United States Patent [19]

Massie

[11] **3,738,337**

[45] **June 12, 1973**

[54] **ELECTRICALLY OPERATED HYDRAULIC VALVE PARTICULARLY ADAPTED FOR POLLUTION-FREE ELECTRONICALLY CONTROLLED INTERNAL COMBUSTION ENGINE**

[76] Inventor: **Philip E. Massie,** 4220 Irving Place, Culver City, Calif. 90230

[22] Filed: **Dec. 30, 1971**

[21] Appl. No.: **213,881**

[52] **U.S. Cl.** **123/90.12,** 123/90.11, 251/30

[51] **Int. Cl.** **F01l 9/02,** F01l 9/04

[58] **Field of Search** 123/90.12, 90.11, 123/90.14

[56] **References Cited**

UNITED STATES PATENTS

885,459	4/1908	Engler et al.	123/90.12
2,827,884	3/1958	Stivender	123/90.12
3,209,737	10/1965	Omotenara et al.	123/90.12
3,548,793	12/1970	Richardson	123/90.12

FOREIGN PATENTS OR APPLICATIONS

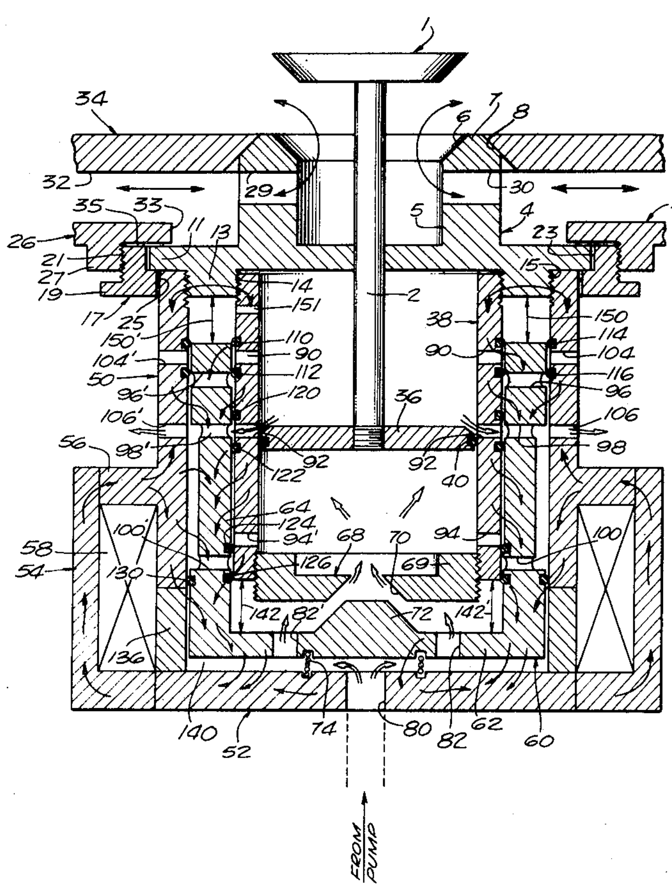
1,916,167	10/1970	Germany	123/90.11
1,944,177	3/1971	Germany	123/90.12
1,962,916	6/1971	Germany	123/90.12

Primary Examiner—Al Lawrence Smith
Attorney—Albert M. Herzig and Albert M. Herzig

[57] **ABSTRACT**

An electrically operated hydraulically driven valve driven by internal combustion engine lubricating oil. A ported valve sleeve is positioned between inner and outer cylinders, the inner of which is the hydraulic valve operating cylinder. All concentric members have radial ports. The electrically operated sleeve member controls the porting controlling the inflow and outflow of hydraulic liquid. The control sleeve is moved electromagnetically by way of electromagnetic windings combined with a permanent magnet adapting the operation to pulse type of digital control adapting the valve to electronic digital control from multiple variable inputs.

