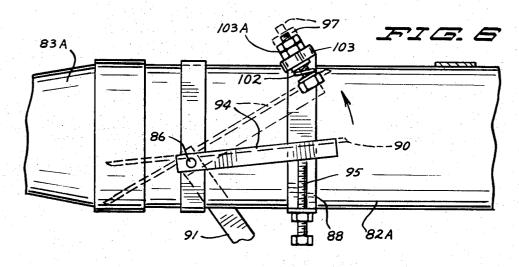
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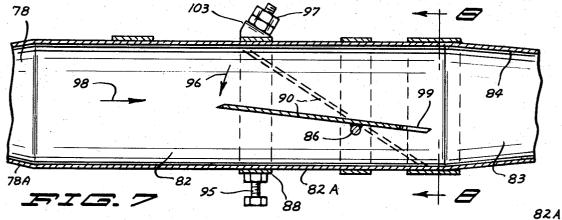
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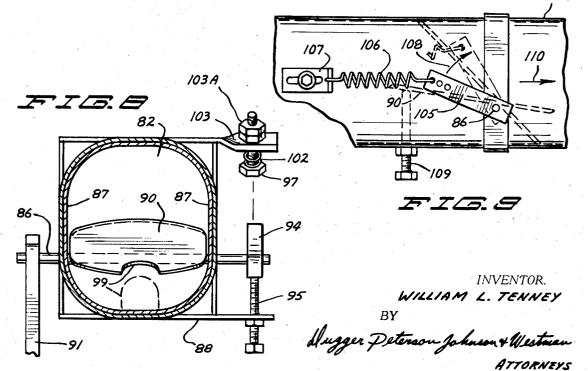


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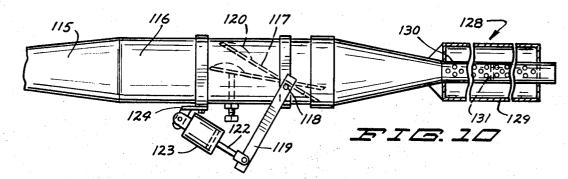


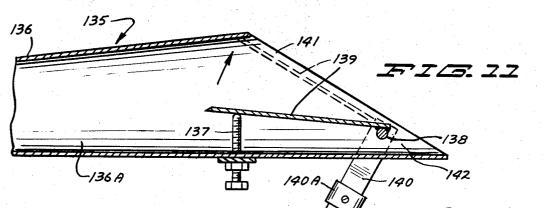


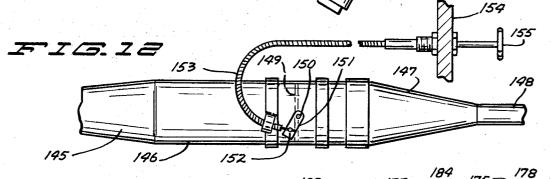


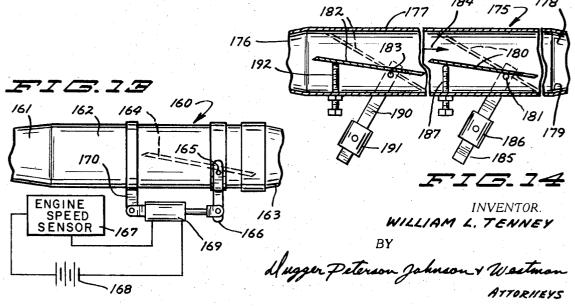
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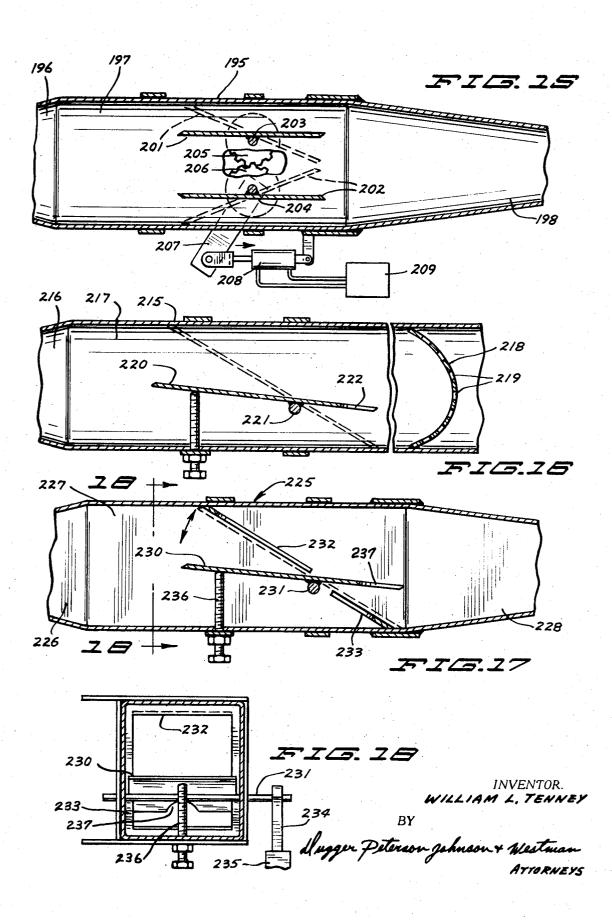






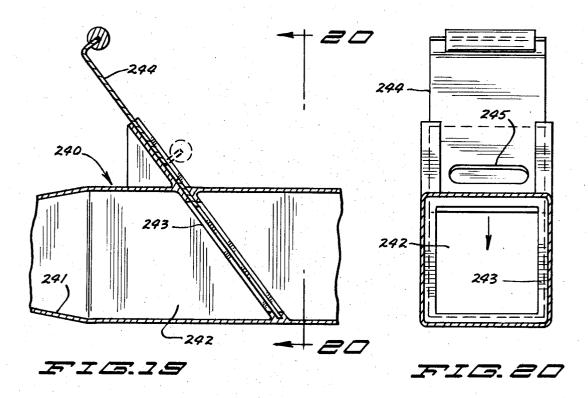
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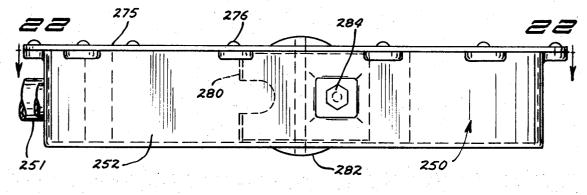


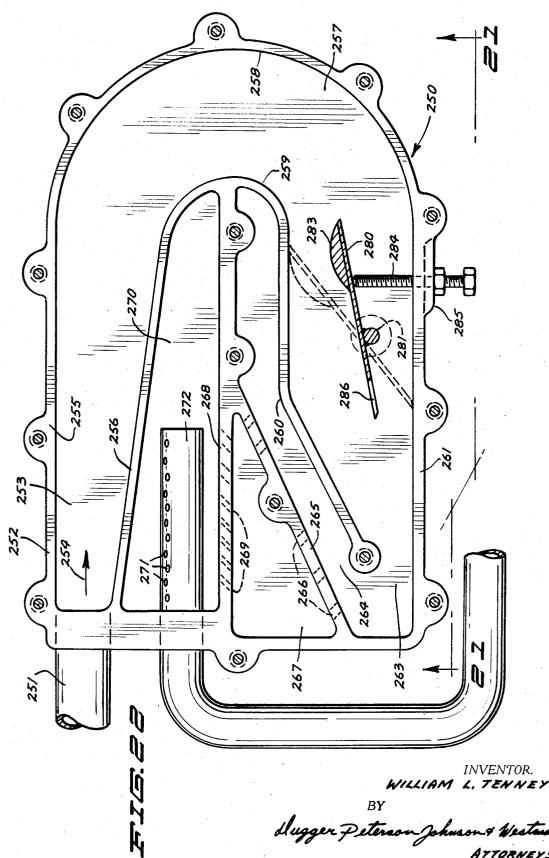
FIG.ZI

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#### MULTIPLE RPM RANGE TUNED EXHAUST PIPE AND SILENCER FOR TWO-CYCLE ENGINE

#### **BACKGROUND OF THE INVENTION**

1. Field of the Invention

The present invention relates to expansion chamber exhaust systems for two-cycle engines.

2. Prior Art

The advantages in the use of expansion chamber exhaust systems with two-cycle engines are well known in <sup>10</sup> the art, including the use of positive wave reflecting surfaces downstream from the expanding section to increase the power output of the engines. It has also been recognized that the useful rpm range of operation of such a resonant exhaust system is relatively narrow. For <sup>15</sup> example, my U.S. Pat. No. 3,367,311 discloses two or more exhaust systems with valve means to direct the exhaust gases from the two-cycle engine to one or the other of the systems in order to provide improved power output at two or more engine speeds or rpm ranges.

