

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

Primary Examiner—William L. Freeh

Attorney, Agent, or Firm—Stevens, Davis, Miller & Mosher

[76] Inventor: **Benjamin Norman Joyce, Sr.**, Rt. 6,
Box 226, Bassett, Va. 24055

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[51] Int. Cl. **F04b 17/00**

[58] Field of Search **418/31; 417/321, 338, 364,
417/375, 380, 396; 74/57**

[56] **References Cited**

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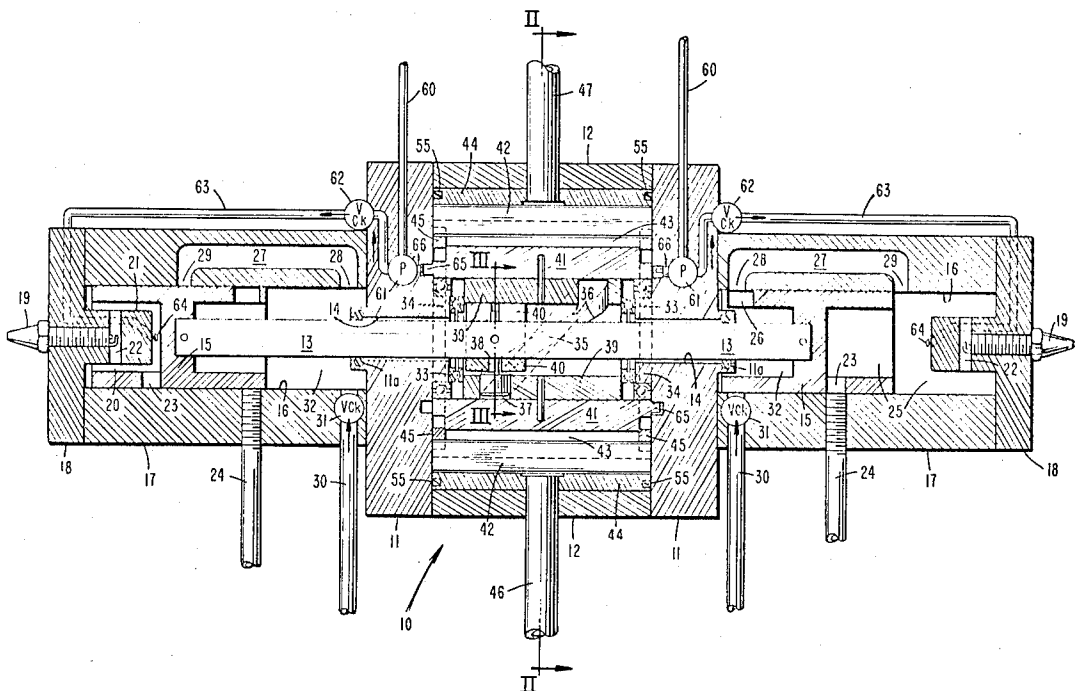
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[57]

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.

