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P. KOLLSMAN

2,624,171

CONSTRUCTION OF EXHAUST PASSAGES OF INTERNAL-COMBUSTION ENGINES

Filed July 10, 1946

3 Sheets-Sheet 1

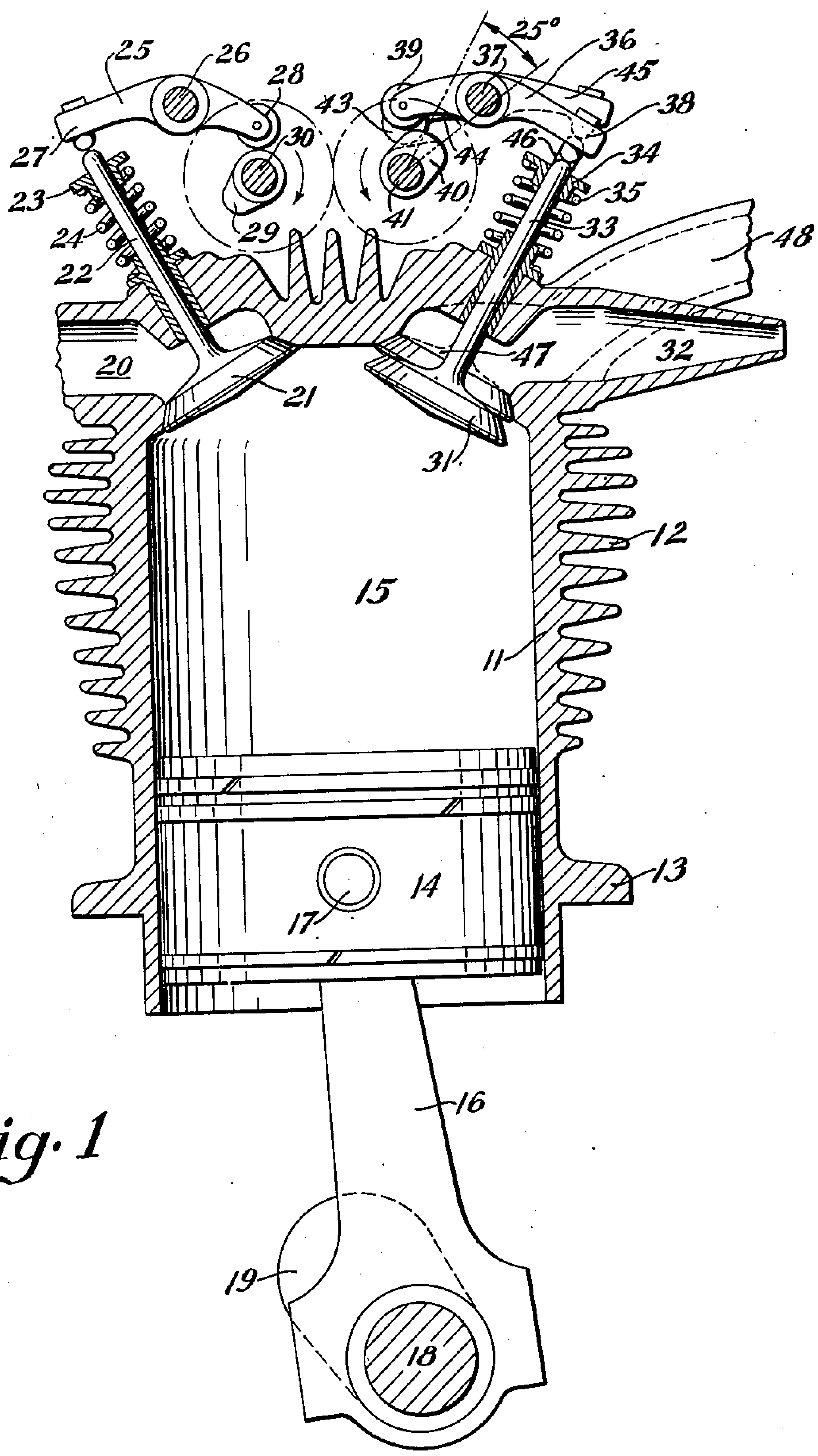

Fig. 1

INVENTOR
PAUL KOLLSMAN
BY
Albert M. Austin
his ATTORNEY

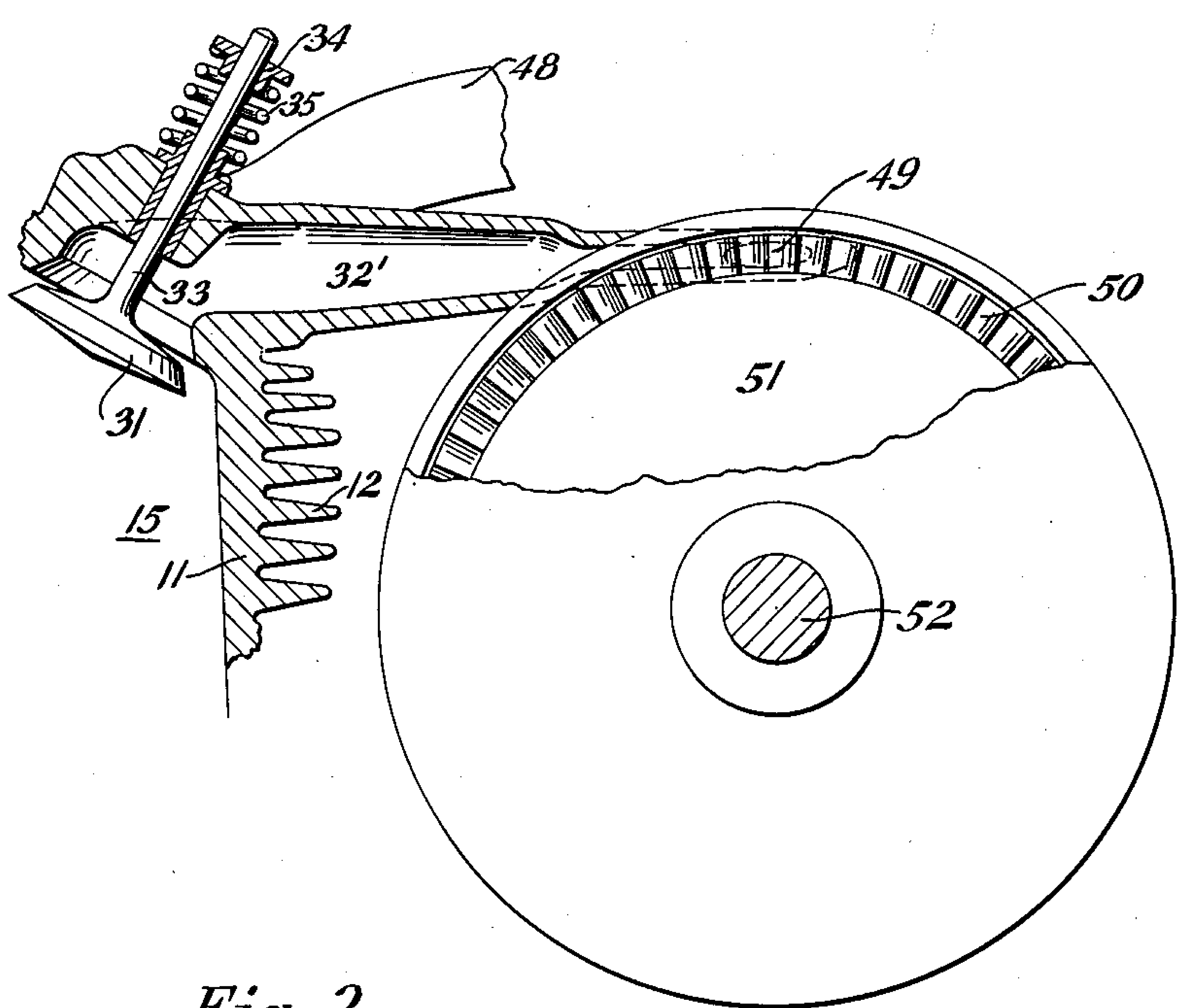

Fig. 2

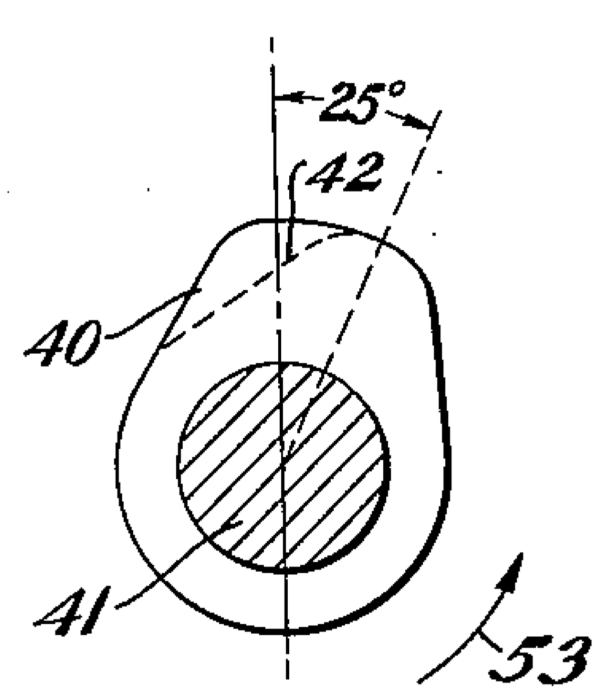

Fig. 3