Further, it has been recognized that one method of changing the useful rpm range of an expansion chamber exhaust system is that of changing the distance of the positive pressure wave reflecting surface from the engine exhaust port by the "slide trombone" or telescoping pipe method. A type of "slide trombone" or extensible telescoping pipe exhaust is shown in the patent to Kopper, U.S. Pat. No. 3,254,484. It can be understood that complex, expensive and difficult structure is necessary for "tromboning" because of the necessary telescoping members with attendant heat, sliding, sealing and control problems.

Another trombone type exhaust is shown in U.S. Pat. No. 3,434,280 to Burkhardt, but this does not appear intended for other than a "fixed" type of adjustment.

Mufflers which utilize internal valves that open when the gas pressure from the exhaust system exceeds a 40 preselected amount have been used, but not for providing a positive pressure wave reflecting surface in order to increase the power output of two-cycle engines. Prior art valved muffler construction is used for the purpose of relieving the back pressure caused by the 45 muffler during periods of high engine output. This mode of operation is opposite from that desired for power increase in two-cycle engines when exhaust pressure wave charging of the cylinder is utilized. The patent to Kopper, U.S. Pat. No. 1,483,354, illustrates a 50 typical muffler configuration utilizing a flapper valve that opens when the speed of the engine increases. Another device of this type which operates as a foot controlled motorcycle engine "cutout" is shown in Austrian Pat. No. 117,331. Another type of "cutout" is 55 shown in U.S. Pat. No. 3,346,071.

These devices all fail to suggest the desired result of obtaining a multiple operating rpm range power increasing, resonance exhaust system for two-cycle engines via extremely simple mechanical devices which <sup>60</sup> can be readily adapted to automatic operation.

#### SUMMARY OF THE INVENTION

The present invention relates to a power increasing exhaust system for two-cycle engines. The system includes an exhaust expansion section in combination with means which may be operated as desired to pro-

vide a positive pressure wave reflecting surface so located as to increase the power output of the engine at some desired rpm range, but that may also be set to a relatively neutral or non-reflective position which does not interfere with lower speed operation. The device therefore provides for selection of ranges of engine rpm at which the maximum power increasing effect of the expansion chamber exhaust system is available. A single expansion chamber pipe is utilized, but the power increasing effects are similar to those which may be obtained by use of alternate pipes attached to a selector valve. The invention comprises the utilization of a valve member which in a first position is open and does not materially restrict exhaust gas flow and in a second or closed position reflects a positive gas pressure wave to the cylinder exhaust port in order to cause a supercharging effect at the engine cylinder at some desired engine rpm range. The valve member is in its closed or positive pressure wave reflecting position at a higher engine rpm than the rpm when the valve is in its open position. When multiple valves are used in series, the position of the valves located downstream from whichever valve is in use as the positive wave reflector,

In exhaust systems where there is a single fixed positive wave reflecting surface positioned for engine performance improvement over a given rpm range, lower rpm performance of the engine is affected adversely when the positive reflected pressure wave arrives at the cylinder early and the scavenging port is still open. The reflected positive pressure wave then inhibits cylinder scavenging, charging and engine performance by interfering with entrance of the scavenging and charging medium through the scavenging port. A device made according to the present invention does not develop this inhibiting effect at low engine rpm, and in preferred forms it provides a positive reflected pressure wave properly timed for low engine rpm. When the valve means is closed, a reflected positive pressure wave properly timed for higher engine rpm is provided.

The invention also includes the use of more than one valve so that increased power output may be achieved at several different engine rpm ranges. In addition, silencing mufflers can be added to or made part of the exhaust system for cutting down the exhaust noise, or the exhaust pipe can be open ended. In the preferred form, there is provided a fixed reflecting surface downstream from the valve, to provide a reflected positive pressure wave timed for lower engine rpm range operation.

The invention further involves the concept of the use of a biasing member for holding the valve in its open, relatively non-reflecting position, wherein the valve is so designed as to close automatically at such time as the engine speed reaches a desired level.

In the forms of the invention shown, a flapper type valve having a blade rotatable through an arc is utilized. Operation of the valve may be either manual or automatic. For the simplest type of automatic actuation, the valve is biased open with weights or springs and is designed so that exhaust gases flowing over the valve blade tend to cause it to close against the bias force. Weights can be mounted directly on the valve blade or attached to a control lever, and the weights can be adjustably mounted. The adjustable weight per-

mits changing the engine speed at which the valve will close in order to provide the positive pressure wave reflecting surface. The flow of exhaust gases over the valve blade creates a pressure differential which causes the valve to close after the gas flow reaches a given 5 velocity.

The full throttle engine rpm at which the valve closes can also be adjusted by varying the angle of attack of the valve blade to the gas flow, with the valve in the open position. The angle of attack setting may be easily varied by means of an adjusting screw.

The valve is not sealed in the closed position because of the need for providing for the relatively spent exhaust gases to escape without undue back pressure. 15 Thus the blade may be provided with an outlet opening or openings, or merely made with suitable clearance inside the exhaust pipe to allow the gases to escape.

In one form of the invention, the low rpm range fixed reflecting surface comprises a muffler. The surface in- 20 series in the exhaust system. corporates outlets of a type that will tend to interfere with the sound waves and thus provide a silencing effect. A muffler of the ordinary "can" type can be utilized to provide a low engine speed positive wave reflecting surface, for example. Multiple exhaust tube 25 mary and in the following description of preferred emmufflers, multiple chamber mufflers, etc., can also be used

The valve may be manually controlled directly via a hand or foot lever, or indirectly via control cable, pushpull rods or the like. Solenoid or hydraulic or pneu- <sup>30</sup> ing a resonating exhaust system made according to the matic cylinder operation in response to either manual selection or to engine speed sensors, such as a flyball governor, an electronic engine speed sensor, or an intake or exhaust airflow sensor, can be utilized if 35 desired.

A form of the invention shown includes a housing having a curved exhaust chamber with a fixed positive wave reflecting surface, and a muffler portion mounted in the space defined by the curved exhaust chamber. The valve in this form may be automatically or manually actuated as desired.

The valves are acted upon by stop means to properly position the valves in their open position. Stop means may also be provided in the closed position in order to  $_{45}$  opposite side from FIG. 5; prevent jamming in this position, in order to regulate the escape of gases, or for other desired purposes.

In the simplest automatic forms, instead of a weight, a spring may be used for urging the valve member in the exhaust system to the normally open position. The 50 weight or spring may be connected to the valve so that the force on the valve acts through a different lever arm leverage ratio when the valve is in the closed position, to help compensate for exhaust gas pressure against the valve blade which tends to hold it quite tightly once it 55 has closed. In some instances the valve will not open until the engine rpm has dropped considerably lower than the rpm at which it closed, due to exhaust gas pressure on the blade tending to hold it closed, once it 60 has closed. In order to overcome this differential in actuating speed, it is in most instances only necessary to momentarily close or "blip" the engine throttle to get opening of the valve. Springs can also be utilized for overcoming this effect of differential in engine speed 65 between valve operation on the "upshift" during increasing speed and on the "downshift" during decreasing speed. As shown, a small spring force exerted on a

stop member for the valve blade tends to compensate for the exhaust gas pressure buildup on the blade when the blade approaches and reaches its closed position.

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It is thus an object of the present invention to provide an exhaust system for a two-cycle engine utilizing an expansion chamber, plus valve means to provide for a positive pressure wave reflecting surface at desired engine rpm which can be moved to position wherein it does not adversely affect engine operation at lower en-10 gine rpm. It is a further object of the present invention to present different means for actuating such valve means. It is a still further object of the invention to provide high power output per cubic inch of engine displacement across a wide range of engine speeds.

It is another object of the present invention to present resonant exhaust systems that are useful through several different engine speed ranges, and which may thus utilize more than one valve located in

It is a still further object of the present invention to provide such exhaust systems which incorporate muffler elements for sound level reduction.

Other objects are apparent from the foregoing sumbodiments.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevational view of a motorcycle havpresent invention installed thereon;

FIG. 2 is a fragmentary vertical sectional view of the valve portion and a section of the muffler utilized with the device of FIG. 1;

FIG. 3 is a sectional view taken as on line 3-3 in FIG. 2:

FIG. 4 is a fragmentary side elevational view of a snowmobile showing an exhaust system made according to the present invention installed thereon; 40

FIG. 5 is a side elevational view of the exhaust system of FIG. 4:

FIG. 6 is a fragmentary side view of a valve portion of the exhaust system of the invention as viewed from an

FIG. 7 is a vertical sectional view showing the internal details of a valve in the exhaust system of FIG. 5;

FIG. 8 is a sectional view taken as on line 8-8 in FIG. 7;

FIG. 9 is a side elevational view of a modification of the device shown in FIG: 5 utilizing a spring for valve control force:

FIG. 10 is a side elevational view of a further modification of the present invention showing a muffler attachment and a dashpot on a control lever;

FIG. 11 illustrates a modification of the present invention showing the utilization of a dual range valve in a resonant exhaust system with the exhaust chamber ending just downstream from the valve;

FIG. 12 illustrates a modified form of the device showing a manual operation device for the valve utilized with the exhaust system of the present invention;

FIG. 13 illustrates a modification of the present invention showing a solenoid operated valve operated in response to an engine rpm sensor:

FIG. 14 illustrates a further modification of the present invention utilizing two internal valves posi-

tioned in series within the exhaust system made according to the present invention to obtain resonance at three engine rpm ranges;

FIG. 15 illustrates further modification of the present invention showing a pair of valves that cooperate to form a double tapered positive wave reflecting surface at high engine speed;

FIG. 16 illustrates a further modified form of the present invention showing a muffler wall installed at the end of an exhaust chamber and forming a positive wave reflecting surface for low speed engine operation;

FIG. 17 illustrates a further modified form of the present invention showing a rim around the interior of the exhaust chamber for seating the value of the  $_{15}$  present invention;

FIG. 18 is a sectional view taken as on line 18–18 of FIG. 17;

FIG. 19 illustrates a further modified form of the invention showing a sliding valve used for dual range 20 resonance in the exhaust system of the present invention;

FIG. 20 is a sectional view taken as on line 20–20 in FIG. 19;

FIG. 21 is a view of a resonant chamber exhaust-muf- 25 fler combination having the resonant chamber curved into a U shape with the muffler between the legs of the U shaped chamber and taken as on line 21-21 in FIG. 22; and

FIG. 22 is a view from the side of the device of FIG. <sup>30</sup> 21 showing it with the cover removed to show the internal construction thereof.