6 Claims, 8 Drawing Figures



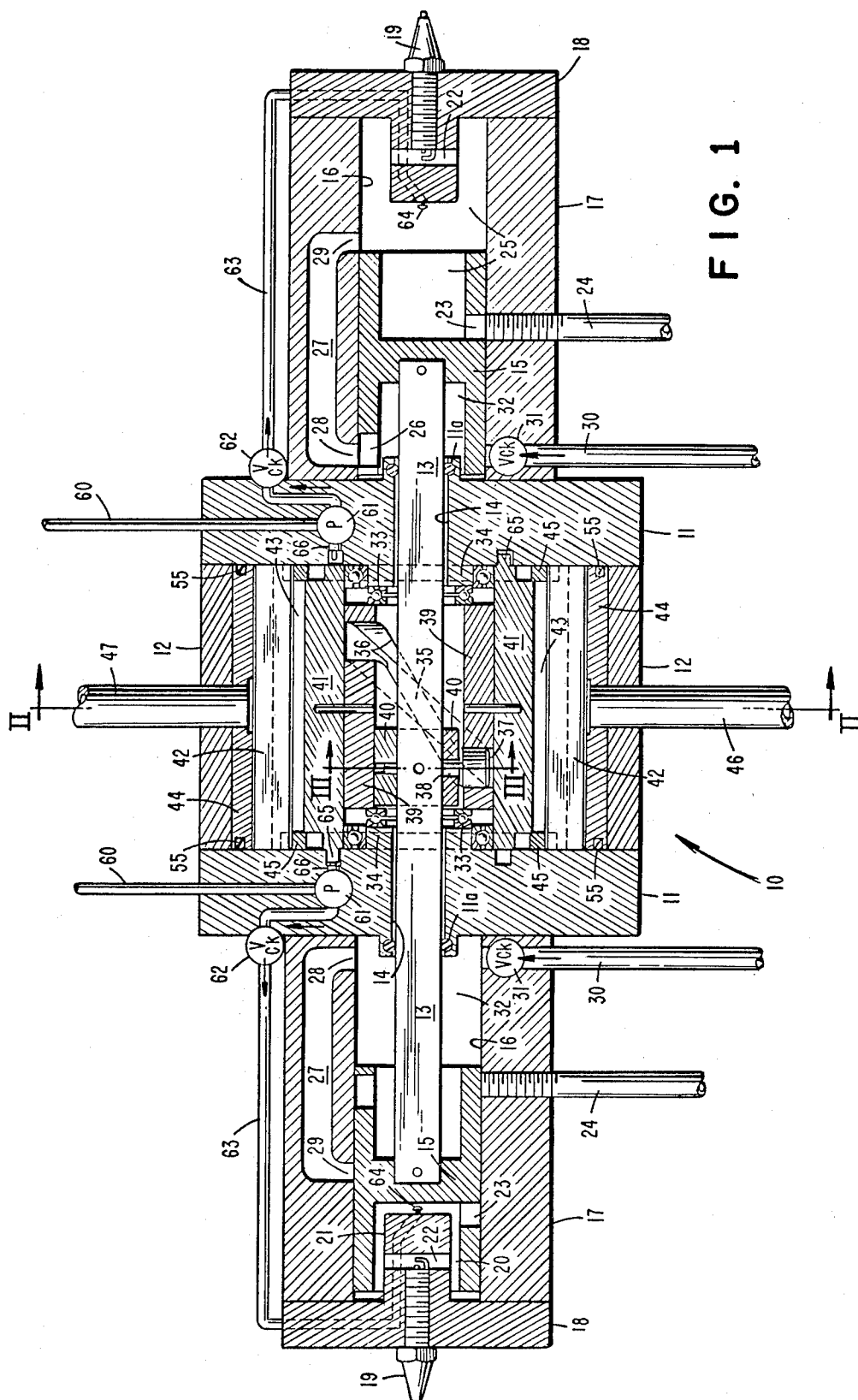


FIG. 1

FIG. 2

