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[45] **Dec. 4, 1973**

[54] **VARIABLE VOLUME ROTARY VANE PUMP HAVING AN INTEGRAL OPPOSED RECIPROCATING PISTON INTERNAL COMBUSTION ENGINE**

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[51] **Int. Cl.** .. **F02b 75/24**, F02b 75/26, F02b 75/32

[58] **Field of Search**..... 123/56 C, 56 R, 58 AB, 123/58 R, 197 R, 193 CH

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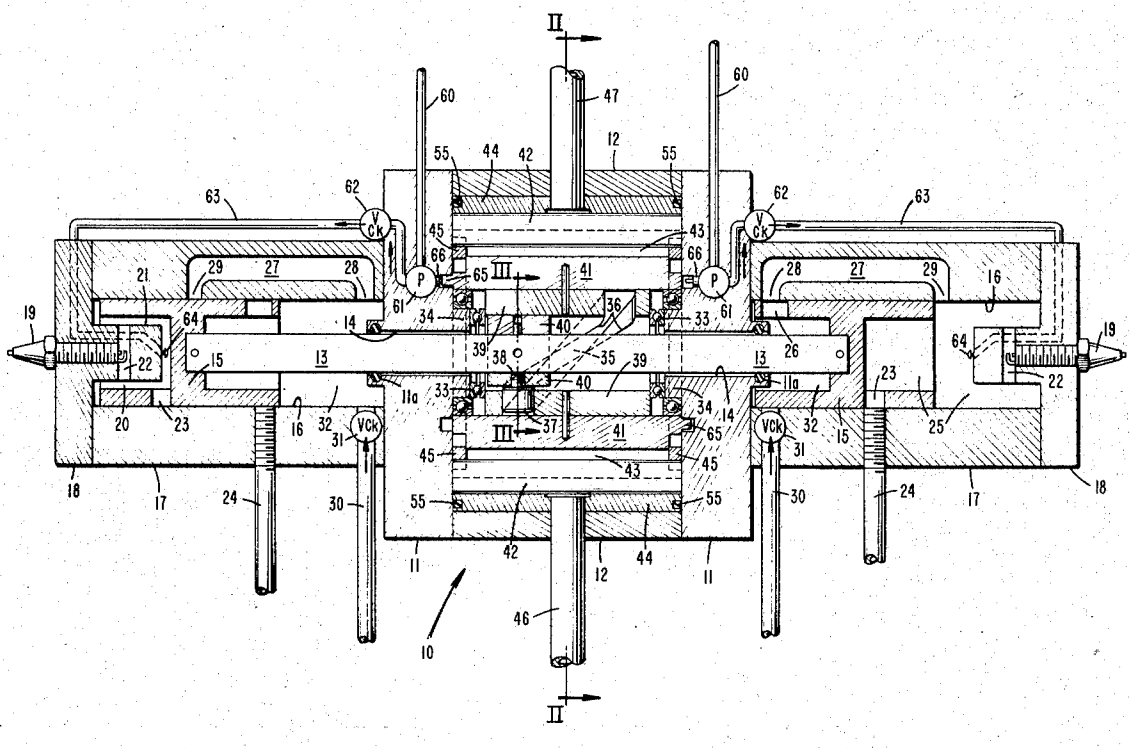
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Primary Examiner—Wendell E. Burns
Attorney—Richard K. Stevens et al.

[57] **ABSTRACT**

The invention comprises variable volume rotary vane pump and integral opposed reciprocating piston internal combustion engine, which comprises a central housing through the ends of which pass a shaft, to each end of which is connected a piston housed within a cylinder, which together form an internal combustion engine. On the reciprocating shaft is rigidly mounted a cam follower engaging a cylindrical camming device coaxial with the shaft and having an endless camming groove in its internal cylindrical surface. To this camming device is attached a cylindrical sleeve which forms the inner ring of a variable volume rotary vane pump. The vane pump also comprises a unitary volume adjustment block slidably mounted within the ends of the central housing, with fluid inlet and outlet orifices in the top and bottom thereof. The internal combustion engine includes improved piston and cylinder head designs, and a secondary fluid injection system.