### DESCRIPTION OF THE PREFERRED EMBODIMENTS

First, in a preferred embodiment shown in FIGS. 1, 2 and 3, the exhaust system of the present invention is installed on a two-cycle engine that is used on a motorcycle illustrated generally at 10. As shown, the motorcy- 40 cle has a frame 11, a front wheel 12 that is the steering wheel operated through handlebars 13, and a rear power driven wheel 14. The motorcycle is powered by a two-cycle engine illustrated at 15, of any desired construction. For example, a single cylinder two-cycle engine is shown having a cylinder 16, a piston 17 mounted for movement vertically in the cylinder, and an exhaust port 18. The engine is shown as being typical of motorcycle type two-cycle engines. The engine can be of the general type shown in my U.S. Pat. No. 3,367,311 or any desired type of two-cycle engine wherein the exhaust port 18 is used for discharging exhaust gases and is opened and closed by actuation of the piston 17 in the cylinder. It can also be of the two-cycle engine type 55 wherein the exhaust port is opened or closed by a valve such as a sleeve valve, rotary valve, or poppet valve. In the engine of illustrated type, transfer ports and transfer passages leading from the crankcase are used for introducing a fresh charge of combustible gases into 60 the cylinder in the usual manner, and it is to be specifically understood that the type of two-cycle engine utilized is not a limitation of the invention, but is merely for illustrative purposes since any of the usual forms of 65 two-cycle engine constructions will benefit by the utilization of the exhaust system of the present invention.

The engine 15 drives through the usual gear shift type transmission controlled by foot and/or handlebar controls on the motorcycle, or an automatic transmission may be used. The chain 21 is used for driving the rear wheel. An operator seat 22 is provided as is the usual fuel tank 23.

The improved exhaust system member is illustrated generally at 25. As shown, the exhaust system has a lead-in exhaust pipe section 26 connected with a flange 10 26A to a mating face on the engine, and open to the exhaust port 18. The exhaust pipe section 26 is bent in a suitable configuration to clear the engine so that the exhaust system can be placed alongside the frame of the motorcycle. The pipe section 26 is joined to a generally expanding cross sectional area exhaust pipe which includes sections 27, 27A and 27B. The pipe as shown, curves to cooperate with the particular configuration of the motorcycle, and expands from the junction with the exhaust pipe 26 in direction away from the exhaust port 18. The pipe comprising sections 27, 27A and 27B of generally expanding cross section aids in reflection of a suitable suction or negative pressure wave to arrive at the exhaust port at a suitable time to aid in exhausting the spent charge from the cylinder and drawing in the fresh charge, as is well known. The cross section of the chamber formed by pipe sections 27, 27A and 27B increases in area until it reaches a constant cross sectional area tubular pipe forming a chamber 28 which is downstream from the expanding pipe. The chamber 28 may be made of other than constant cross sectional area, if desired, as is well known in the art. It is also well known in the art that the pipe 26 need not be of strictly constant cross sectional area.

35 At the downstream end of the uniform cross sectional area chamber 28, there is, as shown, first a reducing cross sectional area pipe forming a chamber 30 which has an interior surface 31 that forms a positive pressure wave reflecting surface for the exhaust, in order to, at a particular engine speed or rpm range, provide for a positive reflected exhaust pressure wave arriving at the exhaust port 18 just prior to the closing of the exhaust port by the piston 17 (substantially in the position shown in FIG. 1) to in effect prevent escape of 45 fresh charge gases that have entered the cylinder 16 through the transfer ports and also force back into the cylinder fresh charge gases that may have passed from the cylinder into the exhaust pipe. The power output of 50 the engine is markedly increased thereby and at the same time the specific fuel consumption is decreased.

The overall length of the exhaust pipe from the exhaust port 18 to the reflecting surface 31, including the exhaust pipe section 26, the pipe sections of expanding cross sectional area 27, 27A and 27B, and the constant cross sectional pipe forming chamber 28 determines the engine speed range at which the positive pressure wave will be reflected back to the exhaust port. This is designed to occur at an advantageous time, so as to increase engine power output as described above, and is herein referred to as the "resonant speed" of the exhaust system 25. With the long pipe shown, the surface 31 will cause properly timed positive pressure wave reflection at a relatively low engine speed. The expanding pipe sections 27, 27A and 27B are also of major importance in such resonant exhaust systems, as is well known in the art.

If the positive pressure wave reflecting surface 31 is positioned so as to provide for arrival of the positive pressure reflected wave at the exhaust port at the proper time for a given engine rpm range, then it will work to the detriment of engine operation at a lower engine rpm range. At such lower engine rpm range the reflected positive pressure wave arrives too early, while the scavenging or transfer ports are too far open, and interferes with the transfer of fresh charge gases into the cylinder. The present invention eliminates this problem.

As is well known in the art the positive pressure wave which is first reflected back to the exhaust port as a negative pressure wave due to passing through the ex-15 panding cross sectional area pipe section, and is then reflected back to the exhaust port as a positive pressure wave due to passing through the reducing cross sectional area pipe section, is generated at the outset by rapid opening of the exhaust port and consequent ex- 20 vides a positive pressure wave reflecting surface plosive release of high pressure exhaust gases from the engine cylinder into the exhaust pipe.

If desired, a silencing muffler 34 can be mounted at the outlet of the exhaust system 25. As shown, this is of a conventional type having an outer casing 35, that is 25 performance is obtained. sealed onto a pipe 36 leading from the reducing cross section chamber 30, and which pipe has a plurality of apertures 37 in the side wall thereof. The end of the pipe 36 is closed off, so that the gases coming from the reducing cross section chamber 30 have to pass 30 through the apertures and thus reduce exhaust noise. An outlet pipe 38 is also sealed with respect to an end wall of the outer casing 35, and has a closed inner end. This pipe 38 has inlet apertures 39 to further attenuate the sound waves so that the sound level is reduced substantially. The silencing muffler is an optional feature, and a straight outlet pipe 36 with an open end can be used. An open pipe does reduce the weight, size and cost of the exhaust assembly and thus where noise is  $_{40}$ not objectionable, the muffler can be omitted.

It also can be seen that a second pipe 41 leads from the constant cross section chamber 28 through the side wall of the reducing cross section chamber 30, and is sealed with respect thereto. Pipe 41 also is sealed with 45 respect to the end wall of the casing 35 of the muffler section, and has a blocked off end with apertures 42 inside the muffler for noise reduction.

A suitable strap or bracket 43 can be used between the muffler casing 35 and the frame 11 of the motorcy- 50 ment 54 and is restrained from turning by a lock nut 55. cle for supporting the unit and also, support bracket 44 can be used along the exhaust system.

Whereas the muffler 34 is shown as a dual muffler which serves both outlet pipe 36 and outlet pipe 41, it is of course understood that a separate muffler of usual 55 configuration may be utilized for each of these two outlet pipes.

It is well known that the engine rpm range across which such resonating exhaust systems or pipes are favorably operative, is relatively narrow. Particularly, <sup>60</sup> for maximum power output, a positive pressure wave reflecting surface which is effective at the top rpm range of the engine is desired. If the exhaust system is thus "tuned" for high speed output, the positive wave reflecting surface is closer to the exhaust port than is desirable for lower speed operation. This results because at higher speeds a shorter effective distance

between the positive wave reflecting surface and the exhaust port is necessary in order to provide for the positive pressure reflected wave to arrive at the exhaust port 18 at the proper time.

In the present invention, as stated previously, the overall length of the exhaust system 25 is such that the positive pressure wave reflecting surface 31 is positioned from the exhaust port 18 a sufficient distance so that the arrival of the positive pressure wave at the ex-10 haust port will be properly timed for lower or medium engine rpm range operation. This will not be satisfactory for high engine output at high engine rpm operation, since the reflected positive pressure wave will then arrive too late to be effective, after the exhaust port has been closed by piston 17.