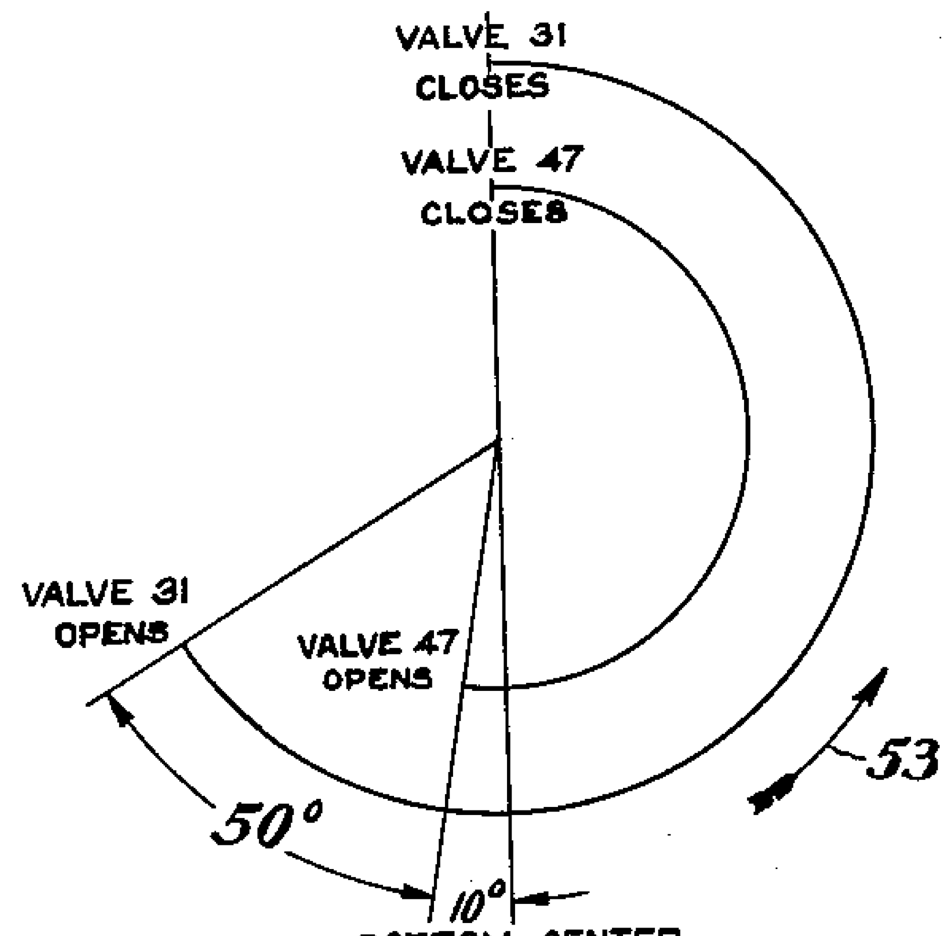

Fig. 4

INVENTOR
PAUL KOLLSMAN
BY
Albert M. Austin
his ATTORNEY

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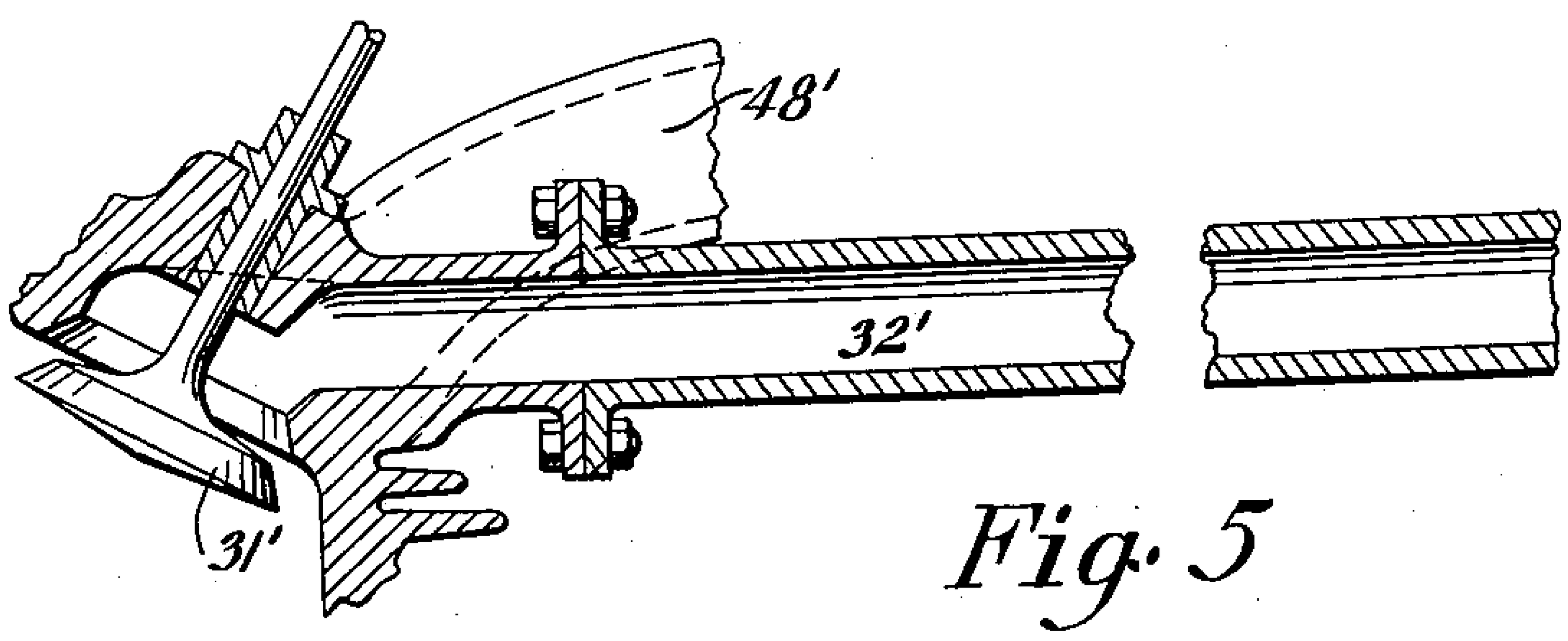