9 Claims, 8 Drawing Figures



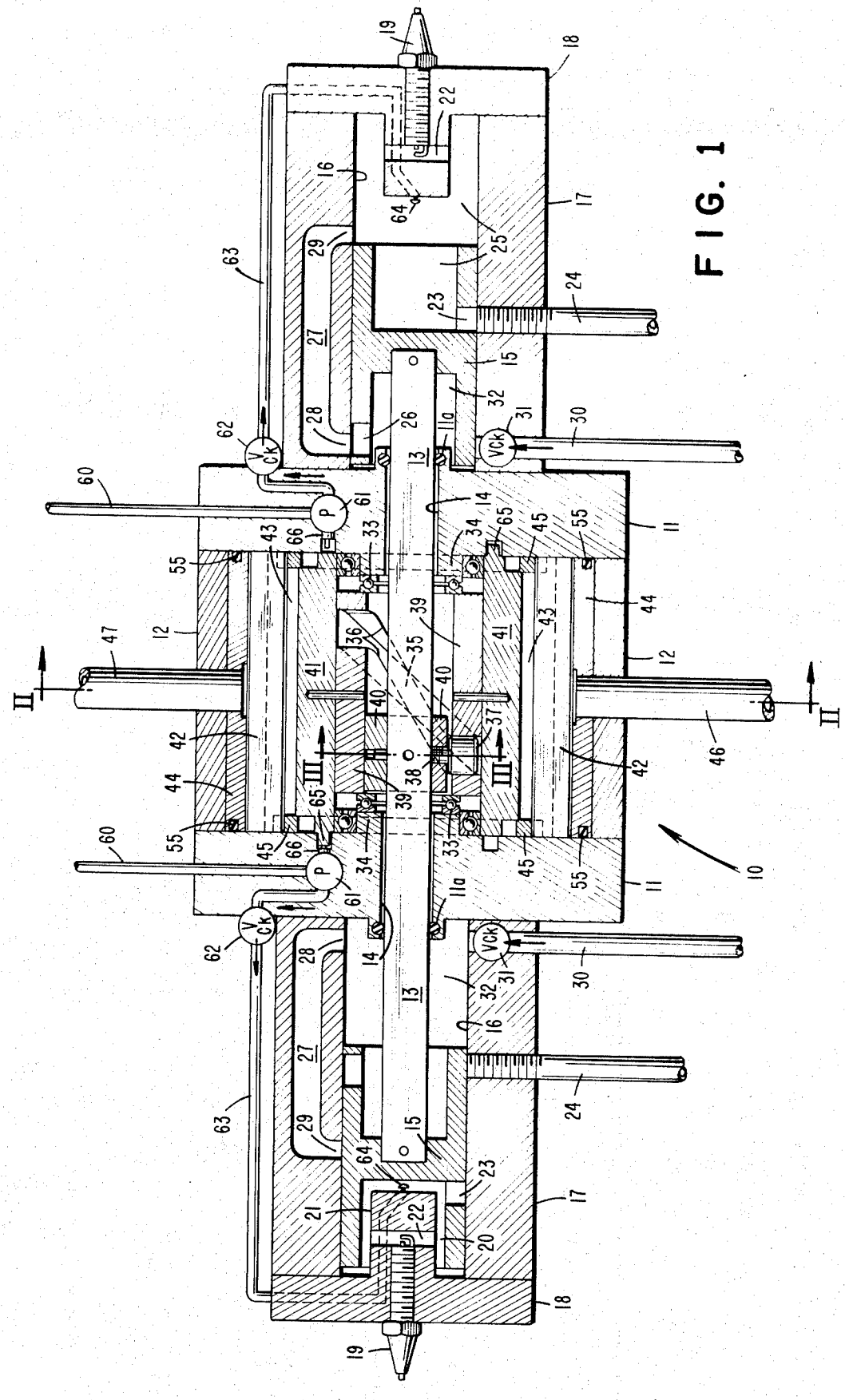


FIG. 1

FIG. 2

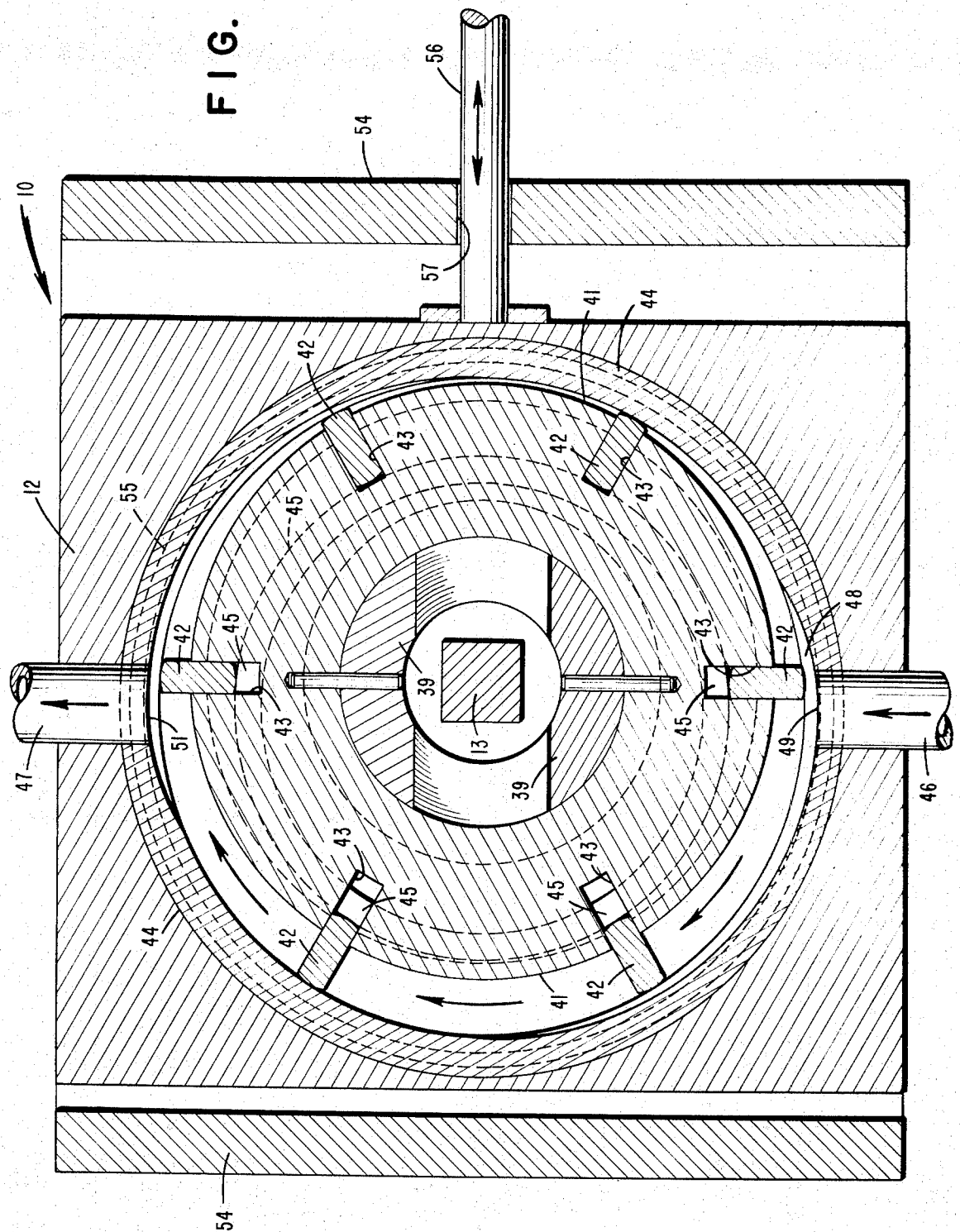


FIG. 3