In order to provide improved engine performance at a high engine rpm range, a movable valve member is placed in the chamber 28. When closed, the valve proproperly positioned for high engine speed operation, and when moved to open position it does not reduce engine performance during lower speed operation. This effectively broadens the rpm range where peak engine

In the embodiment shown in FIGS. 1-3, this is accomplished by mounting a valve assembly 45 in the interior of the pipe section forming chamber 28. As shown, the assembly includes a cross shaft 46 pivotally mounted in the side walls 47, 47 forming the chamber 28 and a valve blade member 48 which is fixed to the shaft 46 and movable therewith about the axis thereof. As shown, the cross section of the chamber 28 is defined by parallel side walls 47 and rounded top and bottom walls 49 and 50. The shape of valve blade 48 is matched to the configuration of the chamber 28, and the blade has side edges that fit between and adjacent the side walls 47, and ends that are curved and beveled to fit up against the top and bottom walls 49 and 50, respectively. The blade member is not centered on shaft 46, but has a longer portion extending upstream from the shaft than that extending downstream, when referenced in the direction of normal exhaust gas flow.

In solid line position, valve blade 48 rests in its open position against a stop screw 53 whereby it is not substantially inhibiting gas flow through the chamber 28 in direction as indicated by the arrow 52. Stop screw 53, as shown is threadably mounted through a reinforce-The stop screw prevents the upstream end of valve blade 48 from dropping downwardly past a position wherein the blade is at the desired angle of attack with respect to the normal exhaust gas flow which is approximately parallel to the longitudinal axis of the chamber 28. A weight member 56 is attached to the leading end portion of the valve blade 48, and this weight 56 is oriented so that it will urge the blade 48 to its open position under the force of gravity. As shown, the weight 56 is made with an approximately streamlined or airfoil shaped cross section having a rounded forward end, and a tapered rearward upper surface so that as gas flows past the weight 56 in direction as indicated by the arrow 52 there will be a lifting action created on the weight and on the entire valve blade because of its angle of attack to the exhaust gas flow. The weight is selected as to size and mass such that when the gas flow

over the valve blade reaches a certain velocity, the leading end of the blade 48 lifts upwardly due to the aerodynamic forces acting on it and the valve will shift to its dotted line position shown in FIG. 2, wherein the bottom surface of the blade, indicated at 48A, will 5 present a pressure wave reflecting surface to exhaust gas pressure waves impinging on this surface. The upstream portion of chamber 28 surrounding the valve blade of course also acts in cooperation with the blade 10 as a wave reflecting surface. The blade 48 when in closed position thus cooperates with the walls of chamber 28 to provide a reducing cross sectional area outlet for the exhaust system at this location. The reducing outlet commences along the leading edge of 15 the valve blade in its dotted line position as indicated by the numeral 60. An adjustable stop screw 59 may be used to stop the blade 48 in its closed position. The screw 59 is threadably adjusted so the weight 56 on the blade 48 strikes the end of the screw when the blade 20 reaches the desired position. This prevents jamming of the blade in the closed position.

Because the valve blade 48 fits quite closely along the inner surface of the upper wall 49, and along the walls 47, 47 it is necessary that an outlet be provided 25 for the exhaust gases. The pipe 41 extends forwardly into the chamber 28 so that when the valve blade 48 is in its dotted line position (high speed positive pressure wave reflecting position) the forward end of the pipe 41 extends just past the lower portion of the blade 48. 30 Blade 48 is provided with a generally U-shaped recess 61 that fits over the sides of the pipe 41 so that the exhaust gases will be permitted to escape into the inlet end of the pipe 41, out through the apertures 42 and into the muffler 34. If a muffler is not used the pipe 41 35 located in the interior of the constant cross sectional can be open ended and discharge the exhaust gases directly into the atmosphere.

As shown, the effective moment arm of control weight 56 about the axis of shaft 46 decreases slightly -40 as the valve blade 48 moves to its closed position. When the exhaust gas velocity is reduced to a point where the weight exerted moment overcomes the gas forces holding the valve closed, the forward end of blade 48 will drop down to its solid line position against 45 the stop 53. The surface 31 will again be effective as the positive wave reflecting surface at the lower engine rpm range corresponding to the lower gas velocity.

The unit is simple, neat, low in cost and reliable. The weight 56 is attached directly to the valve blade 48, and 50 the only external parts are the adjustable stops 53 and 59, and the ends of shaft 46 which may be covered or sealed off, if desired. Automatic operation is achieved for a two speed range resonant pipe, in a simple, low 55 cost, neat and reliable manner.

A modified form of the invention is shown in FIGS. 4-8. Here, the exhaust system is installed on a snowmobile 70 that has a drive track 71 and skis 72 in the usual form. The snowmobile, as shown, is powered with a 60 two-cycle engine 73. The engine has a cylinder 74, a piston 75 that moves up and down in the cylinder in the usual manner, and an exhaust port 76. The exhaust port 76 is again valved by the piston, and opens to an exhaust pipe section 77. It will be understood that an ex-65 haust port valved by other means can also be utilized. The exhaust pipe section 77 leads into an expanding cross sectional area pipe 78A forming an expanding

chamber 78 of the exhaust system 79. The expanding cross sectional area chamber 78 leads into a tubular pipe section 82A forming a substantially constant cross sectional area chamber 82. Again, it will be understood that chamber 82 may be made somewhat varying in cross sectional area without departing from the teachings of the invention. The constant cross sectional area chamber 82 extends into a reducing cross sectional area tubular pipe 83A section forming a chamber 83 of the exhaust system. This reducing cross sectional area chamber has an interior surface 84 forming a positive wave reflecting surface (see FIG. 7). The outer end of the reducing cross section chamber 83 may terminate in pipe 85 with no further sound suppression, or, if desired, a suitable muffler can be attached to or made integral with the pipe 85 in order to reduce the noise level of the machine. A suitable muffler can also take the place of pipe 85, or pipe 85 can be omitted completely.

In order to provide for favorable resonance of the exhaust system at two different speeds, it is provided with a valve blade which operates in much the same way as the blade 48 shown in connection with FIGS. 1-3. Referring to FIGS. 7 and 8, it can be seen that a cross shaft 86 is rotatably mounted through spaced apart side walls 87 of the constant cross sectional area chamber 82 and also the shaft extends into a framework 88 formed around the pipe. The shaft and valve can also be placed in the expanding cross sectional area chamber or reducing cross sectional area chamber, if desired, in accordance with the demands of the particular exhaust system design.

A valve blade 90 is fixed to the shaft 86 and is area chamber 82. The shaft 86, as shown, extends through the walls of chamber 82 on both sides thereof. and a lever 91 is fixedly attached to one outer end of the shaft on one side. A weight 92 is slidably mounted on the lever 91 and a set screw 93 is used for adjustably fixing the weight in position along the lever to change the moment arm of the weight. It should be noted that the lever 91 is positioned so that the weight will normally act to hold the valve blade 90 in open position.

The blade 90 is shaped to fit closely within the periphery of the chamber 82, and there is a longer section of the blade extending forwardly from the shaft 86 with respect to the direction of exhaust gas flow, than extends rearwardly. The opposite end of the shaft 86 from lever 91 has a stop lever 94 attached thereto, and the stop lever 94 is positioned to align with a first stop screw 95 threaded into the frame 88 which engages the lever 94 to prevent the blade 90 from rotating in counterclockwise direction (as indicated by the arrow 96) beyond its solid line position shown in FIG. 7. A spring loaded stop 97 is provided to engage the lever 94 and to prevent the ends of blade 90 from jamming against the walls of the chamber 82, when the blade is in closed position.

The position and mass of the weight 92 on the lever 91 in relation to the angle of attack of the blade will be selected so that when the engine speed has reached the desired level, the exhaust gas velocity in direction as indicated by the arrow 98 will be sufficiently great to create an unbalanced force on the forward portion of the blade which will rotate the blade to its closed position.

The valve blade 90 has a U-shaped opening 99 at the lower portion thereof to permit exhaust gases to escape from the exhaust system out through the tailpipe 85 when the blade 90 is in closed position. When the blade 90 is in its closed position, the forwardly downwardly facing surface of the blade cooperates with the surrounding portions of chamber 82 to form a positive pressure wave reflecting surface effective to reflect a pressure wave back to the exhaust port 76 just before engine. Thus the positive pressure wave reflecting surface is moved from interior surface 84 closer to the exhaust port automatically when the speed of the engine increases and causes the exhaust gas velocity in the closed position.