Fig. 5

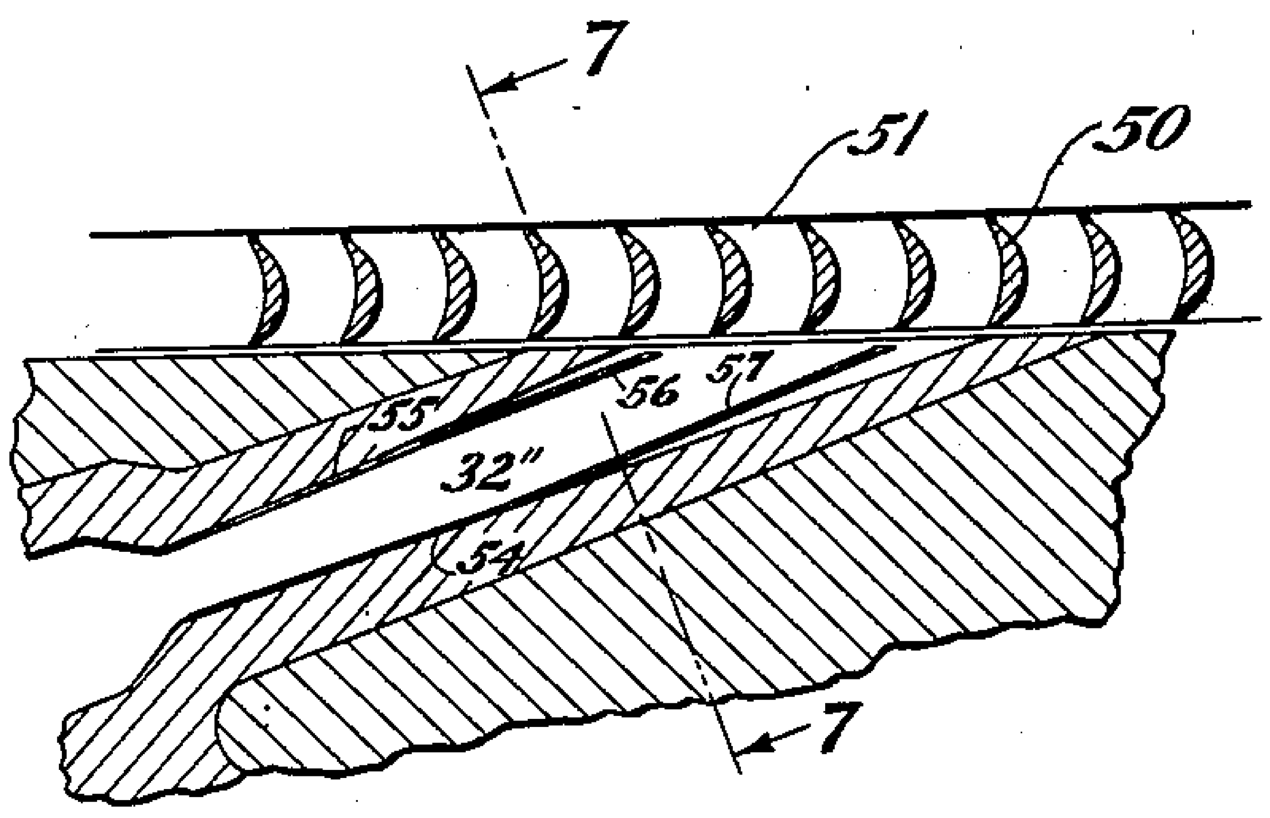

Fig. 6

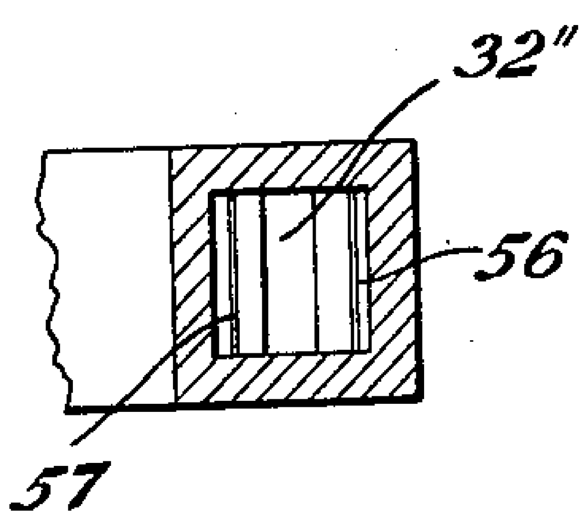

Fig. 7

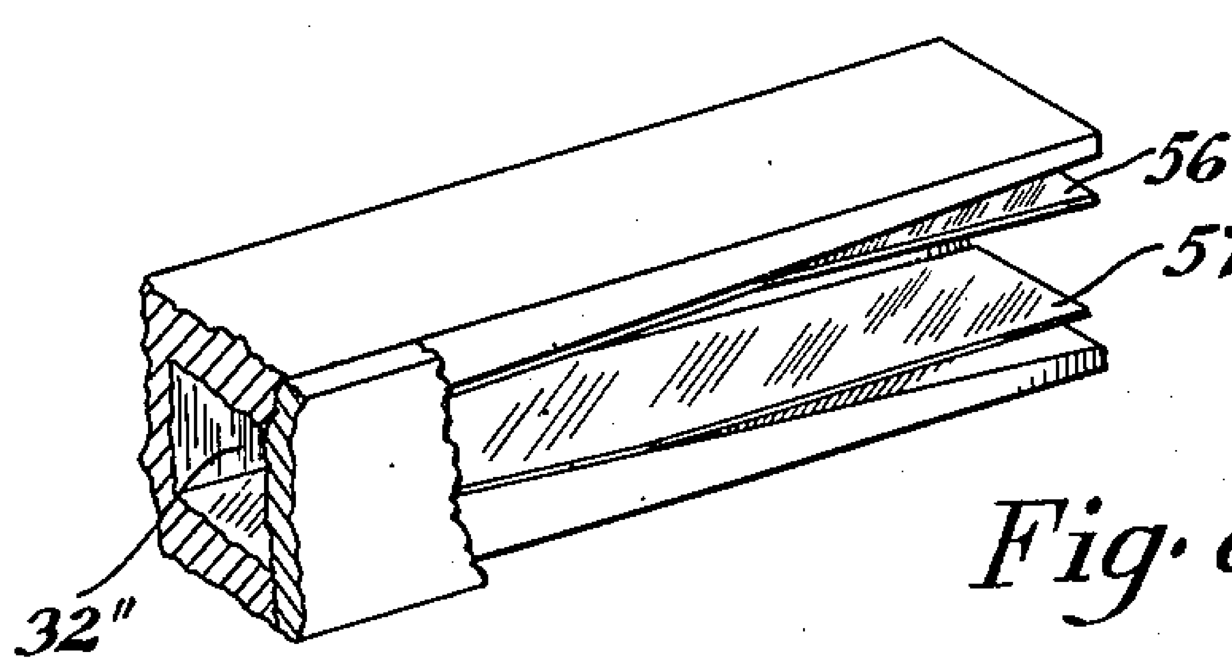

Fig. 8

INVENTOR
PAUL KOLLSMAN
BY
Albert M. Austin
his ATTORNEY

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CONSTRUCTION OF EXHAUST PASSAGES OF INTERNAL-COMBUSTION ENGINES

Paul Kollsman, New York, N. Y.

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4 Claims. (Cl. 60—13)

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This invention provides a method of, and means for utilizing the energy of the exhaust gases of internal combustion engines of the reciprocating type, and has particular application to aircraft engines.

According to the invention the flow of combustion gases from the respective combustion chambers or cylinders of an internal combustion engine is separated into a flow of high velocity and relatively high pressure for conversion into motive power and a separate flow of relatively low velocity and low pressure of the remainder of the gases leaving the combustion chamber. The high pressure flow of gas may be employed to produce reactive thrust by discharge of the gas through an appropriate reaction nozzle. The high pressure flow may also be used to drive a turbine rotor, for example the rotor of a compresser.