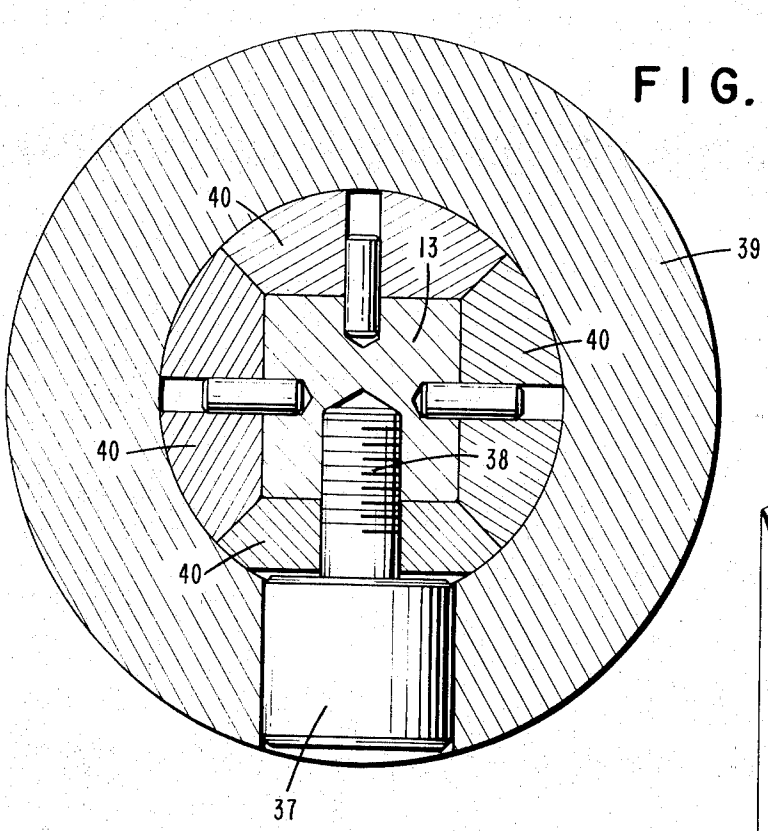


FIG. 5

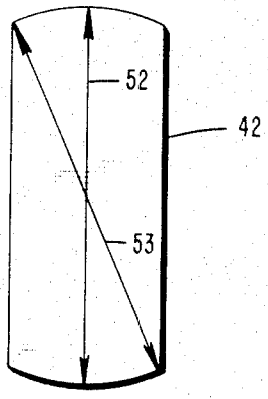
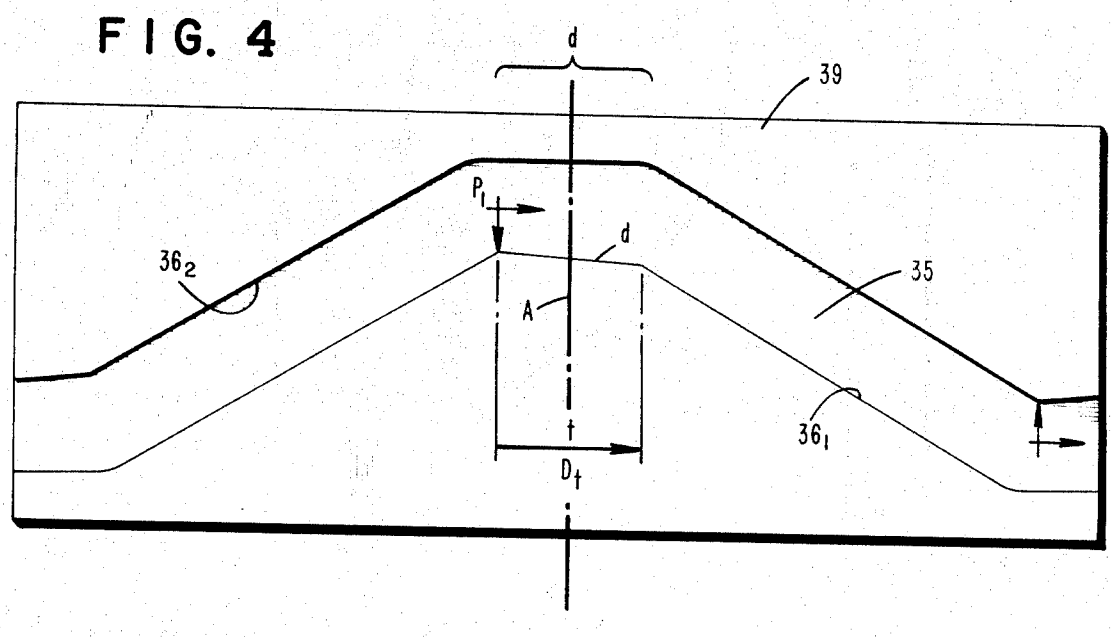