When the blade 90 is in its closed position, the weight 92 acts through a greater effective leverage ratio than in its open position. This can be seen by referring to FIG. 5, wherein the dotted line position of 20 the valve control lever 91 is shown. The effective moment arm about the shaft 86 increases. Even with weight 92 thus exerting additional valve opening force through increased leverage, the exhaust gas pressure tending to hold the blade 90 in its closed position may make the engine speed at which the blade returns to its open position lower than that at which is shifts from open to closed. This means that there may be a speed range on deceleration where full power is not being developed because the valve would be closed, provid- 30 ing a positive wave reflecting surface that causes the reflected pressure wave to arrive at the exhaust port 76 too soon. In order to overcome this tendency, a small spring load acting in a direction tending to open blade 90 when it is in its closed position, may be provided so that there is a force tending to counteract whatever excess gas pressure forces may be holding the blade closed against its seat on the walls of chamber 82. For example, a small spring 102 can be positioned between the head of stop 97 and a bracket 103 fixed to the exhaust pipe. The stop 97 is slidably mounted in the bracket 103 and lock nuts 103A mounted on the stop 97 will determine the position where the head of the stop contacts lever 94. When the blade 90 moves to its 45 closed position, the lever 94 contacts stop 97 and compresses the spring 102 upwardly. This spring load then will tend to urge the blade 90 toward open position to resist the excess exhaust gas pressure forces and help make the shifting of the blade at both increasing speed 50 and decreasing speed occur at substantially the same engine rpm range. This can be of assistance in an instance such as hill climbing on a motorcycle because there may come a time when the engine is decreasing in rpm even though the throttle is held wide open, and if 55 the shifting of the blade 90 does not take place, the positive reflected exhaust pressure wave will arrive at the exhaust port too early, with resultant loss of engine output torque. If the shifting of the blade 90 takes place at the proper time, the beneficial torque increasing ef-60 fects of the positive reflected pressure wave will be available at the desired lower engine range.

The use of the stop 97 also can aid by preventing the blade from closing too tightly and tending to stick or jam against the walls of chamber 82. Additionally, the 65 blade edges may be beveled as illustrated so that these edge surfaces mate with the interior surfaces of chamber 82 when the valve is in the closed position.

In FIG. 9, a modification of the control of the device shown in FIGS. 4-8 is illustrated. Here, the shaft 86 has blade 90 mounted thereon, and in place of using the weight for control force, a lever 105 is mounted onto the shaft 86, and a spring 106 is attached to the outer 5 end of the lever and is attached to a clip 107 that is attached to the outer wall of the exhaust pipe. A series of adjustment holes may be provided in the lever to permit changing the spring force, or the spring force may the port closes, during high rpm range operation of the 10 otherwise be rendered adjustable in a desired manner such as by movement of clip 107. In this modification, when blade 90 is moved to its closed position, it will move in direction as indicated by the arrow 108, and will stretch the spring 106. It should also be noted here chamber 82 to increase and thus flip the blade 90 to its 15 that the effective lever arm ratio of the lever 105 will increase as the blade 90 moves to its closed position so that the spring force from spring 106 will exert greater leverage, and this will aid in getting proper opening of the valve as the speed of the engine decreases. Additionally the spring itself will exert more force as it is stretched further, in accordance with the known physical laws governing spring rates. Another feature of this modification using the spring as shown is that the control force is less subject to disturbance due to inertial 25 effects during acceleration or deceleration, bouncing, etc.

> This exhaust system is attached to an engine as previously explained, and likewise has an expansion section in the exhaust system ahead of the valve. The expansion section increases in cross sectional area in downstream direction of the exhaust gas flow.

An adjustable stop screw 109 is also provided which is similar to and performs the same function as the adjustable stop screw 95, in FIG. 6. Automatic operation 35 is achieved by selecting the angle of attack of the blade 90 (by means of adjustable stop screw 109) with respect to the direction of exhaust gas flow which is indicated by arrow 110, so that the valve will be moved to its closed position when the velocity of the gases in-40 creases a sufficient amount to lift the upstream portion of the blade.

FIG. 10 shows a further modified form of the present invention. The exhaust system includes a pipe section forming an expansion section 115 which increases in cross sectional area in downstream direction with respect to the exhaust gas flow. The expansion section is open at one end to the exhaust port of an engine, and corresponds to the expansion section 78 in FIG. 7. The exhaust system also has a tubular pipe section 116 in which a valve blade member is pivotally mounted for movement between an open position and a closed position as shown in dotted lines. A pivot shaft 118 is used for mounting the valve blade member 117. A lever 119 is attached to the shaft 118 and as can be seen in dotted lines, a weight 120 is used to urge the blade 117 to its open position. The lever 119 is attached to an output shaft 122 of a dashpot 123 of conventional design. The base of the dashpot is pivotally attached to a bracket 124 mounted on the exhaust pipe. The dashpot dampens any tendency toward fluttering of the valve during transient periods or fluttering caused by inertia forces, and smooths the actuation in both the closing and opening directions. This modification can be used in any of the forms of the invention merely by extending the pivoting valve shaft and adding a lever and dashpot. In the case shown in FIGS. 4-8, the dashpot may be attached to the lever on which the weight is mounted.

Also shown in FIG. 10 is an exemplification of a muffler 128 that can be fabricated as part of the single outlet pipe 85 shown in FIG. 4. An outer casing 129 is sealed onto an outlet pipe 130 leading out of the exhaust system. The pipe 130 is blocked by a transverse 5 wall 131. The pipe 130 is provided with apertures in its side wall inside the casing 129. The transverse wall 131 inside pipe 130 divides the pipe into two sections so the exhaust gases must pass through the apertures in the side wall of pipe 130, into the interior of casing 129, and back through the apertures of the downstream section of pipe 130 before being exhausted to the atmosphere through the open outer end of the pipe outside the casing 129. This causes a desirable reduction in 15 the exhaust sound level. It is understood that the muffler 128 may be of other known design and construction. If desired, the muffler could be designed to open directly to the valve chamber of the exhaust pipe, and the muffler itself would then provide surfaces for obtaining a positive pressure reflected wave at low engine speeds.

FIG. 11 shows a modification of the present invention wherein there is no positive pressure wave reflecting wall surface for lower engine speeds, but a valve is provided for positive pressure wave reflection at high speeds where peak power is required. Such an arrangement is very noisy when operating in the low engine rpm range, with the valve in open position, since it then acts substantially as a megaphone type exhaust. A wide, 30 useful low rpm power band is provided with this arrangement and it has the advantage, especially for racing use where the noise is not objectionable, of being more compact, shorter and lighter than the previously described and illustrated embodiments.

As shown, the exhaust pipe member 135 has a tapering expansion section 136 leading from the exhaust port of an engine, for example, in the same manner as the expansion section 78. The chamber 136A expands all the way to the valve in the illustrated form. A shaft 40 138 is rotatably mounted in the walls of the section 136, and a blade 139 is mounted on the shaft. A control lever 140 corresponding to control lever 91 and having a weight 140A is mounted on the outer end of the shaft 138. The weight 140A holds the blade 139 in its open 45 position as shown against an adjustable stop screw 137. The blade 139 is fastened at its lower edge to the shaft 138, and is spaced upwardly from the bottom of the chamber 136A to permit exhaust gases to escape through an opening 142 when the valve is closed.

In this instance, the exhaust pipe 135 is trimmed off along a plane 141 that is parallel to the plane of the valve blade 139 when the blade is in its dotted line or closed position. There is no positive pressure wave reflecting surface provided for low speed operation, and there is no silencing muffler. The exhaust system merely opens into the atmosphere along this plane when the blade 139 is open. As the speed of the engine increases, the blade 139 will be lifted to its closed position because of the angle of attack of the blade and a 60positive pressure wave reflecting surface is formed by the undersurface of the blade 139 in cooperation with the surrounding chamber walls, for high speed operation. The exhaust system will be selected in length so that the reflected positive pressure wave will arrive at the exhaust port at the correct time for high speed operation.

The cross section of exhaust chamber 136A surrounding the blade may be square or rectangular, or of any other cross sectional shape which permits the valve blade to move freely from the open to the closed position and vice versa.

In the device of FIG. 11, one of the important features is the fact that the blade opens and moves out of the way of the exhaust gases so that it does not detract from the normal engine power at lower speeds. The expanding chamber is still present in the exhaust system to provide improved scavenging and with the high speed positive pressure wave reflecting surface out of the way, the engine operation will not be adversely affected at these low speeds.

FIG. 12 shows a further modified form of the present invention wherein the exhaust system has a tubular pipe section forming an expanding chamber 145, another portion forming a chamber 146 which may be 20 of constant or varying cross sectional area, and a trailing tubular pipe section forming a positive pressure wave reflecting surface chamber 147 that has an outlet pipe 148. The outlet pipe may be omitted and the exhaust gases may escape simply through an orifice or 25 orifices, if desired. In this embodiment the chamber surrounding the valve blade may be circular in cross section, if desired.