16 Claims, 5 Drawing Figures



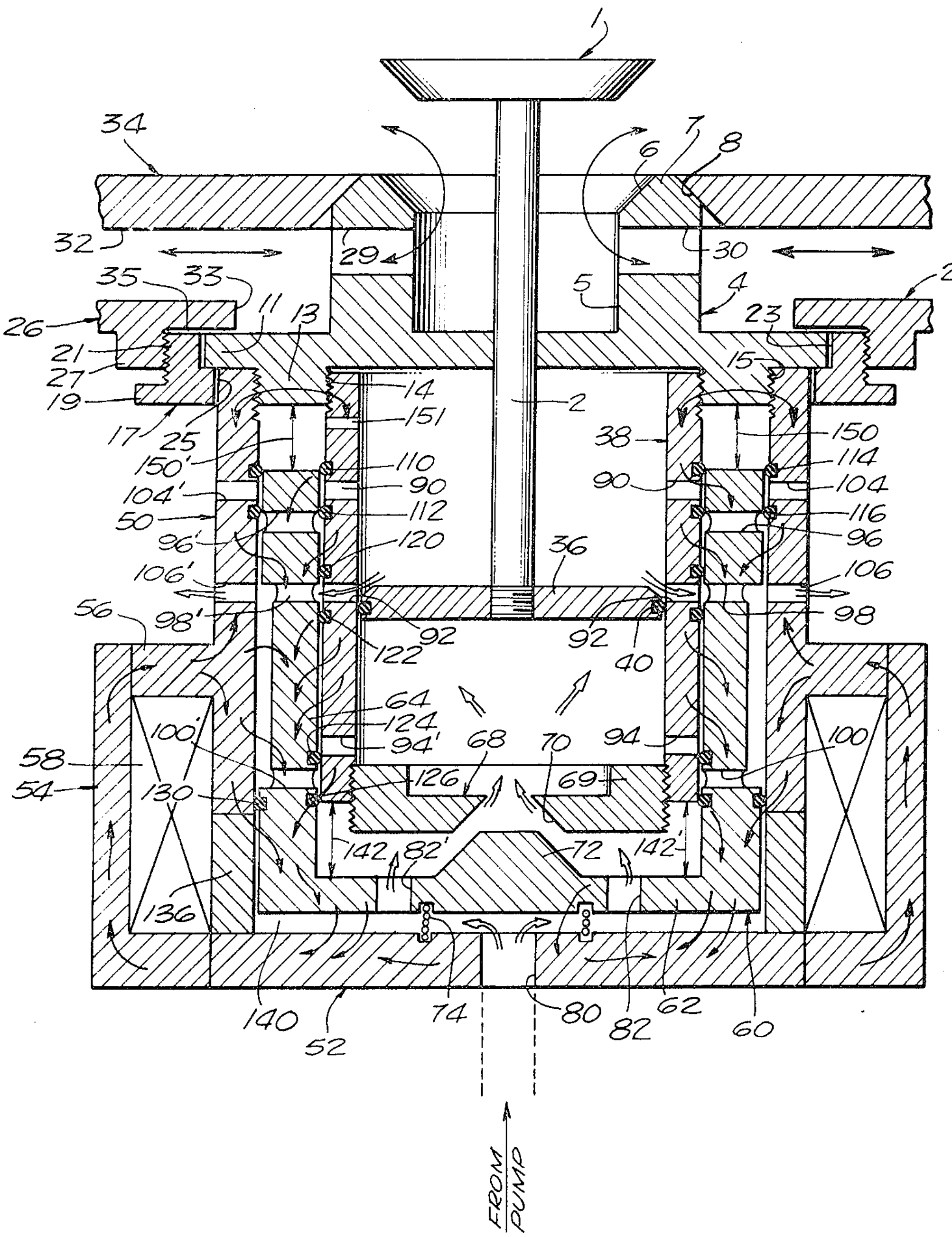


FIG. 1.

INVENTOR
PHILIP E. MASSIE
BY
ALBERT M. HERZIG
EDWARD C. WALSH
ATTORNEYS

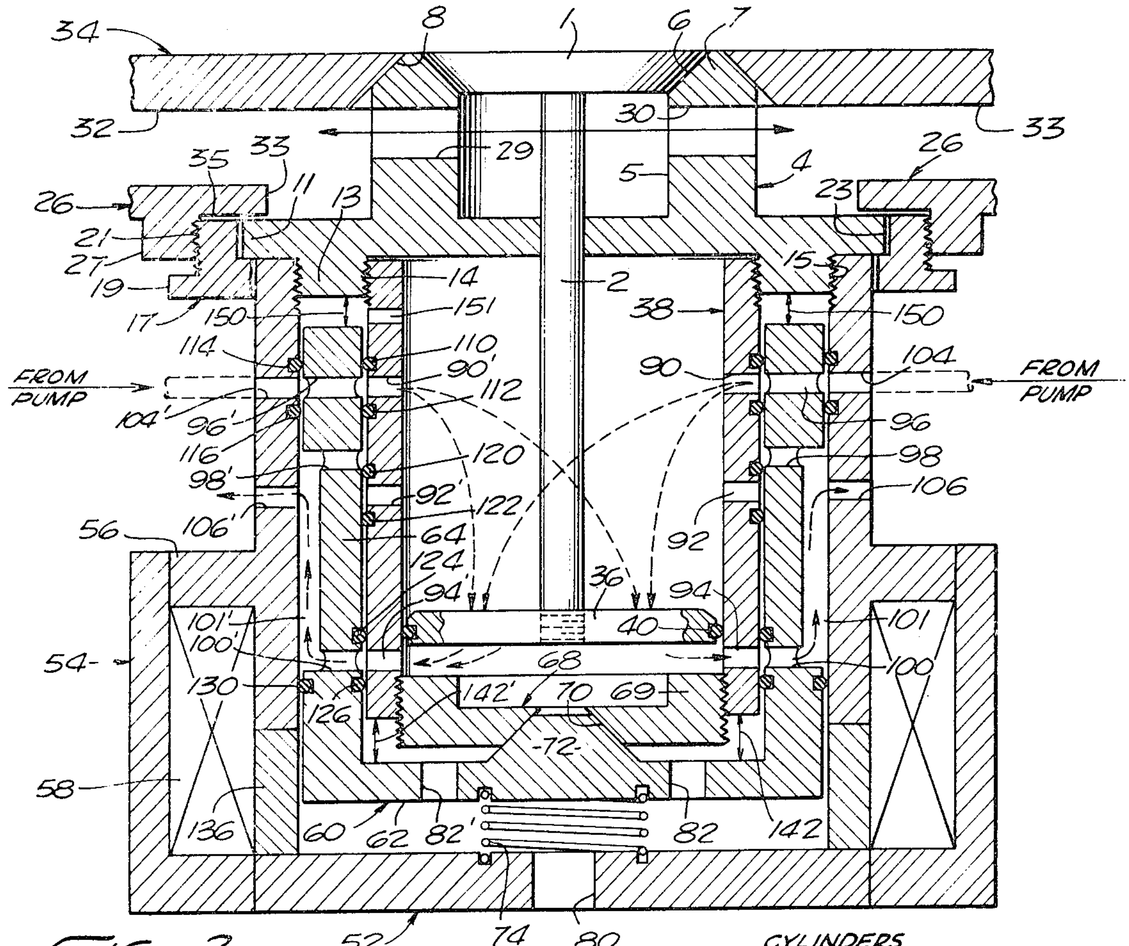


FIG. 2.