FIG. 4



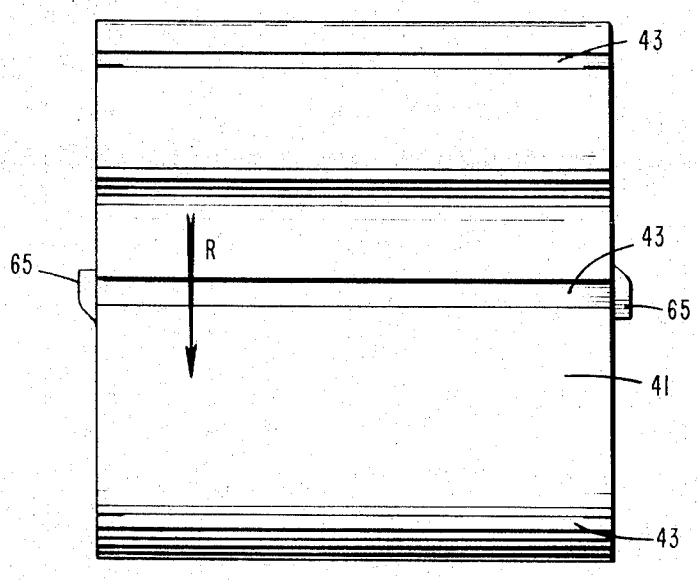


FIG. 6A

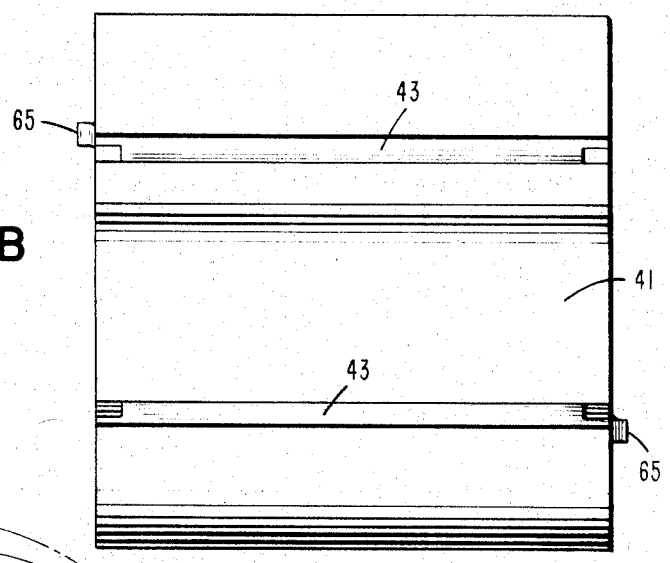


FIG. 6B

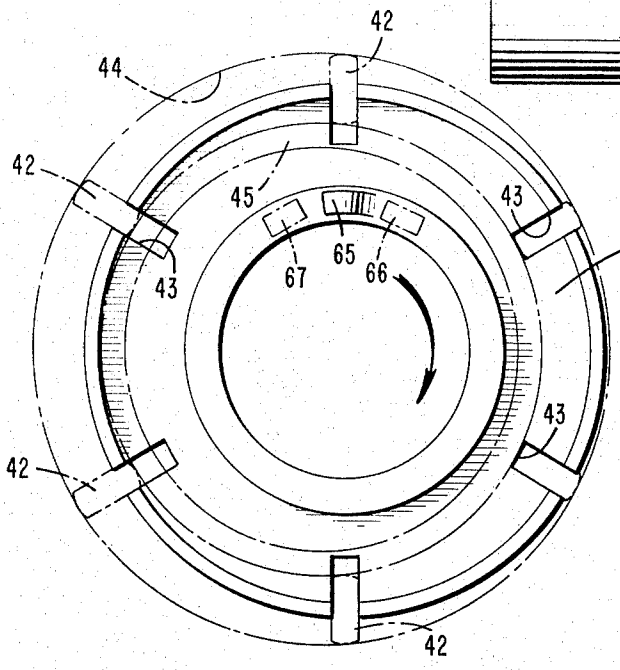


FIG. 6C

VARIABLE VOLUME ROTARY VANE PUMP HAVING AN INTEGRAL OPPOSED RECIPROCATING PISTON INTERNAL COMBUSTION ENGINE

This invention relates in general to opposed piston engines for changing reciprocating motion to rotary motion through an axially moving camming system, and more specifically to unitary apparatus wherein a variable volume vane pump is propelled by such an opposed piston engine.

Various mechanical systems for converting reciprocatory motion into rotary motion are known, for example, as disclosed in Alger U. S. Pat. No. 766,410, and Fasey, et al. U. S. Pat. No. 1,261,111. Of course internal combustion engines are well known and are a fully developed field of art in their own right. The aforementioned Fasey patent, shows that internal combustion engines have been used in conjunction with mechanisms for converting reciprocatory motion into rotary motion.

However, prior to the present invention, the use of mechanisms for converting reciprocatory motion into rotary motion powered by internal combustion engines, have not been known for use in conjunction with variable volume vane pumps, for example, of the type generally disclosed in Traudt U. S. Pat. No. 1,505,982, or Hufferd et al. U. S. Pat. No. 2,678,607.

Although individual elements of the present invention have been known in prior art systems, for example, such as those described in the aforementioned patents, there has still been a need for more efficient mechanisms for converting reciprocatory motion into rotary motion, and for more compact and efficient variable volume vane pumps.

BRIEF SUMMARY OF THE INVENTION

It is, therefore, an object of this invention to provide a reciprocally driven variable volume rotary vane pump which overcomes the above noted disadvantages.

It is another object of this invention to provide an improved internal combustion engine for converting reciprotating motion into rotary motion.

It is another object of this invention to provide an internal combustion engine having improved piston and cylinder head designs.

It is another object of this invention to provide an internal combustion engine with a system for injecting fluids in addition to the combustion mixture, into the combustion chamber.

It is another object of this invention to provide a reciprocally driven variable volume rotary vane pump including means for actuating the timing sequence of the internal combustion engine driving the pump, and for actuating means for injecting fluids, in addition to the combustion mixture into a combustion chamber of the engine.

It is still another object of this invention to provide a more simple variable volume rotary vane pump having a unitary volume adjustment block.

The foregoing objects and others are provided in accordance with the present invention in a variable volume rotary vane pump and integral opposed reciprocating piston internal combustion engine, which comprises a central housing through the ends of which pass a shaft, to each end of which is connected a piston housed within a cylinder, which together form an internal combustion engine. On the reciprocating shaft is rigidly mounted a cam follower engaging a cylindrical camming device having an endless camming groove in its lateral cylindrical surface. To this camming surface is attached a cylindrical sleeve which forms the inner ring of a variable volume rotary vane pump. The vane pump also comprises a unitary volume adjustment block slidably mounted within the ends of the central housing, with fluid inlet and outlet orifices in the top and bottom thereof. The internal combustion engine includes improved piston and cylinder head designs, and a secondary fluid injection system.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention as well as other objects and further features thereof, reference is made to the following detailed disclosure of preferred embodiments of the invention taken in conjunction with the accompanying drawings thereof, wherein:

FIG. **1** is a partially schematic, longitudinal sectional view of a preferred embodiment of the variable volume rotary vane pump and integral opposed piston engine of the present invention.