In FIG. 12 a valve blade 149 is mounted on a shaft 150 that is rotatably mounted in the pipe, but in this instance the valve blade can be centered on the shaft and the axis of the shaft can intersect the longitudinal axis of the pipe chamber. The shaft 150 has a control lever 151 attached thereto on an outer end thereof. A pushpull control wire 152 is attached to the outer end of the 35 lever 151, and the control wire slides inside a housing 153. The housing 153 may be attached to a panel or similar mounting 154 for example on the snowmobile shown at 70 in FIG. 4, and the control button 155 attached to the control wire 152 is used for actuating the blade 149 when desired. Manual valve actuation is thus provided for. When the control knob is pulled outwardly, away from panel 154, the blade is moved to high speed operating position. By being able to recognize the speed of the engine, the operator can obtain satisfactory dual range resonance. The positive wave reflecting surface formed by the reducing cross sectional area chamber 147 is effective at low speeds, and the surface of the blade 149 provides the positive pres-50 sure wave reflecting surface for higher speeds. The blade 149 of course will have an opening therethrough for escape of exhaust gases as previously shown or may have openings of other suitable design.

Referring now to FIG. 13, a further modified auto-55 matic control system is shown. In this instance, a valve is shown mounted in an exhaust system 160 which corresponds to the exhaust system 79 in FIG. 4. The exhaust system has an expanding cross sectional area chamber 161, a valve chamber 162, and if desired has a reducing cross sectional area chamber 163. Of course, the control means shown and about to be described can be used with any of the previous forms of the invention, even that shown in FIG. 11, and can be used in place of the manual control means in FIG. 12. In FIG. 13. a blade 164 corresponding to the blade 90 in FIG. 7 is mounted onto a shaft 165 that is rotatably mounted in the valve chamber 162 and a control lever 166 is

mounted on the outer end of the shaft. The cross sectional shape of the valve chamber 162 can be made of desired contour which will cooperate with the shape of blade 164.

The blade 164 is automatically controlled in 5 response to engine speed, but in this embodiment a separate engine speed sensor 167 actuates a switch (not shown) for controlling a circuit from a battery 168 to a solenoid 169. The solenoid is attached to the lever 10 166 and to a bracket 170 that is attached to the exhaust system. The solenoid 169 can be of any desired form and is shown merely schematically in the present device.

The engine speed sensor 167, likewise, is shown 15 schematically because many different types of engine speed sensors can be utilized interchangeably. There are solid state electronic engine speed sensors presently available which are extremely accurate; fly ball devices can be utilized; inlet gas flow sensors to determine the 20 mass rate flow of inlet gas can be used, and different types of engine speed sensors that operate from the exhaust gases can also be utilized. For example, in my U.S. Pat. No. 3,367,311 there is a showing of several different types of engine speed sensors that could be 25 tion at a higher rpm range than the reflecting surface utilized with this present invention as well.

As explained above, the engine speed sensor 167 in turn controls suitable contacts to control the circuit to solenoid 169 when the proper engine speed has been reached for shifting the blade 164 to its closed position 30 and thus introducing a high speed positive pressure wave reflective surface. The solenoid 169 may be power actuated to either open or close the valve at the proper engine rpm. The solenoid may be spring loaded 35 to the open or closed valve position if desired, and then for high or low speed operation, when the correct engine rpm has been reached, the solenoid only has to be relaxed. The valve can also be spring loaded by an "over center" type spring and lever arrangement, whereby the valve is retained in both its open and closed positions by spring pressure.

The solenoid can be replaced with a fluid pressure cylinder actuated from a source of fluid pressure through a valve controlled by speed sensor 167, if 45 dotted lines, then it provides a positive wave reflecting desired.

Referring now to FIG. 14, a modified form of the invention which will provide for at least three resonant engine speeds is shown. In this form of the invention, an exhaust system 175 includes an expanding cross sec- 50 blade 182 is properly timed is higher than the proper tional area pipe forming a chamber 176 leading from an engine exhaust port into a valve chamber 177. The cross sectional shape of the chamber 177 can be of any desired configuration, but for purposes of explanation may be assumed to be the same as that shown in FIG. 8. 55 It can, as in any of the previous forms, be rectangular, square, elliptical or of any other desired cross section. which will cooperate properly with the particular shape of the blade utilized.

In this exhaust system, a reducing cross sectional <sup>60</sup> area chamber 178 is shown and forms a positive pressure wave reflecting surface 179 suitable for low engine speed operation.

The device shown in FIG. 14 is made for operation as 65 a tuned pipe at three separate engine speeds or ranges of speeds. There are, as shown, two blades, 180 and 182. Blade 180 is mounted on a shaft 181 that is

rotatably mounted between the side walls of the valve chamber 177, and blade 182 is mounted onto a shaft 183 also extending between the side walls of the chamber 177. The blade 180 is positioned for power increase at medium speeds, and is the blade that is farthest downstream with respect to the direction of gas flow, which is indicated by the arrow 184. Shaft 181 has a lever 185 attached thereto, with a weight 186 mounted thereon and operating as the lever 91 and weight 92 of FIG. 5. The weight 186 will retain the blade 180 in its open (solid line) position under slow speed conditions. As shown, the weight 186 is also adjustable along the lever 185. The blade 180 will be stopped in open position with a suitable adjustable stop screw 187, and when the velocity of the exhaust gas reaches a preselected level, the leading portion of blade 180 will be lifted up by gas flow action because of its angle of attack with respect to the gas stream, and moved to its closed position shown in dotted lines. The lower surface of valve blade 180 will then form a positive pressure wave reflecting surface in cooperation with the surrounding walls of valve chamber 177, and will be properly positioned for improving engine opera-179. The valve blade 180 of course will have an outlet opening provided therethrough, or at least will have a loose enough fit inside the exhaust pipe chamber 177 so that a sufficient flow of the exhaust gases can escape past the blade 180.

The shaft 183 for the blade 182 has a lever 190 attached thereto, and a weight 191 mounted on the lever to urge the blade 182 normally to its open position. shown in FIG. 14, resting against an adjustable stop screw 192. The weight 191 may be of greater mass than weight 186 or may act through a greater effective leverage ratio so that the valve blade 182 is held open until the engine rpm is higher than that at which valve  $_{40}$  blade 180 closes. Thus valve blade 182 is the one that, when closed, provides a positive pressure wave reflecting surface for top engine speed operation. When the flow of exhaust gases past valve blade 182 becomes sufficient to move the blade to its closed position shown in surface in cooperation with the surrounding valve chamber walls, and because it is positioned closer to the exhaust port than the other valve blade 180, the rpm at which the positive pressure reflected wave from rpm for the blade 180. Openings through or in cooperation with the valve blade 182 will permit the exhaust gases to escape when the blade is in the closed position.

It is apparent of course that separate engine rpm sensors could be used for operating these series valve blades 180 and 182 if desired, or that manual control also could be used. With an engine rpm sensor, the valve blade 180 would be actuated to close at medium rpm, and at a higher engine speed the valve blade 182 would be actuated to close.

In FIG. 15 a modified form of the invention is utilized wherein two separate valves are positioned to form a double tapering positive pressure wave reflecting surface in cooperation with the surrounding tubular chamber. The exhaust pipe system 195 includes the pipe section forming an exhaust expanding chamber 196 that extends from the exhaust port of a two-cycle engine, and a pipe section forming a valve chamber 197. It also can include, if desired, the reducing cross sectional area chamber 198 which provides the positive pressure wave reflecting surface for low speed operation. In this instance, the cross sectional shape of the 5 chambers 196, 197 and 198 can be rectangular or can be such as that shown in FIG. 8.

In the valve chamber 197, a pair of valve blades 201 and 202 are mounted. The valve blade 201 is mounted onto a shaft 203 that is rotatably mounted in the walls <sup>10</sup> of chamber 197 of the exhaust system and the valve blade 202 is mounted onto a shaft 204 which is also rotatably mounted in the chamber 197. The shafts 203 and 204 in turn have gears mounted thereon. The shaft 203 has a gear 205 mounted thereon and this gear meshes with a gear 206 that is mounted on the shaft 204. A lever 207 is also mounted on the shaft 204 and is actuated by means of a hydraulic cylinder 208. The hydraulic cylinder controls movement of the lever 207 20 about the axis of the shaft 204. The cylinder 208 can be controlled by means of an engine rpm sensor and suitable valving. The sensor and valving are shown only schematically as a control system box 209.

When the cylinder 208 is actuated it moves lever 25 207. Lever 207 drives valve blade 202 and gear 206 drives gear 205 and valve blade 201, so the valve blades move to their dotted line positions. The two valve blades 201 and 202 then provide a V-shaped positive pressure wave reflecting surface in cooperation with 30 the surrounding chamber wall. The control system 209 actuates the cylinder 208 to return the valve blades to their open positions when the engine speed drops below a preselected level. The cylinder shifts the valve 35 blades to their dotted line or closed positions for high speed operation. The valve blades 201 and 202 provide for exhaust gas escape where their ends mate as shown in dotted lines, or the valve blades can have separate openings through which the exhaust gases can escape.

The cylinder **208** could be pneumatically actuated, or it could be replaced with an electric actuator. Control system **209** could then be modified to suit the type of power actuator being utilized.