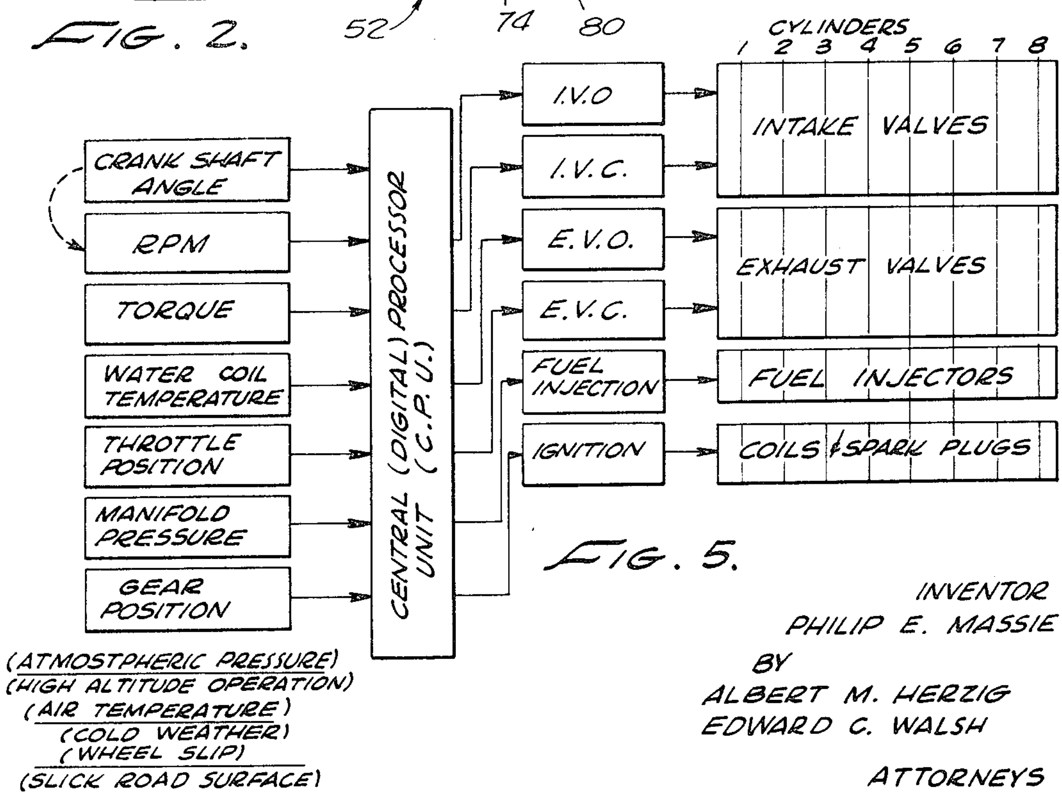


FIG. 5.