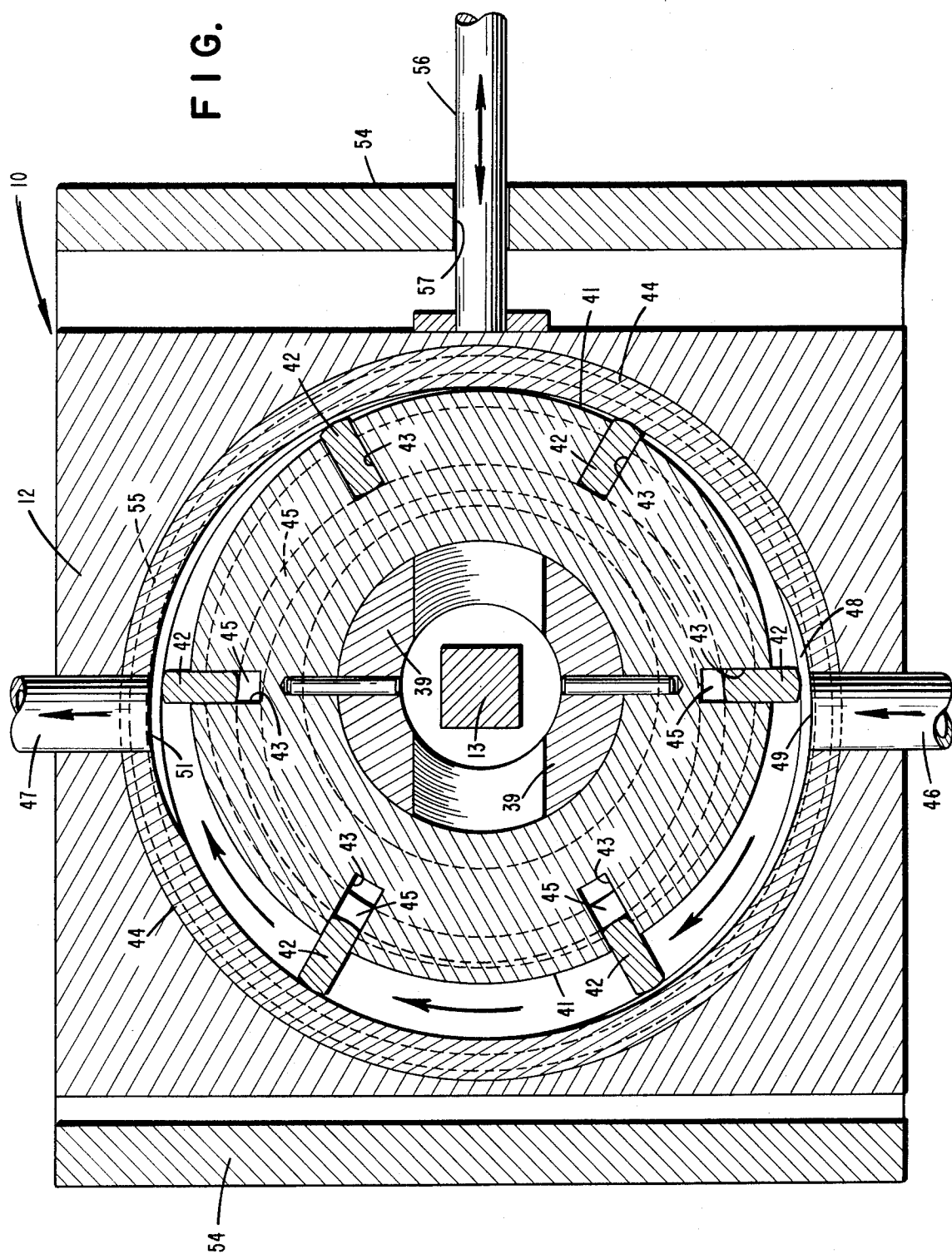


FIG. 3

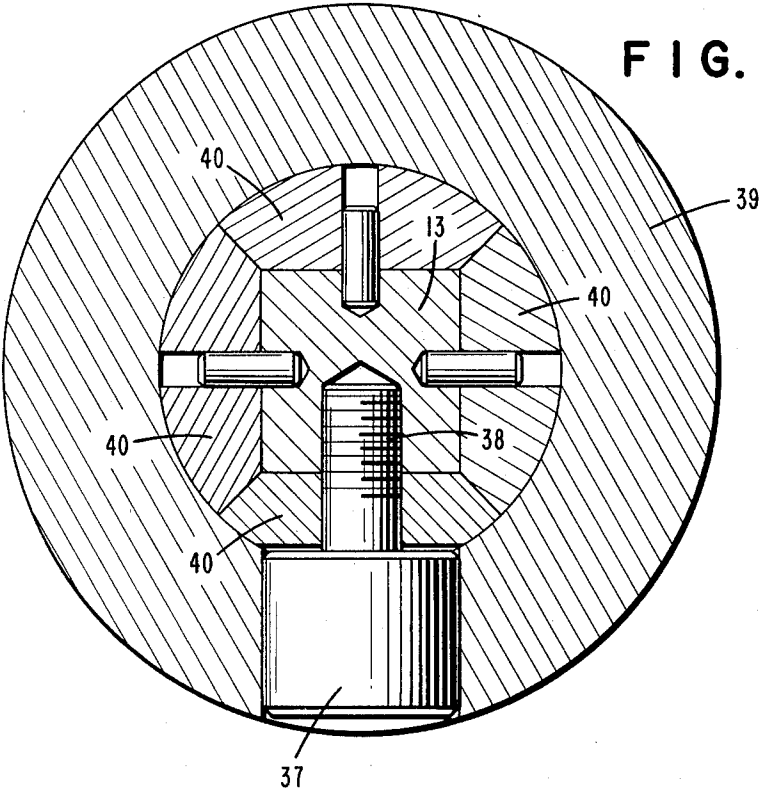