According to the invention each combustion chamber, or cylinder, is provided with two separate discharge or exhaust passages, each passage being controlled by a separate exhaust valve. One of the passages is of relatively narrow cross section, preferably narrower than the passage provided by the respective exhaust valve when the valve is open. By such proportioning of the exhaust passage a sudden and substantial pressure drop at the valve and a corresponding energy loss is prevented. At points beyond the exhaust valve the passage may diverge, gradually increase in cross section, to provide for a most advantageous increase in velocity of the expanding high pressure flow of gas. The passage may lead to a reaction nozzle for producing a reactive thrust, or may lead to a turbine nozzle for discharging the high velocity flow of combustion gas against the vanes or blades of a turbine rotor.

The second discharge passage is of substantially larger cross section and serves to remove substantially all of the remainder of the combustion gases not flowing through the first named passage to the atmosphere or other point of combustion gas disposal.

The valves controlling admission of combustion gases to the first high velocity passage and the second low velocity passage are operated in timed relationship with respect to the movement of the piston of the respective combustion chamber, and in such manner as to cause discharge of a portion of the combustion gases under high pressure through the high velocity passage, while the second low velocity passage is still closed. After the peak pressure has been spent by discharge of a flow of gas of high velocity through

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the high velocity passage, which flow is converted into motive power as hereinbefore mentioned, the second exhaust valve opens and permits removal of substantially all of the remaining combustion gases from the combustion chamber through a passage of low resistance. The first discharge valve controlling the high velocity passage may be caused to open while the piston is still on its downward combustion stroke, for example approximately 50° to 70° before bottom center of the respective crank, and the second exhaust valve controlling the second discharge passage may open approximately 10 or 20° before bottom center.

While the timing of the opening of the two valves is important and should occur successively as hereinbefore described, the two valves may close substantially simultaneously, for example when the respective crank reaches top center.

The objects, features, and advantages of this invention will appear more fully from the detailed description which follows accompanied by drawings showing for the purpose of illustration devices for practicing the invention.

The invention also consists in certain new and original features of construction and combination of parts hereinafter set forth and claimed.

Although the characteristic features of the invention which are believed to be novel will be particularly pointed out in the claims appended hereto, the invention itself, its objects, and advantages and the manner in which it may be carried out may be better understood by referring to the following description taken in connection with the accompanying drawings forming a part of it in which,

Figure 1 is a side elevation, partly in section, of a cylinder piston and crank of an internal combustion engine;

Figure 2 is a partial view of a high velocity exhaust passage leading from an engine of the type shown in Figure 1 to a turbine rotor;

Figure 3 is a detailed view illustrating, on an enlarged scale, the cams for operating the two exhaust valves of the engine shown in Fig. 1;

Figure 4 is a diagram illustrating the timing of the two exhaust valves;

Figure 5 is a view of a modified form of high velocity exhaust passage;

Figure 6 is a sectional view through a high velocity exhaust passage having divergent walls automatically adjustable, in dependence on the pressure of the exhaust gases flowing through the passage;

Figure 7 is a section taken on line 7—7 of Fig. 6; and

Figure 8 is a perspective view of the passage shown in Figs. 6 and 7.

In the following description and in the claims various details will be identified by specific names for convenience. The names however are intended to be as generic in their application as the art will permit. In the drawings parts of the engine not necessary for an understanding of the invention are omitted for the sake of clarity.

Like reference characters refer to like parts in the several figures of the drawings.

In the drawings accompanying, and forming part of, this specification certain specific disclosure of the invention is made for the purpose of explanation of broader aspects of the invention, but it is understood that the details may be modified in various respects without departure from the principles of this invention, and that the invention may be applied to and practiced by other structures than the ones shown.

Referring to the drawings the engine shown in part in Figure 1 comprises a cylinder housing 11 having cooling fins 12 and a flange 13 for mounting on an engine housing (not shown).

A piston 14 is movable in the cylinder and forms with the cylinder a combustion chamber 15. The piston is pivotally attached to a connecting rod 16 by a pin 17, and the connecting rod 16 engages a crank pin 18 of a crank shaft 19.

Combustible mixture is admitted into the combustion chamber 15 through an intake passage 20 controlled by an intake valve 21. The intake valve 21 has a stem 22 carrying a collar 23 against which a valve spring 24 bears tending to maintain the intake valve closed. The intake valve 21 is operated by an intake valve lever 25 pivotally mounted at 26 and engaging with one end 27 the stem of the intake valve 21. The other arm of the intake valve lever 25 carries a roller 28 which engages the periphery of a cam 29 on an intake cam shaft 30. The intake cam shaft 30 is coupled to the crank shaft 19 in conventional manner (not illustrated) to cause the cam shaft 30 to turn at half the rate of the crank shaft 19.