INVENTOR
PHILIP E. MASSIE
BY
ALBERT M. HERZIG
EDWARD C. WALSH
ATTORNEYS

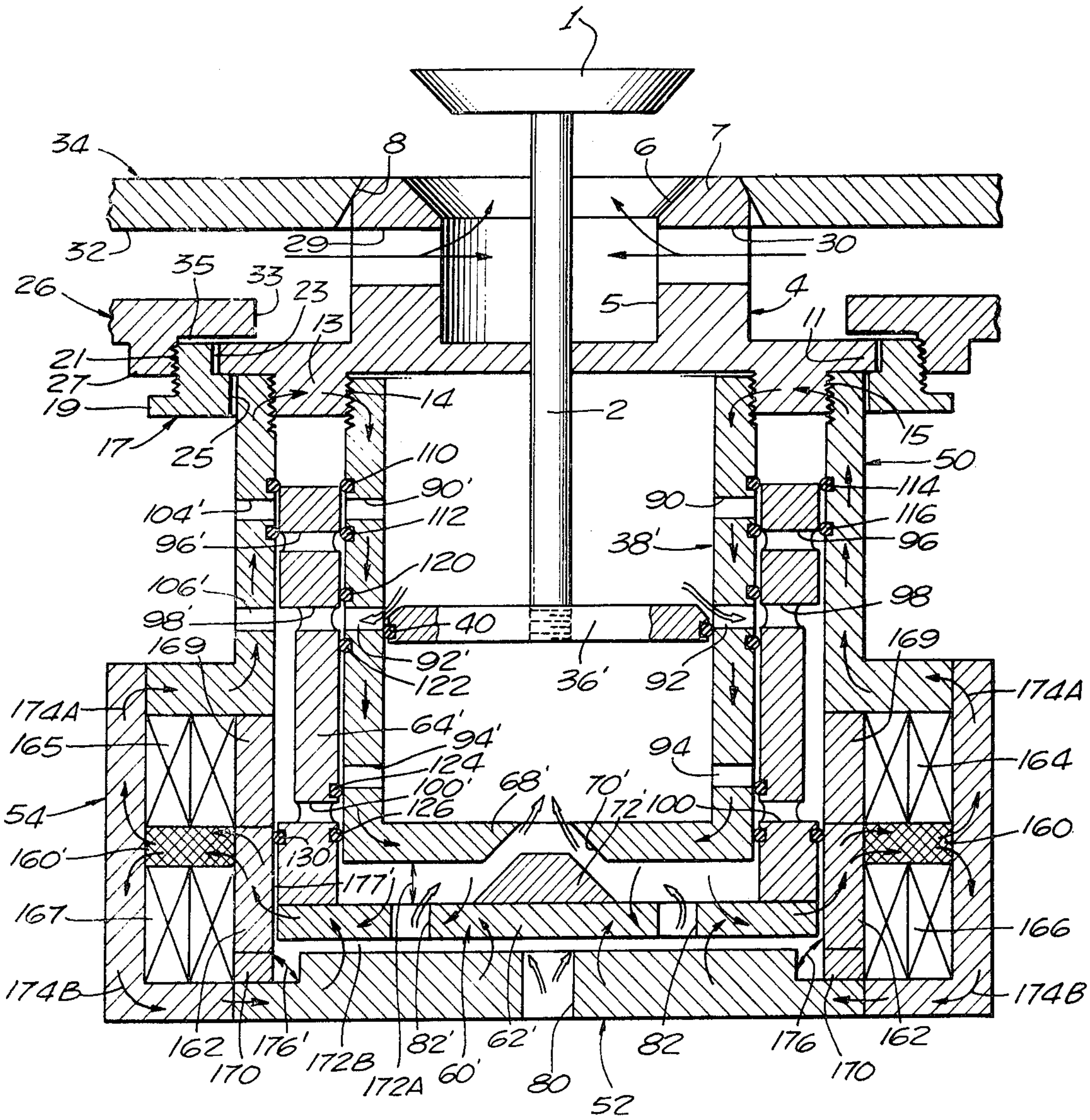


FIG. 3.

INVENTOR
PHILIP E. MASSIE
BY
ALBERT M. HERZIG
EDWARD C. WALSH
ATTORNEYS

PATENTED JUN 12 1973 3.738,337

SHEET 4 OF 4

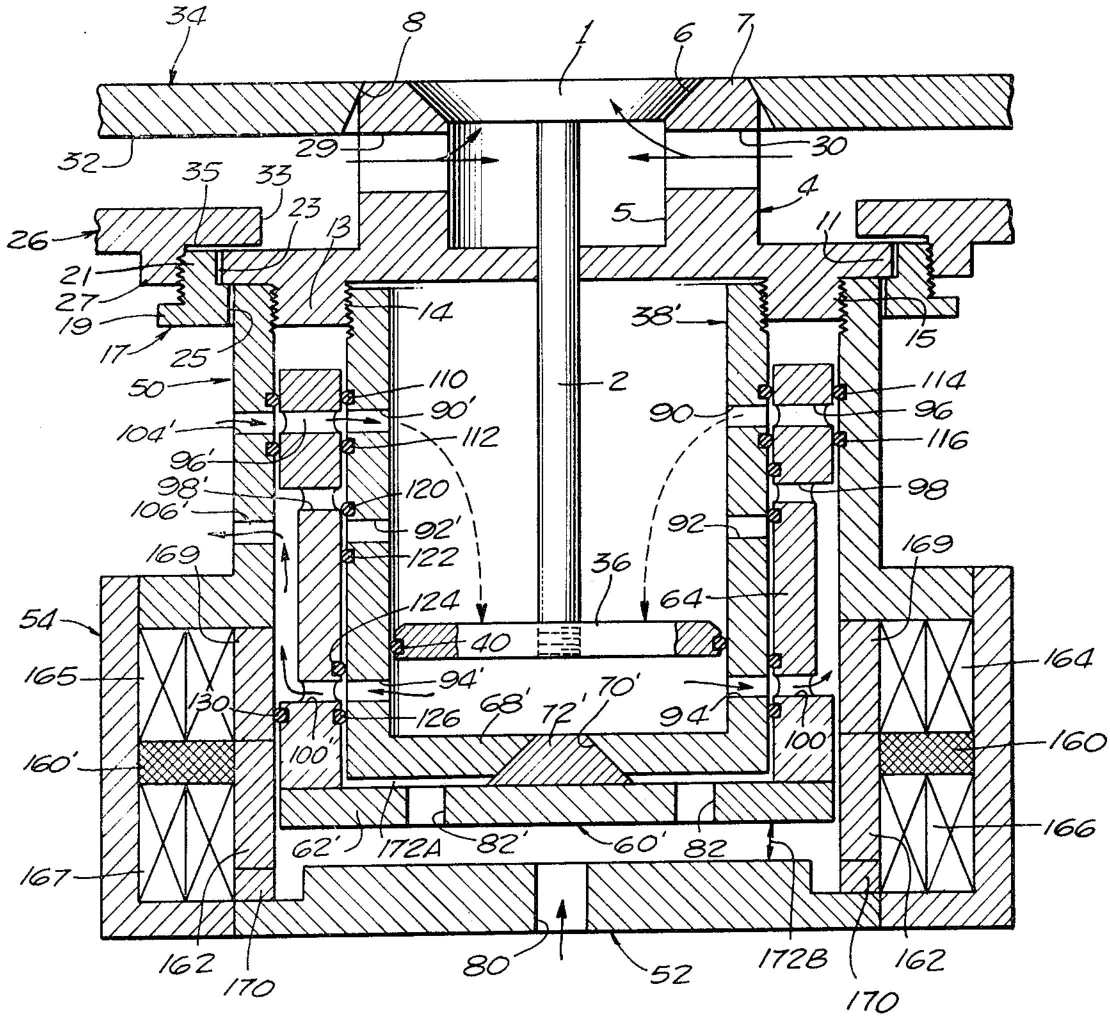


FIG. 4.

INVENTOR
PHILIP E. MASSIE
BY
ALBERT M. HERZIG
EDWARD C. WALSH
ATTORNEYS

ELECTRICALLY OPERATED HYDRAULIC VALVE PARTICULARLY ADAPTED FOR POLLUTION-FREE ELECTRONICALLY CONTROLLED INTERNAL COMBUSTION ENGINE

SUMMARY OF THE INVENTION

This valve is an electric/hydraulic Servo Valve designed to be installed as either the intake or exhaust valve on an internal combustion engine.