FIG. 5

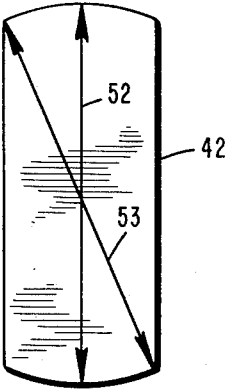
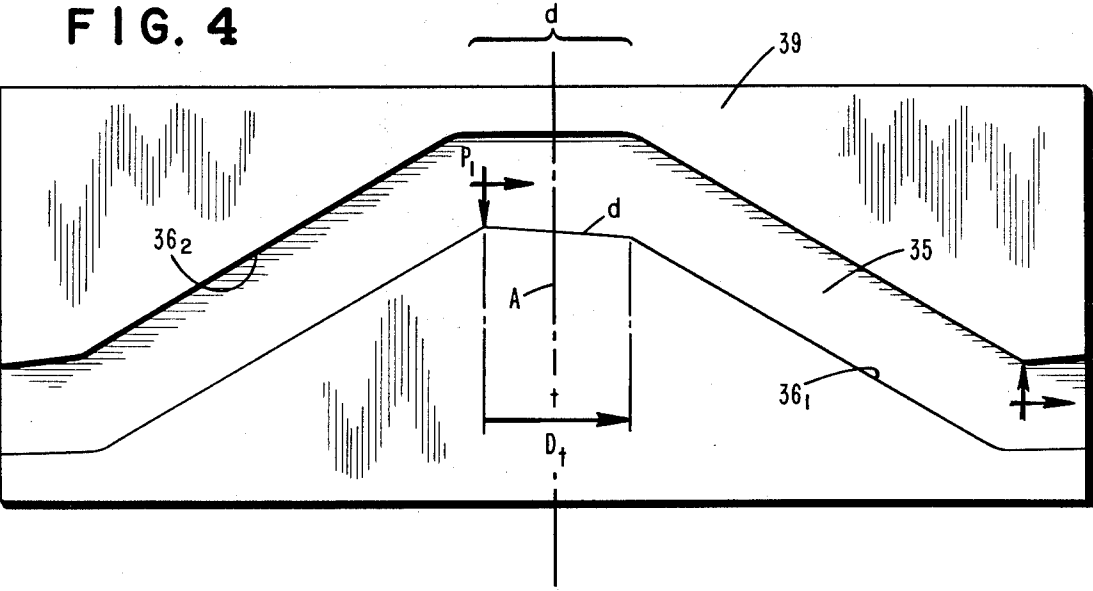