FIG. **2** is a partially schematic, enlarged, cross-sectional view of the device of FIG. **1**, taken along line II—II of FIG. **1**.

FIG. **3** is a partially schematic, enlarged, cross-sectional view of a portion of the device shown in FIG. **1**, taken along line III—III of FIG. **1**.

FIG. **4** is a partially schematic, enlarged, layout view of the surface of the cylindrical camming sleeve from the device illustrated in FIG. **1**.

FIG. **5** is a partially schematic, enlarged, cross-sectional view of a vane from the vane pump portion of the present invention.

FIGS. **6A**, **6B**, and **6C** are partially schematic, enlarged, side, top, and end views, respectively, of the cylindrical sleeve which forms the inner ring of the vane pump portion of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** illustrates a preferred embodiment of the variable volume rotary vane pump and integral opposed reciprocating piston internal combustion engine of the present invention in longitudinal section. The device comprises a central housing **10** having end walls **11** within which is slidably mounted unitary block **12** of the variable volume vane pump portion of the device. The unitary block **12** is more fully shown in the cross-sectional view of FIG. **2**. Extending through the end walls **11** of the central housing and through seals **11***a*, is drive shaft **13** supported in bearings **14** to each end of which are attached pistons **15**. Each piston **15** is slidably mounted within cylindrical bore **16** in cylinder block **17**, and the cylinders **16** are closed by cylinder heads **18** which are bored to receive spark plugs **19**.

In the internal combustion engine portion of the present invention, the pistons **15** and cylinder heads **18**, are specially designed to cooperate with each other to get fuel into the top of the cylinders, and to uniformly burn the fuel upon ignition by the spark plug **19**. As shown in the lefthand portion of FIG. **1**, the minimum compressed volume **20** of one of the cylinders is defined by the U-shaped cross section of the face portion of piston **15**, which cooperates with the extended portion **21** of the cylinder head **18**. The extended portion **21** has one

or more bores **22** therein through which the combustible fuel mixture permeates, and in which the fuel can be uniformly burned upon ignition.

The pistons **15**, which have an H-shaped overall longitudinal section, are also designed to include an exhaust orifice **23** which extends through one of the walls which form the U-shaped cross sectional face portion of the piston. As illustrated in the right hand portion of FIG. **1**, the exhaust orifice **23** is designed to align in an operative relationship with exhaust port **24** in cylinder wall **17** when the piston **15** is in its retracted position at which the effective volume of the combustion chamber **25** is maximized.

Each of the pistons **15** also includes an intake orifice **26** through the lower cylindrical flange of the piston head **15**, and intake orifice **16** is designed to operatively align with a first end **28** of fuel intake passage **27** which is bored within one wall of cylinder block **17**, and extends parallel to each cylinder **16** opening into the cylinder **16** first at port **28** and exiting back into the combustion chamber portion of cylinder **25** at port **29**. Each cylinder is also provided with an inlet bore **30** which is bored through block **17** at a point low in the cylinder wall. Each intake bore **30** contains a one way valve **31** which will allow fuel to pass into the cylinders, but will not allow fuel to pass from the cylinders through the inlet bores **30**.

In operation, as piston **15** moves upward toward its cooperative cylinder head **18**, the lower volume of the cylinder **32** expands, creating a partial vacuum therein, which opens one way valve **31** allowing fuel to enter the lower portion of the cylinder. Upon ignition and commencement of the power stroke of the piston, the lower volume **32** of the cylinder is compressed so that when the cylinder reaches the low point of its reciprocal movement, thereby venting combustion chamber **25** through exhaust port **23** and exhaust bore **24**. Piston **15** simultaneously opens port **29** to fuel intake passage **27** so that the gases compressed in the lower volume of the cylinder **32** expand through ports **26** and **28**, passage **27**, and port **29** into the combustion chamber **25**, simultaneously aiding expulsion of exhaust gases, and filling the combustion chamber with a fresh supply of unburned fuel mixture. It will be appreciated that in the two-cycle internal combustion engine described herein, each of the opposed pistons on opposite ends of the reciprocating shaft **13** is performing a different function at each point of its reciprocal movement from the function being simultaneously performed by the other piston.

The advantageous construction of the two-cycle engine described above provides a positive exhaust and fuel injection system in a combustion chamber which is designed to enhance combustion of the fuel gases to a greater degree because of the special cooperative designs of the piston face and cylinder head.

While the internal combustion engine portion of the present invention has been described in a preferred embodiment having an opposed pair of two-cycle internal combustion cylinders, it will be appreciated by those skilled in the art that the present invention could also be operated using four, four-cycle cylinders wherein a pair of pistons were connected in tandem to each end of the reciprocating shaft **13**. At each point during the reciprocation of such a shaft and its cylinders, each one of the four, four-cycle cylinders operates simultaneously in a different cycle of the well known four-cycle internal combustion engine sequence.

As already discussed above herein, ports **23** and **26** in the walls of the piston heads **15** are designed to operatively align with exhaust bores **24** and intake bores **28**, respectively. This requires that the relative angular positions of the pistons and cylinder walls remain substantially constant. The cam follower should also move in a straight line path. In the present invention this is achieved by providing shaft **13** in the form of a longitudinal rod having a square cross-section. While shaft **13** is shown having a square cross-section, any other suitable cross-section, such as grooved cross-sections, or other polygonal cross-sectional shaft shapes may be used to achieve the desired result. Of course the more simple the cross-sectional shape of shaft **13** the easier it will be to provide bearings **14** in which the shaft **13** is seated, which bearings maintain the shaft and its attached pistons in the desired orientation within the cylinders. Standard piston rings are used in the inventive device, but not illustrated in the Figures herein.