This valve is designed to enable the timing of the opening and closing of the intake and exhaust valves of an I.C. engine to be operated and varied by a digital processor (computer). Such operation will permit changing the four significant valve operating points to match the operating conditions of the engine. It will serve as a replacement for "full race" cam, three-fourths race cam, "normal" cam and low speed cam shaft. By varying the operating times of the four valve points (in conjunction with fuel injection and ignition) the I.C. engine can be operated at the optimum (smog-free) timing, regardless of engine speed, torque, temperature or acceleration demand. It should enable a single I.C. engine to idle at 300 to 500 rpm without excessive pollutants or at maximum engine speed, under low speed and high torque (drag race) or high speed acceleration (freeway passing).

The assembly opens and closes the valve to allow for fuel/exhaust between the intake/exhaust manifold in the engine cylinder head to the combustion chamber. Since I.C. engines may operate at rotational speed to 11,000 rpm, valve operation time must be in the fractions of millisecond time.

The particular, unique design of the valve described herein involves some further considerations. As stated above, the valve may be installed as either the intake or the exhaust valve on an internal combustion engine. All parts of the valve are cylindrical, positioned about a common axis which is the axis of the valve stem. These considerations are significant to the installation of the valve. Space considerations are another factor, the space required by the porting arrangement of the valve being such as to optimize it from the standpoint of space required. The valve is operated directly by the lubricating oil system of the internal combustion engine and its construction is such as to eliminate need for plumbing connections inasmuch as inlet ports to the oil operated valve and vent ports may in effect be built-in, having direct connection to the pressurized side of the lubricating system and back to the crankcase. Another factor is that all of the parts of the valve being cylindrical, their fabrication and that of the porting is simplified inasmuch as it can be accomplished by unsophisticated machine operations.

The primary object of the invention is to make available a valve which is adapted for hydraulic operation by lubricating oil of an internal combustion engine and which is electrically controlled, being adapted for pulse-type digital control. The particular construction of the valve is such as to realize a number of particular objects as follows.

An object is to provide a valve of appropriate size adapting it to be installed as either the intake or the exhaust valve of the internal combustion engine and characterized in that the valve is movable between fully opened and closed positions in response to a single electromagnetically operated control valve member in the form of a ported sleeve.

Another object is to realize a valve of the type operated by a hydraulic piston in a cylinder wherein the cylinder has side ports for admission and exhaust of hydraulic fluid which are controlled by a ported sleeve reciprocatable with respect to the cylinder.

Another object is to realize a valve of the type referred to in the previous object wherein the control sleeve is positioned between the inner cylinder and an outer cylinder and constitutes the armature of an electromagnetic system adapted to move it so as to produce valve operation between fully open and fully closed positions.

Another object is to realize a valve of the type referred to wherein all of the parts are cylindrical having a common axis thereby facilitating fabrication of its parts.

BRIEF DESCRIPTION OF THE DRAWINGS

Further objects and additional advantages of the invention will become apparent from the following detailed description and annexed drawings wherein:

FIG. 1 is a cross sectional view of one form of the valve of the invention illustrating the fluid flows and magnetic flux flows;

FIG 2 is a cross sectional view of the valve of FIG. 1 showing the valve in a closed position;

FIG. 3 is a cross sectional view of another form of the valve of the invention using a different electromagnetic system, this figure showing the electromagnetic flux flow;

FIG. 4 is a cross sectional view of the form of the invention shown in FIG. 3 with the valve in closed position; and

FIG. 5 is a diagrammatic view of an internal combustion engine controlled by a digital processor.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIGS. **1** and **2** show one form of the invention, and these figures are schematic in order to clearly illustrate the structure and operation. The valve head is designated at **1.** The valve has a stem **2** and seat. The valve assembly comprises an upper body **4** having a bore **5** in it and a tapered counterbore **6** which forms the seat for the valve. Body **4** is fitted into the cylinder head by way of the upper cylindrical part **7** of the body **4** being fitted into conical bore or opening **8.** Body **4** has an extending flange **11** and has downwardly or depending extending circular rib or flange **13** which is internally and externally threaded as shown at **14** and **15.** Numeral **17** designates a ring member which has a bottom flange **19** formed as a hexagonal nut and which is externally threaded as shown at **21.** Body **4** seals to bore **8.** Ring **17** seals to **11** and **27.** The valve is rotatable into position. Cylinder head **34** has an extending flange **27** which is internally threaded. Ring member **17** is threaded into the internal diameter of this flange. The upper cylindrical portion of the body member **4** has bores or channels **29** and **30** communicating with the axial bore **5.** These channels communicate with channels **32** and **33** within head **34.** These channels are for admission of combustible materials when the valve is installed as an inlet valve, or for products of combustion if the valve is installed as an exhaust valve.

Part **7** seals against surface **8.** Flange **11** seals against nut **27.** The valve itself must be free to rotate to the correct installation position. Member **17** is a nut, and it creates the seal at these points. A high pressure seal is formed at conical surface **8**. A clearance is provided at **35**, this area being subjected to manifold pressure only, which is usually negative. To realize the wedging action seal between part **7** and **8**, clearance **35** must be provided so that all of the pressure of the installation nut **17** will be at the joint between parts **7** and **8**. This same pressure is exerted between parts **17** and **11**. Sealing between nut **17** and cylinder head flange **27** is obtained by the same pressure exerted by nut **17** made possible by clearance **35**. Installation clearance **13** is provided between flange **11** and nut **17**. The assembled valve is inserted through the bore in the cylinder head and into the conical area **8**. Nut **17** is tightened by means of hexangonal flange **19** to press part **7** against remaining surface **8**. This forms one seal. The internal shoulder of nut **17** bears on the flange **11** to exert pressure and to form a seal at the internal annular shoulder of the nut. Clearance **35** is necessary to assure that all the pressure of nut **17** is exerted on flange **11** and the seal at **8**. Threads between nut **17** and flange **27** form the other seal surface between head **34** and upper valve body **4** to seal the manifold against outside pressure. All O-ring seals are in annular grooves, as shown.