In FIG. 16, a further modified form of the invention 45 is shown. An exhaust system 215 has an expanding chamber 216 leading from the exhaust port of a twocycle engine, into a valve chamber 217. Downstream from the valve chamber is a perforated baffle wall 218 which has openings 219 provided therein. This perforated wall provides an exhaust silencing effect, and at the same time provides a low speed positive pressure wave reflecting surface. There could also be perforated pipes provided, each opening through a separate aperture in a wall similar to 218. If desired, the wall 218 55 could be planar and normal to the axis of the exhaust pipe, or could be tapered, or in any other desired configuration. Any configuration desired may be placed downstream of wall 218, such as additional muffler baffles, perforated tubes or simple outlet pipes. The ex-60 haust pipe could also terminate at wall 218, if desired. For high speed operation, a valve blade 220 is mounted onto a shaft 221 that is rotatably mounted in the walls forming the chamber 217, and can be actuated as ex-65 plained before and held in its open position as before with suitable weights or springs or with a power actuator or manual control. The valve is shown merely for il-

lustrative purposes to demonstrate that it will cooperate with the perforated end wall **218** fixed in place as a muffler wall or as part of a silencing system. The valve blade **220** is designed and actuated so that it will move to its dotted line position when the engine rpm increases, forming a positive pressure wave reflecting surface for high rpm operation. The valve blade **220** includes an opening **222** for exhaust gases to escape when the valve is closed. The wall **218** will provide an exhaust silencing effect whether the valve **220** is open or closed.

In FIGS. 17 and 18 there is shown a further modified form of the invention. In this form, the exhaust pipe 225 is of the expansion chamber type as before, and has 15 a tubular pipe section forming an expanding chamber 226 and a pipe section forming a chamber 227. A reducing cross sectional area chamber 228 may be provided for a low speed positive pressure wave reflecting surface. In this instance, a valve blade 230 is mounted onto a cross shaft 231 and is controlled with a suitable weight or spring system holding the blade in open position as before, and there is also provided a stop member 236 for stopping it in proper open position. The valve blade 230 extends across the cross sectional area of the chamber, and moves from an open position shown in solid lines in FIG. 17, to a closed position shown in dotted lines. In this particular form of the invention, the valve blade 230 rests against a projecting rim arrangement 232 and 233 when in closed position. A first rim member 232 is provided adjacent the upper portions of the chamber 227 and the upper edges of the upstream part of the valve blade 230 will rest against this rim member when the valve is in closed position. A separate rim member 233 is provided along the lower portions of the chamber 227 and the lower edges of the downstream portion of the valve blade will rest against this rim member. Thus the rim members will contact the edge surfaces of the valve blade 230 when the valve 40 closes so as to give positive sealing around the peripheral edges of the valve blade and also to support the blade when it is closed and thus prevent it from jamming or sticking against the interior surfaces of the chamber 227, while at the same time maintaining a positive gas seal. The rim members are in offset planes. as shown, so that they will seal on opposite sides of the valve blade when it pivots to its closed position.

The valve blade 230 provides, in combination with 50 the surrounding tube walls, the positive pressure wave reflecting surface for high speed operation and may automatically be shifted to its closed position, or can be manually controlled if desired. The shaft 231 can have a lever 234 (FIG. 18) thereon and a weight 235 on the lever for urging the valve to open position in the same manner as shown in FIGS. 4–8. In this particular instance, the valve chamber can be rectilinear in cross section as shown. This does not affect the operation of the valve or exhaust, because the cross sectional shape can be varied as desired to cooperate with the particular valve blade outline and pivot location. A gas outlet opening 237 is provided in blade 230.

In FIGS. 19 and 20 a further modified form of the present invention is shown wherein an exhaust pipe 240 has expansion section 241 leading from the exhaust port of a two-cycle engine, and a valve chamber 242. The chamber 242 can be open at its downstream end,

or can have a reducing cross sectional area chamber, or a muffler or any desired configuration downstream of the valve blade 244. Guide tracks 243 in which a sliding valve blade 244 can be mounted are positioned along the sides of chamber 242. The slide valve blade 244 can be manually operated (as shown) or can be controlled through a suitable linkage so that the blade can be moved to a position wherein it substantially blocks the chamber 242, or can be slid outwardly as shown in solid lines to where it substantially clears the interior of the 10 chamber 242 so that there is a straight through flow of exhaust gases. The slide valve passes through a slit in one wall of the exhaust pipe, and can have an insulated handle as shown. 15

When the sliding blade valve 244 is in open position, the engine will operate with the benefits of the expansion section exhaust available and whatever exhaust arrangements may be located further downstream, and when the blade 244 is in the closed position it provides, 20 toward the outer wall section 261 to form a positive in cooperation with the surrounding duct walls, a positive pressure wave reflecting surface that is inclined with respect to the longitudinal axis of the exhaust chamber so as to provide positive pressure wave reflection suitable for high speed operation of the engine. As 25 vide for a positive pressure reflected wave to arrive shown, an opening 245 can be provided in the sliding blade 244 to permit exhaust gases to escape when the blade is in closed position. If desired, the sliding blade 244 could instead have a plurality of perforations in it to help in muffling the engine noise rather than a single 30 261 so that there is an outlet opening 263 provided opening 245. Also, the sliding blade can otherwise be designed so as not to close the the chamber completely, when in closed position, thus permitting the escape of exhaust gases.

The slide member here is shown in a valve chamber <sup>35</sup> having a substantially square cross section. The guide tracks 243 for the valve blade can be of any desired configuration and as shown, extend on the outside of the exhaust pipe to support the slide valve blade when it is open. The handle for the valve passes between the guides. The friction of the guide members holds the valve in its open or closed position or other suitable arrangements can be provided for this purpose.

A further modified form of the present invention in a  $_{45}$ different type of exhaust system is shown in FIGS. 21 and 22. FIG. 21 is an edge view of an expansion chamber muffler assembly as viewed along line 21-21 in FIG. 22. FIG. 22 is a side view showing the unit as it would be placed along the side of the motorcycle in 50 FIG. 1 or the snowmobile in FIG. 4. The muffler assembly shown in FIGS. 21 and 22 is disclosed in its general form in my copending application, Ser. No. 9,507, filed Feb. 9, 1970 and entitled "IMPROVE-MENTS IN TWO-CYCLE ENGINE RESONANCE 55 EXHAUST SYSTEMS." The description in this application will therefore be abbreviated.

First, the exhaust system 250 comprises a relatively flat housing 252 that encloses a complete resonant exhaust system and muffler combination by curving or <sup>60</sup> bending the central axis of the tubular resonant system at least once, preferably at least 90°, between its inlet and outlet and positioning a muffler in the space defined by the curved tubular member. As shown, the tubular resonant chamber member is bent or curved 65 into a "U" and the muffler is located between the legs of the U. Also as shown, the entire tubular exhaust

channel and muffler are in a single housing, but they could be separate. As shown in FIG. 22, the cover 275 of the exhaust system is removed. An exhaust or header pipe 251 leads from an exhaust port of a two-cycle engine such as the exhaust or header pipe 26 in FIG. 1 or pipe 77 in FIG. 4. The pipe 251 opens into a chamber 253 that is expanding in cross sectional area in direction of exhaust gas flow indicated by the arrow 254. This chamber is defined between an outer wall 255 of the unit, and a divider wall 156. These walls extend to a constant cross sectional area chamber 257 of the unit defined between a curved portion 258 of the outer wall 255 and a curved inner wall 259 that joins wall 256. It should be noted that the expanding chamber extends partially around the curved walls.

The curved wall 259 merges into a wall 260 that extends substantially parallel to an outer wall section 261 for a short distance, and then extends at an angle pressure wave reflecting area near the outlet of the resonant exhaust chamber. The reflecting area is sufficiently far from the exhaust port of the engine with which the exhaust system 250 is used so that it will proback at the engine exhaust port at the proper time for aiding engine power output during lower speed operation of the engine.

The wall 260 terminates spaced from the wall section from the curved tubular exhaust channels formed in this housing. This outlet opening 263 leads into a channel 264 that is defined between the wall 260 and another wall 265. There are a plurality of apertures shown in dotted lines at 266 opening through the wall 265 into a second chamber 267. A partition wall 268 also is provided with a plurality of apertures shown in dotted lines at 269 that lead from chamber 267 into an 40 outlet chamber 270. The apertures 266 and 269 through the walls tend to break up the exhaust sound waves as the gases flow from the outlet opening 263 to the outlet chamber 270. The exhaust gases then pass through apertures 271 of an exhaust outlet pipe 272. This causes further muffling of the engine noise. The exhaust outlet pipe 272 passes out through the end wall of the housing 252.

As shown in FIG. 21, the housing 252 has a cover member 275 mounted thereon to close off the open side of the chambers. In FIG. 22 the cover member is removed, and this cover member can be held in place with suitable cap screws or other fasteners 276. The interior walls extend from a fixed outside wall to the cover to form the necessary chambers.