The portion of the inventive device which converts the reciprocal motion of the piston rod or shaft **13** into the rotary motion which drives the variable vane pump portion of the device comprises a cam follower which is rigidly fixed at one point on the reciprocating shaft, and a rotatably mounted annular sleeve having a camming groove formed in its interior cylindrical surface, the sides of said groove forming cam surfaces which cooperate with the cam follower to rotate the annular sleeve about the axis of the shaft as the shaft reciprocates through the interior of the annular sleeve.

This portion of the inventive device is illustrated in FIGS. **1** and **3** wherein cam follower **37** is illustrated in the form of a cylindrical roller pivotally mounted on pin **38** rigidly attached to the square reciprocating shaft **13**. The annular sleeve in which the camming groove is formed is here designated **39** and is shown in FIG. **1** mounted coaxially to the axis of reciprocating shaft **13** and seated between bearings **33** which are seated on shoulders **34** which are an integral portion of the endwalls **11** of the central housing of the advantageous reciprocally driven variable volume rotary vane pump of the present invention. As shown in FIGS. **1** and **3**, the interior of annular sleeve **32** is hollow, and groove **35** opens into the interior cylindrical surface of annular sleeve **39**. Quadrant segments **40** are pinned to shaft **13** about the region where cam follower **37** is attached to that shaft, and those quadrant segments form a cylindrically shaped plug which minimizes any radial vibration in shaft **13** as it reciprocates within annular sleeve **39**. In the embodiment illustrated in FIG. **1**, the cam following roller **37** is shown to extend through the thickness of the annular sleeve **39**, but for the purposes of illustrating the circuitous nature of the path of the groove **35**, the ends of the groove as illustrated in FIG. **1**, are curved out of the proportions which would appear in a strictly illustrated sectional view. The side surface **36** of groove **35** are the surfaces which cooperate to provide the reaction forces between the cam following roller **37** which is attached to the reciprocating shaft **13**, and the camming surface **35** of the annular sleeve **39** which rotates about its axis.

A full 360° layout of the path of the camming groove **35** is illustrated in FIG. **4** in order to show other preferred features of the present invention. It will be appreciated that as the internal combustion pistons fire,

and as the shaft **13** reciprocates, that the cam follower **37** races through groove **35**, but typically makes firm contact with one side 36_1 of the camming groove **35** during the power stroke of one piston, while it makes contact with the other side 36_2 during the power stroke of the opposite piston. The present inventor has found that the efficiency of internal combustion mechanisms for converting reciprocating motion into rotary motion can be enhanced both from the point of view of realizing more useful power from the power stroke of the internal combustion engine, and from the point of view of facilitating complete combustion of the fuels used therein, by controlling the shape of the camming surface **36** throughout that portion thereof which, is in contact with the cam follower when the piston actuating the camming surface is in the initial stages of its power stroke. The shape of the camming surface **36** is designed to include a dwell flat, designated *d* in FIG. **4**, which has little or no pitch with respect to the axis of the annular sleeve in which the camming groove is formed. (That axis is directionally designated by line A in FIG. **4**). By providing a dwell flat d, if one of the pistons starts its power stroke when the cam follower **37** is located at the point designated P_1 in FIG. **4**, the dwell flat *d* maintains the piston in its substantially fully compressed position for a time *t* which is conceptionally designated by arrow *t* in FIG. **4** and is the time during which the annular sleeve **32** rotates the circumferential distance D_t. During this time *t*, the combustion of the fuel in the cylinder is allowed to sustain itself substantially to completion, and the substantially complete combustion maximizes the amount of combustion product gases within the cylinder chamber to maximize the pressure therein and therefore maximize the thrust force of the piston on the shaft, which force is transferred through the cam follower **37** to the camming surface 36_1. While the thrust forces are building to a maximum during the time *t*, the annular sleeve **39** is rotating so that at the end of the dwell time *t*, when the axial thrust force is maximized, the cam follower **37** starts into the portion of the camming surface 36_1 which has a greater pitch with respect to axis A, and angularly accelerates and imparts rotary motion to the annular sleeve **39** and to the variable volume vane pump mechanism of the device of the present invention. As illustrated in FIG. **4**, the dwell flat may be slightly pitched with respect to the axis A in order to maintain angular rotation of the annular sleeve even during the dwell period, although in other embodiments, the inertia of the device may be sufficient to allow operation thereof without any pitch in the dwell flat portion of the camming surface **36**. The incline of the operative camming surface **36** can be tailored to the power curve of the piston in each specific embodiment of the inventive system.

The pump portion of the inventive device is located within the central housing **10** between the endwalls **11**, coaxially around reciprocating shaft **13** and rotating sleeve **39**. Sleeve **39** is attached to the interior surface of a sleeve **41** which is more recognizable as the interior ring **41** in FIG. **2**. Sleeve **41** is shown pinned to sleeve **39**, and both sleeves **39** and **41** are coaxial to the centerline of square shaft **13**. Sleeve **41** is isolated in FIGS. **6A**, **6B**, and **6C** which are described in detail later herein.

The variable volume vane pump portion of the device further comprises a series of vanes **42** which are located in slots **43** spaced around the circumference of sleeve **41**, and whose radially iner edges sometimes bear in contact with the bottom of slots **43** (as shown for example in the right hand portion of FIG. **2**), and whose radially external edges bear against the internal cylindrical surface of outer sleeve **44**. Each of the vanes **42** comprises a flat strip or vane whose major direction is substantially parallel to the axis of the reciprocating shaft and entire rotary pumping mechanism, and whose minor axis is typically substantially parallel to a diameter of the pump device. The vanes longitudinally extend throughout the distance between the two end walls **11** of the central housing **10**, and the angular spacing between the individual vanes is maintained by the slotted sleeve **42**. Rings **45** are located at each end of vanes **42** float in bearing contact with the inner faces of the end walls **11** of the central housing **10**. These so-called floating rings **45** maintain bearing contact with the ends of the radially inner edges of the vanes **42** and maintain the radially outer edges of the vanes **42** in contact with the inner cylindrical surface of outer sleeve **44**, even when the vanes slide within slots **43** in sleeve or inner ring **41**.