The valve is hydraulically operated as previously pointed out by the lubricating oil of the engine. On the end of the stem **2**, is the piston member **36** which operates within cylinder **38**. The upper end of it is externally threaded and threads into the inside threaded surface of the depending flange **13**. Piston **36** is sealed to the interior of cylinder **38** by appropriate seals diagrammatically designated at **40**. These seals may be of a conventional type.

Numeral **50** designates another cylinder which is coaxial with cylinder **38** and is spaced therefrom. Its upper end is internally threaded into depending flange **13**. Numeral **52** designates a bottom wall. Numeral **54** designates a further cylinder having a bottom horizontal wall extending outwardly from the walls of cylinder **50** so that an annular chamber is formed between the cylinders **50** and **54**. As will be pointed out, an electromagnetic operating coil **58** is received in this annular chamber, the top of which is formed by flange **56**.

As stated, the valve is hydraulically operated and porting is provided to admit oil under pressure to one side of the piston while releasing or venting it from the opposite side to drive the piston in one direction. On the other hand to drive the piston in the opposite direction, porting is provided to admit oil under pressure to that side of the piston and to release or vent it from the first side. The opening and closing of all ports for operation of the hydraulic valve is accomplished by a single valve member which is the cup-shaped member **60** which has a bottom wall **62**, the side walls being identified by numeral **64**.

The lower end of cylinder **38** is closed by a circular head **68** having an extending flange **69**, the head being threaded and being threaded into the cylinder **38**. The head is made of nonmagnetic material for reasons which will be explained presently. This head has a tapered or bevelled bore **70** as shown. The cup-shaped valve member **60** has a tapered circular boss **72** upstanding from its bottom which forms a valve head cooperable with the tapered bore or port in the head **68**, for controlling of admission of hydraulic fluid to the cylinder **38**. The cup-shaped valve member **60** is biased by spring **74**. Oil pressure can be admitted through the bottom member **52** through the port **80**, this port having connection to the high pressure side of the lubricating oil system of the internal combustion engine, and through ports **82** and **82'** in the bottom or end of cup-shaped valve member **60**.

The valve **1** is normally operated between a fully opened or fully closed position by means of the hydraulic piston **36**. That is, this piston is moved through a complete stroke in either one direction or the other.

Porting is provided in the side walls of the cylinders **38** and **50** and the cup-shaped valve member which in cooperation with the ports **80**, **82** and **70** control admission of a hydraulic oil (lubricating oil) to the volume above the piston **36**; for the release therefrom; to the volume below the piston **36**; and the release therefrom. The cylinder **38** is provided with diametrically opposed side ports **90, 92** and **94**; and **90', 92'** and **94'** positioned at levels as shown in FIGS. **1** and **2**. The side walls of the cup-shaped valve member **60** are similarly provided with diametrically opposed ports as designated at **96, 98** and **100**, and **96', 98'** and **100'** situated at levels cooperable with the ports in the cylinder **38**. The cup-shaped valve member of course is movable axially to control flow through the ports. The cylinder **50** is provided with diametrically opposed radial ports **104** and **104'** and **106** and **106'** cooperable with the upper sets of ports in the valve member **60**. As will be observed, the cup-shaped valve member **60** is positioned between the cylinders **38** and **50**. Its axial movement controls the alignment and misalignment of ports to provide for the flows of hydraulic oil as described above. The figures, which are schematic, show an arrangement of seals to appropriately seal the porting. The seals may be in the form of O-rings situated in appropriate O-ring grooves. FIG. **2** shows the closed position of the valve. The upper radial ports are aligned admitting pressure above piston **36** as will be explained. Numeral **110** designates a seal between the cylinder **38** and valve member **60** and numeral **112** designates a similar seal between the valve member **60** and the cylinder **38**. Numerals **114** and **116** designate similar O-ring seals situated on the opposite side of radial ports in the valve member **60**. Numerals **120** and **122** designate another pair of O-ring seals positioned on opposite sides of the ports **92** and **92'** between cylinder **38** and the valve member **60**. Numerals **124** and **126** designate another pair of seals on opposite sides of the ports **94** and **94'** in the cylinder **38**, between this cylinder and the valve member **60** and an additional seal member **130** is positioned between the valve member **60** and cylinder **50** adjacent to the ports **100** and **100'** in the valve member **60**. All sealing rings are in annular grooves, as shown.

As previously stated, an electromagnetic winding as designated at **58** is positioned in the annular space between the cylinders **50** and **54**. Numeral **136** designates an insert of nonmagnetic material forming the lower part of cylinder **50**. Other parts are of magnetic material except for the head **68** which is nonmagnetic. FIGS. **1** and **2** show the open and closed positions of the valve respectively; and these figures by the arrows illustrate the oil flows for the opening and closing movements of the valve and other arrows also indicate the magnetic flux flow pattern. These flows are referred to hereinafter more in detail in connection with the description of the operation.