FIG. 4



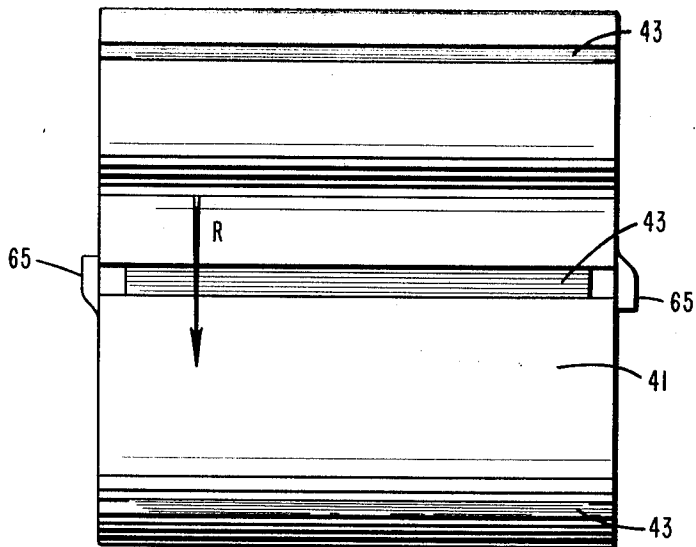


FIG. 6A

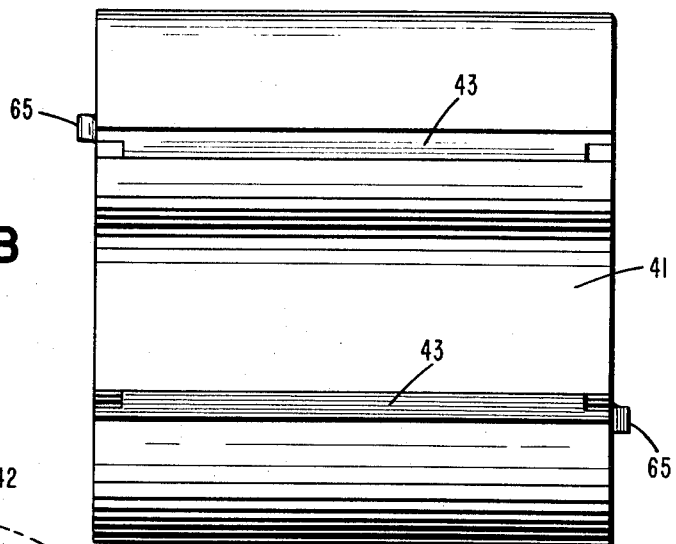


FIG. 6B

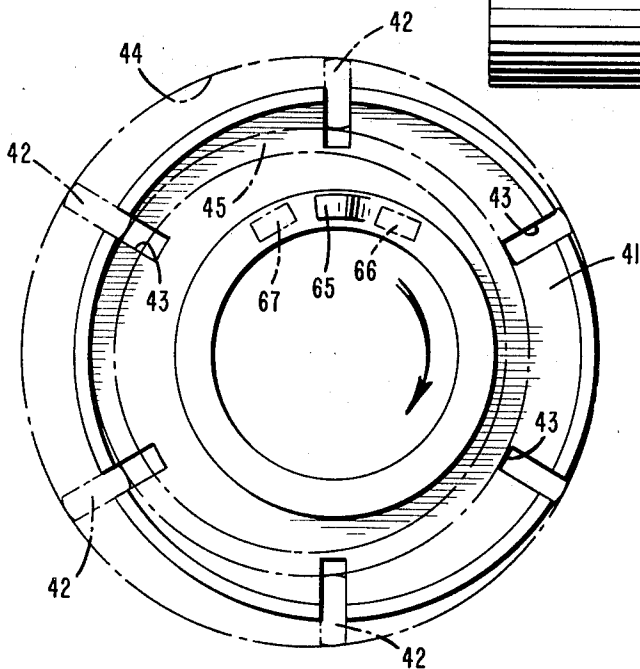


FIG. 6C

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

This is a division, of application Ser. No. 285,650, filed Sept. 1, 1972.

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. 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 reciprocating 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 11a, 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 26 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 end-walls 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 ap-

preciated 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 36₁ of the camming groove 35 during the power stroke of one piston, while it makes contact with the other side 36₂ 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 P₁ 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_r. 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 36₁. 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 36₁ 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 inner 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 next 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 open-

ing 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_1 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 camming surface 36, 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 synergize 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. Pumping apparatus, 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;

and a variable volume vane pump, the inner sleeve of which is coaxial with and connected to said annular sleeve, for rotary movement of said vane pump.

2. The apparatus of claim 1, wherein said variable volume vane pump includes a unitary adjustment block, in which said pump is mounted, said adjustment block slidably mounted for movement transverse to the direction of reciprocal motion of said shaft for changing the eccentricity of its inner sleeve to the remainder of the pump mechanism.

3. The apparatus of claim 1, additionally comprising a cam surface on the end surface of said inner sleeve, and a pump cam follower mounted for engagement with said cam surface on the end surface of said inner sleeve, for initiating ignition of a combustible mixture in an engine cylinder.

4. Pumping apparatus, 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, wherein the pis-

ton for at least one cylinder 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;

and wherein at least one 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;

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;

means for injecting a second fluid into an engine cylinder;

and a variable volume vane pump, the inner sleeve of which is coaxial with and connected to said annular sleeve for rotary movement of said vane pump, said means for injecting a second fluid into an engine cylinder being actuatable by a cam surface on the end surface of said inner sleeve.

5. The apparatus of claim 4, wherein said means comprises a fluid supply conduit connected to a pumping mechanism actuatable by a pump cam follower mounted for engagement with the cam surface on the end surface of said inner sleeve, and a fluid conduit connecting the exit of said pumping mechanism to a jet nozzle located on the internal surface of the cylinder head.

6. The apparatus of claim 5, additionally comprising a pump cam follower mounted for engagement with said cam surface on the end surface of said inner sleeve, for initiating ignition of a combustible mixture in an engine cylinder, said pump cam follower located to contact said cam surface when the cam follower which extends radially from the reciprocating shaft starts to contact a dwell flat,

and said pump cam follower located to contact said cam surface just before the cam follower which extends radially from the reciprocating shaft leaves said dwell flat.

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