Also illustrated in FIGS. **1** and **2** are inlet and outlet conduits **46** and **47** through which the fluid being pumped by the advantageous device of the present invention enters and leaves the pumping apparatus. In conjunction with inlet conduit **46**, FIG. **2** illustrates enlarged inlet groove **48** which is a circumferential extension of the inlet port **49** which opens into the interior cylindrical surface of sleeve **44**. Similarly, exit conduit **47** has a smaller circumferentially enlarged portion **50** of exit port **51**. Each of the grooves **48** and **50** extends from a point somewhat circumferentially ahead of its corresponding port, and then through the vext 90° of circumference to provide relief for any fluid trapped and compressed between vanes after passing the exit port.

FIG. **2** further illustrates preferred features of the present invention wherein each edge of each vane **42** is rounded in an arc having a diameter equal to the width (minor axis) of the vane, as further illustrated in the enlarged view of FIG. **5**. In FIG. **5** diameters **52** and **53** of vane **42** are equal. Pump vanes of this shape facilitate minimizing friction between the vane edges and the interior cylindrical wall of sleeve **44** and the exterior wall of rings **45**, while providing an efficient seal between the vane and walls to provide the pumping action desired in variable volume vane pumps of this type.

FIG. **2** further illustrates the advantageous unitary block construction **12** of the adjustable portion of the main housing **10**. As shown in FIG. **2**, sleeve **44** is tightly fitted within a large cylinder bored through slidable block **12** in the direction which the reciprocating shaft **13** passes therethrough. The end walls **11** of the central housing **10**, first referred to in FIG. **1**, are joined by side walls **54** and the distance between those side walls is greater than the thickness of the slidable block **12**. The vane pumping mechanism is sealed between end walls **11** by circular seals **55** which, as shown in FIG. **1**, are seated within grooves in the ends of outer sleeve **44**, and make sealing contact with end walls **11**. Slidable adjustment block **12** is moved by means of forces applied to shaft **56** which extends through opening **57** in side wall **54**, and is rigidly connected to one side face of block **12**. Any suitable source of force, such as various manual, hydraulic, or mechanical lever

systems may be used to adjust the location of the slidable block **12.**

It will be appreciated that when the source of fluid to be pumped is connected to input channel **46,** that movement of the slidable block **12** to a position so that the major bore of the pumping mechanism in block **12** is off-center with respect to the axis of rotation of the rotary portion of the mechanism driven by shaft **13,** the eccentric position of the rings controlling the movement of the vanes will cause a reduction of pressure just inside intake port **49** so that the fluid will have a tendency to flow into the pumping mechanism, and will be compressed as the fluid arrives near exit port **51** so that it will be pumped through exit conduit **47** at a higher pressure than it entered intake conduit **46.** By varying the relationship of the eccentricity of the interior portion of the rotary vane pump to its exterior ring **44,** by adjusting the position of block **12,** the volume, and therefore the rate of delivery of the pump may easily be controlled.

It will also be appreciated that by changing the eccentricity of the adjustment block **12** from one side of the shaft **13** to the other, that the direction of flow of fluid through the pump mechanism can be reversed. That is, if block **12** is shifted to the right in the view shown in FIG. **2,** the pumped fluid will flow in conduit **47,** clockwise around the right side of the vane mechanism, and exit through conduit **46.**

The advantageous unitary construction of slidably mounted control block **12,** greatly simplifies the structure of the variable volume vane pumping mechanism portion of the present invention over those used in variable volume vane pumps now available. The reduction in the number of moving parts provides a simple and economical mode in which to manufacture and use the present device. This pump is also less susceptible to mechanical failure due to its inherent simplicity.

In addition to the features of the present invention already described above herein, the variable volume rotary vane pump and integral opposed reciprocating piston internal combustion engine includes a secondary system for injecting fluids (in addition to the combustion mixture), into the combustion chambers. This secondary injection system is actuated by a cam-operated tripping mechanism which is located in conjunction with the end walls of the central housing and the inner sleeve of the variable vane pump portion of the mechanism. Similarly, the timing sequence which initiates ignition of the combustible mixture in the cylinders of the internal combustion engine, may be controlled by such a cam-operated tripping system.

As shown in FIG. **1,** the inventive device is provided with conduit **60** a portion of which is bored into end plates **11** of the central housing, and which therein connect with a pump **61.** A small piston-type pump may be used here. This pump exits through valve **62** into conduit **63,** a portion of which is also bored in end plates **11** and then passes externally parallel to cylinders **16,** re-entering the cylinder heads **18,** and emerging at the circular surface of the extended portion of the cylinder head **18** which cooperates with the shaped face of piston **15.** This end of conduit **63** is provided with an injection nozzle **64** such as those used in the fuel systems of diesel engines, which facilitates throwing a fine mist of fluid into the combustion chamber.