With electric power off, the sleeve valve **60** is held "up" by spring **74**. Oil pressure is admitted through ports (aligned) **90, 90', 96, 96', 104,** and **104'** to apply pressure to the top of the piston **36** and hold the valve assembly down, seating head **1** firmly in seat **6**. Oil vent ports **94, 100** and **94', 104'** vent oil from below the piston **36** through circular vent grooves **101** and **101'** and the oil vent flow space **144–144'** between the sleeve valve **60** and cylinder **50** and ports **106** and **106'**. This relieves any residual pressure below piston **36** by venting the volume below it. Seals as described (of any type, not necessarily O-rings) direct the flow in the proper channels.

When electrical power is applied to coil **58**, magnetic flux flows as shown by the arrows in FIG. **1** to create a magnetic flux in the working air gap **140**. The non-magnetic portions **68** and **136** (300 series stainless steel or brass) prevent flux flow from by-passing the working gap **140**. Parasitic air gaps **150** and **142** are made long to reduce flux flow in these gaps. The magnetic flux in the working air gap **140** creates a force between the sleeve valve **60** and the cylinder body end cap **52**. Since the end cap **52** is fixed, the sleeve valve **60** is moved against the force of the spring **74**. This movement (FIG. 1) opens the valve **72** and admits oil pressure to the bottom of the piston **36** through port **80**, ports **82, 82'**, past valve seat **70**. Movement of the sleeve valve puts vent ports **98, 98'** of the valve in alignment with vent ports **92, 92'** in the operating cylinder and opening into vent space between valve **60** and cylinder **50** to the vent ports **106** and **106'** and back to the engine oil system. This vents oil from above the piston to permit the piston to rise and open the valve by action of valve stem **2**. Movement of the sleeve valve **60** cuts off pressure to the volume above piston **36** by moving ports **96, 96'** in the sleeve valve **60** out of alignment between ports **90, 90'** in the cylinder **38** and ports **104, 104'** in the valve body or cylinder **50**. The dead space in air gap **150, 150'** is allowed to fill with oil (as the sleeve valve moves down) since seals **110, 112** move with the sleeve valve and exposes ports **90, 90'** to the dead space. This space may be vented as shown at **151**.

The upward movement of piston **36** and valve head **1** may be limited in several ways. One method is to let the piston seal **40** close the vent port **92, 92'** trapping oil in the volume above piston **36** and preventing further movement of the valve. Mechanical means can also be used.

When electrical power is removed from the coil **58**, the spring **74** moves the sleeve valve **60** up and vents the volume under the piston **36** and applies oil pressure to the volume above the piston, closing the valve **1**. FIG. **2** shows the positions of the ports and the flows as described above.

The limiting factors on the operatimg time of the valve are:

The inertia of the valve assembly **1, 2** and the oil in volume above piston **36**.

The inertia and friction of the sleeve valve assembly **60**.

The force of the spring **74**.

The time constant of the magnetic circuit.

The time constant of the magnetic circuit is kept small by keeping the inductance of the magnetic circuit small. This requires the use of long (relatively) length working air gap **140** at the expense of added electrical power required to operate the sleeve valve **60**. The magnitude of the spring force must be balanced between the magnetic force required to move the sleeve valves **60** and the mechanical force required to close the sleeve valve rapidly. The inertia and friction forces are subject to astute mechanical design.

A modest amount of oil leakage through the valve is probably desirable to minimize oil stagnation and "silting" of the system. Further, some flow of oil will aid in cooling the valve and prolonging valve life.

The sealing area **8** and the mounting ring **17** provide a means of installing the valve and valve seat in the cylinder head **34**. The threaded portions between the body **4**, the cylinder **38** and the valve body cylinder **50** and between the piston **36** and the valve stem **2** provide means for assembly of the complete unit prior to installation in the cylinder head **34**.

FIGS. **3** and **4** are a modification of the previous design of the valve that adapts it to pulse-type digital control.

The advantages of this design are:

1. "Logical" operation.
2. Faster operation.

Logical operation simply means that the valve has two stable states, a concept that fits in the pattern of logic design generally. The problem was to fit in the two state coil design to this package.

The design is adapted to use in an electronically controlled Internal Combustion engine operated by a digital processor. The concept is to vary intake valve open and close time. exhaust valve open and close time, fuel injection time and quantity, ignition time and possibly water injection quantity and time in response to the change in input functions of rpm, torque, manifold pressure, atmospheric pressure, water (and/or oil) temperature, air temperature, gear shift position, throttle position and wheel slip. Possible engine states under analysis include: cold start, cold idle; negative, idle, low, medium and high torque at low, medium and high engine rpm.

The ultimate goal is to provide optimum combustion efficiency at all engine operating conditions for maximum efficiency and minimum pollution. The design will eliminate completely: cam shaft, valve train, distributor, carburetor, breaker points and possibly one forward gear.

The embodiment described above has a basic operating characteristic of a solenoid valve, i.e., power on/open and power off/close. The modified version of the valve permits operation in a "logic mode", i.e., pulse coil **166** to open, pulse **164** to close, with no power consumed between operations.

FIGS. **3** and **4** each show a cross section of the valve. The valve is identical to the previously described valve form (and numbered the same) down to the sleeve valve, valve seat, and operating coils. (Valve **1** is the intake/exhaust valve between manifold and cylinder.) This is driven by the double-acting piston **36** by pressuring the volume below the piston and venting volume above the piston to open the valve and a reverse process to close the valve. The operation of the valve ports in the sleeve valve **60** and operating cylinder **38** is like that of FIGS. **1** and **2** and need not be repeated. If sleeve valve **60** is moved down, valve **1** opens. If sleeve valve **60** is moved up, valve **1** closes.