A first exhaust valve 31 controls the admission of combustion gas from the combustion chamber 15 to a relatively narrow discharge passage 32. The exhaust valve 31 has a stem 33 to which a collar 34 is attached. A valve spring 35 bears against the collar 34 and tends to maintain the exhaust valve 31 closed. A first exhaust valve lever 36 pivotally mounted at 37 engages with one end 38 the valve stem 33 and carries at its other end a roller 39 engaging the periphery of a first exhaust valve cam 40 on an exhaust valve cam shaft 41.

A second exhaust valve cam 42 (Fig. 1) is fixed on the same exhaust valve cam shaft 41 and engages with its periphery a roller 43 at one end of a second exhaust valve lever 44. The second exhaust valve lever is likewise pivoted on the shaft 37 and engages with its other end 45 the stem 46 of a second exhaust valve 47 controlling admission of combustion gas into a relatively wide exhaust passage 48.

The two cams 40 and 42 are so arranged as to cause the first exhaust valve 31 to open before the second exhaust valve 47 to permit the combustion gas of high pressure to pass through the relatively narrow first exhaust passage 32. At the time of opening of the first exhaust valve 31 the gases inside the combustion chamber 15 are at peak pressure. The gas flowing through the exhaust passage 32 attains a very high velocity, up to sound velocity and even beyond the velocity of sound, depending on the shape of the passage 32 and the pressure drop encountered by the gas during its flow through the passage.

After the peak pressure of the combustion gases is spent the second cam 42 causes the second exhaust valve 47 to open, whereby substantially all of the remainder of the combustion gases, which now have dropped to a relatively low pressure, are permitted to escape from the combustion chamber 15 in preparation of the next suction and compression strokes of the engine.

The energy of the high pressure combustion gases may be utilized in various ways.

The gases may be used to drive the rotor of a turbine. This is illustrated in simplified manner in Figure 2 of the drawing. The exhaust valve 31 controls the admission of combustion gases at peak pressure into a relatively narrow discharge passage 32′ leading to a discharge nozzle 49 directing a jet of gas against the vanes 50 of a turbine rotor 51 on a rotor drive shaft 52. The passage is preferably narrower than the passage provided by the exhaust valve 31 when the valve is open.

A second exhaust valve (not shown) is provided for opening and closing a second exhaust passage or exhaust stack 48 of relatively wide cross section for the removal of combustion gas still remaining in the combustion chamber 15 after the gases of peak pressure have been removed through the first exhaust passage 32′.

A typical cam arrangement for the two exhaust valves is shown in Figure 3. The cams 40 and 42 are fixed on the same exhaust valve cam shaft 41 and move in the direction of the arrow 53 at half the rate of the engine crank shaft. The elevated portion of the two cameras are offset so as to cause actuation of the exhaust valve controlling the high pressure exhaust passage before actuation of the second exhaust valve which controls the exhaust passage of large diameter. In the illustrated embodiment the cams are offset 25° which, considering the ratio at which the cam shaft 41 is geared to the engine crankshaft, amounts to an advance opening of the first exhaust valve over the second valve of 50° in terms of engine crankshaft movement.

A typical diagram illustrating the timing of two exhaust valves of an engine embodying the invention is shown in Figure 4. The diagram is in terms of crankshaft movement. According to the illustrated arrangement exhaust valve 31 opens approximately 60° before bottom center. The exhaust valve 31 opens during the combustion stroke, at a time the piston is on its downward movement. When the exhaust valve 31 opens the mixture in the combustion chamber of the engine was just fired by a spark plug or otherwise, is fully ignited and at high pressure forcing the piston downwardly. While the pressure is still high the first exhaust valve begins to open causing a flow of combustion gas of high pressure to pass through the first exhaust passage at great velocity. The energy of this exhaust gas is utilized either to produce a reactive thrust or to drive a suitable prime mover as hereinbefore described. Ten degrees before bottom center of the crankshaft the valve 47 opens to permit the remainder of the combustion gases to escape. Both valves remain open throughout the upstroke of the piston and close at top center of the crankshaft when the suction stroke of the piston is about to begin.

It is evident that the timing of the two valves relatively to each other may be changed as well as the opening and closing points of the valves with respect to bottom and top center.

The exhaust passage for the high pressure gases may be made of substantially uniform cross section and of considerable length to produce slugs of gas of considerable pressure which pass through the passage at high velocity timed with the opening of the exhaust valve **31'**. As shown in Figure 5 the passage **32'** is of uniform cross section and preferably narrower than the passage past the valve **31'**. The purpose of making the exhaust passage **32'** relatively narrow is to make the pressure drop at or near the valve small whereby energy losses at this point are maintained correspondingly low.