Adjacent the downstream end of the exhaust chambers which curve from the header pipe 251 to the outlet 263, there is a planar valve blade 280 positioned in constant cross sectional area chamber 257. Valve blade 280 is mounted onto a shaft 281 that is in turn rotatably mounted in the cover 275, and also is rotatably mounted through the fixed side wall of the housing 252 with a boss 282. The shaft 281 is free to pivot about its axis, and as shown, the valve blade 280 includes an airfoil shaped or streamlined weight 283 adjacent the leading end thereof, when viewed with reference to direction of exhaust gas movement past the valve. The weight 283 is positioned with respect to the shaft 281

so that when the housing 252 is properly positioned, the weight will bias or urge the blade 280 to its open position shown in solid lines in FIG. 22. A stop screw 284 is threaded through a boss 285 provided on the housing 252 and this stop can be locked in place with a 5suitable lock nut to support the blade in its desired open position at the selected angle of attack. When the exhaust gas velocity and pressure coming from the exhaust pipe 251 through the chamber 257 reaches a preselected level, the blade will be lifted up to its dotted line position, and the surface of the blade facing the exhaust pipe 251 will provide a positive pressure wave reflecting surface, in cooperation with the surrounding chamber walls, so located that the system will 15 resonate at a higher rate than the resonating rate with the reflecting area adjacent outlet opening 263. An opening 286 is provided in the blade 280 so that exhaust gases can escape. The exhaust gases then go out the outlet opening 263 into the muffler section through 20 the apertures 266, 269 and 271 and out the pipe 272.

When the engine rpm drops so that the pressure of the gas against the valve blade 280 drops sufficiently, the blade will drop to the open position, and the area adjacent outlet opening 263 will again be operative as 25 the positive pressure wave reflecting area. Thus the concept of having a plural range of resonant speeds in one single exhaust system is carried out in this mufflerresonant pipe combination structure.

In all instances, the cross sectional shape of the exhaust chambers can be varied as desired or as necessary to cooperate usefully with the shape of the valve blade, and in FIGS. 21 and 22, of course, the device is rectilinear in cross section.

35 Also, the spacing between the valve means and the fixed reflecting surface or area provided for lower engine speed operation can be varied to meet design objectives for different usages. The valve means and fixed reflecting surface or area thus need not be as close  $_{40}$ together as shown in the drawings.

What is claimed is:

1. An exhaust system for two-cycle engines including an exhaust port, a tubular exhaust duct member including a portion generally expanding in cross sectional 45 position. area in direction of exhaust gas flow from said exhaust port and in communication therewith, and having an exhaust gas outlet, valve means positioned in said tubular exhaust duct member, means to move the valve means between a first position wherein said valve 50 means does not substantially influence exhaust gas flow through said tubular member, and a second position where it forms a pressure wave reflecting surface so positioned with respect to said exhaust port as to reflect a positive pressure wave timed to arrive back at the ex- 55 haust port of said engine immediately prior to closing of said exhaust port when said engine is operating in a preselected speed range.

2. The combination as specified in claim 1 wherein said valve means comprises a blade member pivotally mounted about an axis positioned in a preselected relationship with respect to exhaust gas flow in said exhaust system.

3. The combination as specified in claim 2 wherein said means for moving said valve means toward its first position comprises bias means acting to create a moment about the axis of pivot of said blade member.

4. The combination as specified in claim 3 wherein said bias means comprises a weight member.

5. The combination as specified in claim 3 wherein said bias means comprises a spring.

6. The combination as specified in claim 3 wherein said blade member is positioned at a preselected angle of attack with respect to direction of normal exhaust gas flow through said exhaust system, means mounting said blade member so that said exhaust gas flowing 10 across said blade member creates a lift on a portion of said blade member to move said blade toward said second position when the exhaust gas flow across said blade member has substantially reached a preselected velocity.

7. The combination of claim 4 wherein said weight member is mounted directly on said blade member adjacent the leading edge thereof with respect to the direction of flow of exhaust gas.

8. The combination as specified in claim 2 wherein the axis of mounting of said blade member is offset with respect to a transverse bisecting line of said blade member and the major portion of said blade member is upstream from the axis.

9. The exhaust system of claim 1 further characterized in that means forming an engine noise silencing device is mounted downstream from said valve means.

10. The exhaust system of claim 9 wherein said noise silencing device forms a fixed wave reflecting surface 30 located farther downstream from said valve means.

11. The combination as specified in claim 1 and a chamber wall forming a fixed positive pressure wave reflecting surface spaced in downstream direction away from said valve means with respect to the direction of exhaust gas flow.

12. The combination as specified in claim 1 and manually operable means to operate the valve means between its first and second positions.

13. The combination as specified in claim 2 wherein said blade is mounted onto a shaft, said shaft being pivotally mounted in said tubular duct member, a lever on said shaft, bias means acting through said lever and arranged to bias said blade member toward its open

14. The combination as specified in claim 13 and means to permit adjustment of said bias means with respect to the axis of rotation of said shaft to change the effective moment of said bias means on said shaft.

15. The combination as specified in claim 2 and stop means to stop said blade member in its first position at a preselected angle with respect to the direction of exhaust gas flow and permit said blade member to move to its second position.

16. The combination as specified in claim 2 and stop means to stop said blade member when said blade member moves to its second position.

17. The combination as specified in claim 2 and separate bias means urging said blade member from its 60 second position toward its first position during at least initial portions of blade travel from its second position.

18. The combination as specified in claim 1 and at least one second valve means located in said tubular member a different distance from the exhaust port than said first valve means, said second valve means being movable from a first position wherein it does not substantially influence flow of gases through the exhaust

system, to a second position where it forms a pressure wave reflecting surface so positioned with respect to said exhaust port as to reflect a positive pressure wave timed to arrive back at the exhaust port of said engine immediately prior to closing of said exhaust port when 5 said engine reaches a second preselected speed of operation.

19. The combination as specified in claim 1 and power means to operate said valve means, an engine speed sensor means to actuate said power means at a 10 means operating said blade members together for coorpreselected engine speed to selectively move said first valve means to its first and second positions.

20. The combination as specified in claim 19 wherein said power means comprises a solenoid.

21. The combination as specified in claim 19 wherein 15 the direction of exhaust gas flow. said power means comprises a fluid pressure actuated cylinder.

22. The combination of claim 1 wherein said valve means comprises a blade member, and guide means to support said blade member for sliding movement 20 between said first and second positions.

23. The combination of claim 1 and rim members positioned around the inner periphery of said tubular. exhaust member, said valve means comprising a pivoting blade member, said blade member at least partially 25 respect to said exhaust port as to reflect a positive presengaging said rim members when said blade member pivots to its second position.

24. The combination of claim 1 and an outlet pipe positioned in said tubular member, said valve member comprising a blade having a U-shaped opening that fits 30 over said pipe when said valve member moves to its second position whereby exhaust gases will be discharged from said pipe when the valve member is in its second position.

25. The combination of claim 1 wherein said tubular 35 exhaust duct member has a central flow axis that changes direction, and muffler means positioned generally within the space defined by the tubular duct member.

26. The combination of claim 25 wherein said tubu- 40 lar duct member bends into a generally "U" shape, and said muffler means is positioned between the legs of the "U.'

27. The combination as specified in claim 25 wherein said muffler means and curved tubular exhaust duct 45 exert a force urging said blade means toward its first member are formed with divider walls inside a common housing.

28. The combination as specified in claim 2 and

dashpot means coupled to said pivoting blade member to dampen movement of said blade member.

29. The combination of claim 1 and bias means to exert a force urging said valve means toward its first position when the valve means has substantially reached said second position.

30. The combination as specified in claim 1 wherein said valve means comprises a pair of blade members, each pivotally mounted in said exhaust duct member, dinated movement whereby in said first position of said valve means the blade members are substantially parallel to the flow of exhaust gases and in said second position cooperate to form a surface means converging in

31. An exhaust system for two-cycle engines having an exhaust port, an exhaust pipe open to said exhaust port and having an exhaust gas outlet, and blade valve means positioned within said exhaust pipe, means to hold the blade means in a first predetermined position wherein it does not substantially influence exhaust gas flow through said tubular member, and means to move said blade means to a second position wherein it forms a pressure wave reflecting surface so positioned with sure wave timed to arrive back at the exhaust port of said engine shortly prior to closing of said exhaust port when said engine is operating in a speed range preselected to be a higher speed range than when said blade means is in its first position.

32. The exhaust system as specified in claim 31 wherein said blade means is pivotally mounted about an axis substantially transverse to the direction of exhaust gas flow through said exhaust pipe, and stop means to support said blade means in its first position at a preselected angle of attack with respect to exhaust gas flow whereby when exhaust gas flow reaches a predetermined velocity said blade means will be moved to its second position by action of aerodynamic forces.

33. The exhaust system as specified in claim 32 wherein said means for holding said blade means in its first position comprises bias means to create a moment about the axis of pivot of said blade means.

34. The combination of claim 27 and bias means to position when the blade means has substantially reached said second position.

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