Pump **61** and its associated valve **62** are activated through a cam-operated tripping system, a portion of which is located on each end of annular sleeve **41** which forms the inner ring of the variable vane pump portion of the device. Annular sleeve **41** is illustrated in FIG. **6A** which is a top view showing the plan of tripping cams **65** which are designed to operate when the sleeve **41** rotates in a direction indicated by arrow R. FIG. **6B** shows the sleeve **41** of FIG. **6A,** but in side view, and FIG. **6C** shows an end view of the same sleeve, additionally illustrating the relative positions of a pump tripping cam follower **66** and a point cam follower **67.** The cam followers illustrated in FIG. **6C** are not actually attached to the ring-like surface **68** which forms the end of the sleeve **41,** but are illustrated in FIG. **6C** to show their positions relative to the surface **68** and to the tripping cam **65** which is formed on that surface. FIG. **6C** also shows in phantom lines, the vanes **42,** inner surface of outer sleeve **44,** and floating ring **45.**

The relationship of the cam followers to the rest of the apparatus can more clearly be seen in FIG. **1** wherein the square face of tripping cam **65** is shown extending laterally from the cross-section of one half of sleeve **41** in the upper portion of the longitudinal section of FIG. **1.** Contacting the outer surface of tripping cam **65** is a roller portion of pump cam follower **66,** the extension of which is shown engaged with pump **61.**

While the point cam follower, which is used to activate the electrical timing system which initiates ignition of the combustion mixture in the cylinders, is not illustrated in FIG. **1,** the point cam follower **67** is substantially identical to the construction of pump cam follower **66,** and is operably connected to mechanically activate an electrical switching mechanism to trigger ignition in the internal combustion engine. Other portions of the electrical ignition system of an internal combustion engine are not illustrated here since they are well known elements in the internal combustion engine arts.

In operation, the secondary injection system described herein is typically used to inject water, steam, or any other suitable fluid into the combustion chambers, to thereby internally cool the engine, provide additional pressure by vaporization of the fluid or expansion of the steam within the combustion chambers, thereby utilizing the heat energy from the exhaust gases, which energy is presently discarded in the exhaust system, and saturate the exhaust gases with steam thereby diluting pollutants in the exhaust gases. A preferred mode of injecting steam into the combustion chamber in the present invention comprises setting the angular spacing between the pump cam follower and point cam follower such that the point cam follower triggers combustion of the combustible fuel mixture in the cylinders at the time the cam follower **30** is located at about the point P_1 in FIG. **4,** and the pump cam follower is angularly spaced around the surface **68** (FIG. **6**) an angular distance D_t corresponding to the angular length of dwell flat *d* (FIG. **4**) so that the pump cam follower activates the pump to release steam through jet **64** into the combustion chamber just as the pressure in the combustion chamber is maximized and the axial force starts cam follower **37** into the steeper portion of the camming surface 36_1 to angularly accelerate sleeve **39.** Injection of the water or steam enhances the pressure in the combustion chamber and provides the other effects noted above. Of course it will be appreciated that the angularly spacing of the point cam follower

and pump cam follower may be adjusted in various embodiments of the invention to provide any desired sequence of ignition and secondary injection.

Although specific components and designated proportions and arrangements of elements have been stated in the above description of preferred embodiments of this invention, other suitable equivalent components and arrangements of elements may be used with satisfactory results and various degrees of quality, or other modifications may be made in this system to synerigize or enhance its construction to thereby increase its utility. It will be understood that such changes of details, materials, arrangement of parts, and uses of the invention described and illustrated herein are intended to be included within the principles and scope of the claimed invention.

What is claimed is:

1. An apparatus for converting reciprocal motion into rotary motion, comprising:

a shaft slidably mounted for reciprocation parallel to its length;

an internal combustion engine cylinder mounted at each end of said shaft with the piston of said cylinder connected to said shaft for reciprocal motion parallel to the length of said shaft;

a cam follower extending radially from said shaft at a point located between said cylinders;

an annular sleeve having a continuous camming groove formed in its internal cylindrical surface, said sleeve located coaxially to the axis of said shaft between the cylinders connected to the ends of said shaft, and said cam follower which extends radially from said shaft engaging the camming groove in the interior cylindrical surface of said sleeve;

said camming groove having side camming surfaces which comprise dwell flats, the leading portion of said dwell flats positioned for contact by said cam follower when one of said pistons is at the beginning of its power stroke, for maintaining said one piston in its compression position for a dwell period.

2. The apparatus of claim **1** wherein each of said pistons comprises a cylindrical block everywhere having an H-shaped cross-section, the major axis of said H-shaped cross-section parallel to the axis of said shaft, and an end of said shaft connected to the portion of said cylindrical block which forms the cross bar of said H-shaped cross-section.

3. The apparatus of claim **2,** wherein each cylinder additionally comprises a cylinder head having a generally cylindrical portion which extends into the open combustion chamber portion of said engine cylinder.

4. The apparatus of claim **3,** wherein the cylindrical portion of said cylinder head which extends into said engine cylinder has a surface which substantially parallels the surface of the piston face portion of said H-shaped piston, so that said extending cylindrical portion of said head and said piston face portion cooperate to form a compressed combustion zone having substantially uniform thickness at maximum compression.

5. The apparatus of claim **4,** wherein said extending cylindrical portion of said cylinder head has at least one passage therethrough into which extends means for igniting combustible gases.

6. The apparatus of claim **2,** wherein each of said engine cylinders additionally comprises a fuel intake valve opening into said engine cylinder near the base of the engine cylinder below said piston;

an intake passage extending from about the level of said intake valve, through the wall of the block in which said engine cylinder is bored, and connecting the upper portion of said engine cylinder at a point above the piston face of said piston when said piston is in its lowest position;

and an exhaust port located in the side wall of said engine cylinder;

and said piston having a port in the cylindrical flange which forms the lower side wall of said H-shaped cross-section, for operative alignment with the lower opening of said intake passage in the side wall of said engine cylinder;

said piston also having a port therein in the cylindrical flange which forms the upper side wall of said H-shaped cross-section, extending into the piston face for operative alignment with the exhaust port in the side wall of said engine cylinder.

7. The apparatus of claim **6,** additionally comprising means for injecting a second fluid into an engine cylinder.

8. The apparatus of claim **7,** wherein said means comprises a fluid conduit terminating in a jet nozzle on the internal surface of a cylinder head.

9. The apparatus of claim **6,** wherein said shaft has a cross-sectional shape which is polygonal.

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