Figures 6, 7 and 8 illustrate an exhaust passage **32''** of gradually increasing cross section to permit flow velocities to be obtained which are in excess of the velocity of sound. Two walls **54** and **55** of the passage **32''** are adjustable in dependence on the changes in pressure of the exhaust gases flowing therethrough. Flexible blades **56** and **57** of an alloy capable of resisting high temperatures are acted upon on the inside by the pressure of the gas flowing through the passage **32''** and are acted upon on the other side by the ambient pressure which may be the exhaust pressure of the turbine driven by the exhaust gas, this pressure being near atmospheric pressure. Exhaust gases flowing through the passage **32''** may attain velocities in excess of the velocity of sound assuming the pressure drop of the gas is in excess of the so called critical drop. This pressure ratio is measured at the intake point where the pressure of the gas is a maximum and the velocity substantially zero and at the discharge point of the nozzle or passage **32''** where the velocity is a maximum and the pressure the lowest, for example substantially atmospheric pressure. The combustion gases are discharged at high velocity against the vanes **50** of a turbine rotor **51** to drive the same.

The invention thus provides a method of and means for utilizing a great percentage of the energy of combustion gases of internal combustion engines which is ordinarily lost or wasted. The invention can conveniently be practiced with existing engines equipped with two exhaust valves after appropriate modification of the engines to provide for actuation of the two exhaust valves one after the other and by providing separate exhaust passages for the two valves.

While the invention has been explained and illustrated by application to an engine equipped with poppet valves it may also be practiced by or applied to engines having sleeve valves. It is also applicable to engines of two cycle or two stroke type in which the piston acts as a valve member and controls appropriately located ports in the cylinder wall. Rearrangement of the ports or appropriate shaping of the edge of the piston controlling the ports manifestly produces the same results as the valve mechanism of the illustrated four cycle engine. Thus various changes, additions, omissions, substitutions and other modifications may be made, as will occur to persons skilled in the art without departure from the spirit and the teaching of this invention.

What is claimed is:

1. In a reciprocating internal combustion engine the combination with a cylinder, of two distinct exhaust passages, namely a first high pressure passage of relatively narrow cross section, and a second low pressure and low velocity passage of a cross section larger than said first passage; a poppet valve in each of said passages; and means for opening in timed sequence first the valve in the high pressure passage and thereafter the valve in the low pressure passage, the narrow high pressure passage having a restricted portion downstream of its valve for maintenance of back pressure and a high velocity nozzle portion downstream of said restricted portion for conversion of pressure energy into high kinetic energy, the high pressure passage upstream of the restricted portion being so dimensioned with relation to its controlling valve that its cross sectional area is at all points less than the valve opening considering the valve in fully open position, whereby turbulence losses at the valve proper are minimized.

2. In an internal combustion engine the combination with a cylinder and a piston reciprocable therein, of, a first exhaust passage having at least one movable wall acted upon by the pressure on the interior side of the wall and by the pressure on the exterior side of said movable wall, respectively, the wall being unbiased and face to adjust its position in dependence on the difference between said two pressures acting on the wall to increase and decrease the angle of divergence of said passage; stop means for limiting the extent to which the movable wall may be flexed to a pre-determined maximum angle of divergence of the nozzle passage toward the discharge end of the nozzle under predominant gas pressure on said interior side; a first exhaust valve for opening and closing said first passage; a second exhaust passage of larger cross section than said first passage; a second exhaust valve for opening and closing said second passage; means timed with said piston for opening first said first valve and thereafter said second valve, whereby high and low pressure flows of combustion gases are discharged through said first and second passages, respectively; and a turbine rotor adapted to be acted upon by the gases discharged through said first passage.

3. In an internal combustion engine the combination with a cylinder and a piston reciprocable therein, of an exhaust valve; an exhaust passage extending from said exhaust valve, said exhaust passage having a portion of narrowest cross-section less than the area of passage of said exhaust valve when the valve is in fully open position, said exhaust passage further having a divergent portion including at least one adjustable wall adapted to increase and decrease by adjustment the degree of divergence of said passage portion; and means responsive to changes in pressure inside the passage for automatically adjusting said wall.

4. In an internal combustion engine the combination with a cylinder and a piston reciprocable therein, of a pair of exhaust valves, means for operating said valves in timed sequence, separate exhaust passage extending from said valves, the passage extending from one valve having a divergent portion bounded by fixed rigid walls, a flexible blade lying adjacent one of said walls, said blade being secured to said one wall at one end near the valve and being free to move at the other end remote from the valve, said blade being acted upon by the gas pressure on the interior side tending to flex the blade in a direction to increase the cross-sectional area of the nozzle if the gas pressure on the interior side is greater than the pressure on the exterior side of the blade, the rigid wall adjacent the blade limiting the extent to which the blade may be flexed to a predetermined maximum angle of divergence

of the nozzle passage towards the discharge end of the nozzle.

PAUL KOLLSMAN.

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