The modified electrical operating means consists of permanent magnet **160**, pole piece structure for said permanent magnet **162**, operating coils **164** and **166**, and feedback coils **165** and **167**. The sleeve valve **60'** is now made of a nonmagnetic cylinder **64'** and a magnetic armature **62** with a nonmagnetic valve poppet **72'**. The hydraulic operating cylinder **38'** is all magnetic material, including the element **68'**. The magnetic circuit is divided into A and B sections by the nonmagnetic inserts **169** and **170.** Two magnetic working gaps are used, closing gap **172A** and opening gap **172B.** Magnetic flux flows **174A** and **174B** control the position of the valve. The permanent magnet, windings, pole piece structure, and nonmagnetic inserts as shown are all ring shaped. They may have other shapes.

The armature **62'** has two stable positions with either gap **172A** or **172B** closed. The permeance of a closed gap is designed to be several times larger than the permeance of an open gap. Thus, the major portion of the flux from the permanent magnet will flow through the closed gap. Since force varies as the square of the flux, the force will be many times larger in the closed gap than in the open gap. The parasitic gap **176** between pole pieces **52** and magnet shoe **162** is made large to reduce flux leakage. Similarly gap **176'** is made large.

Flux **174A** flows up through part **54**, cylinder wall **50** and down through cylinder wall **38'** to the pole face **68'** and through working gap **172A** to armature **62'**, across radial gap **177'** to pole shoe **162** and back to the permanent magnet. Flux **174B** flows down through cylinder **54** to pole piece **52**, through working gap **172A** to armature **62'**, through radial gap **177'** and pole shoe **162'** to the permanent magnet **160'**. Since the length of the gap **172A** is small relative to gap **172B**, most of the flux will flow through this gap, thus holding the valve **1** closed. See FIG. **4.**

To open engine valve **1**, an electrical pulse is applied to operating coil **166.** This applies a magnetomotive force to the magnet circuit "B" and increases the flux flow **174B.** Since the total flux through the permanent magnet **160'** is limited by the rapid decrease in permeance with increase of flux above the knee of the magnetization curve, flux increase in circuit "B" will produce a flux decrease in circuit "A". Since this is "flux switching" rather than flux increase, the time constant is smaller and flux buildup in circuit "B" can be more rapid than for a solenoid type valve. The increase of flux in circuit "B" causes an increase of flux in working gap **172B** and a decrease of flux in working gap **172A.** The balance of flux shifts to working gap **172B** and causes the armature **62'** and sleeve valve assembly **60'** to move down. This opens valve poppet **72'** and admits oil under pressure below piston **36'**. Ports **92, 98, 106** and **92', 98', 106'** are aligned and vent the volume above piston **36.** This combination produces a force on the piston that lifts the engine valve **1** and: (a) admits fuel/air mixture to the engine cylinder or (b) emits exhaust gas from the engine cylinder.

An electrical pulse applied to operating coil **164** reverses the flux flow and closes the engine valve **1.** The coil is stable in either position and requires no sustaining electrical power due to the magnetomotive force of the permanent magnet **160** maintaining a flux in the working gap with the higher permeance, shorter air path.

Coils **165** and **167** are feed back coils that can be connected as such adapting the valve to control by way of a logic circuit.

One form of logic circuit that can be used to operate the valve is shown in U. S. Pat. Application Ser. No. 113,321 filed Feb. 8, 1971, of this inventor entitled SEALED PUMP AND DRIVE THEREFOR and it is hereby incorporated herein by reference.

FIG. **5** is a diagrammatic illustration of the operation of an eight cylinder engine under control of a digital processor with the valve of FIGS. **3** and **4** installed in the inlet to and exhaust from each of the eight cylinders. Six events should take place at each engine cylinder as a function of crankshaft angle which controls piston position; intake valve open, intake valve close, exhaust valve open, exhaust valve close, fuel injection (which may be a two stage process for minimum emission) and ignition.

The variables that determine the best piston position for each event are: rpm, torque, water temperature (fuel quantity for cold start), throttle position (demand), manifold pressure and transmission gear position. The continuous variable (clock) is the 720° of crankshaft rotation. All other variables are algebraically summed to provide a reference against which crankshaft position matches to command an event. The events number 6 × 8 (for an 8 cylinder engine) and each has an optimum time as a function of the variables.

Atmospheric pressure is a significant variable in high altitude operation. Air temperature may be required to supplement water temperature in cold weather starts. Wheel slip is being implemented on some cars now.

The CPU has the function of combining **6** variables, matching to crankshaft angle and commanding **48** events. Much of the work of the CPU is accomplished by making each of the seven input transducers provide a variable digital output. This eliminates the requirement for analog to digital conversion in the CPU.

The digital outputs of the transducers may be in Gray code and, the preferred transducers used may be like that of U. S. Pat. Application Ser. No. 64,029 filed on July 20, 1970, of the herein inventor and hereby incorporated herein by reference. As stated, these outputs are summed by the CPU which then controls the six events shown in FIG. **5** with reference to crankshaft angle. Each of the six events for each cylinder has a digital code number which is set into a register or comparator, that is, the number peculiar to that event for that cylinder. Currently, technology is readily available to implement the CPU in the manner described.

The fuel injector is preferably a type of device referred to in U. S. Pat. Application Ser. No. 113,321 filed on Feb. 8, 1971, already referred to in the foregoing. With respect to ignition in the system described, preferably, a type of ignition is employed wherein a single small ignition coil is used for each cylinder using a closed iron magnetic circuit.

From the foregoing, those skilled in the art will readily understand the nature and the construction of the invention and the manner in which it achieves and realizes all of the objectives and advantages as set forth in the foregoing.

The foregoing disclosure is representative of the preferred form of the invention and is to be interpreted in an illustrative rather than a limiting sense, the invention to be accorded the full scope of the claims appended hereto.

What is claimed is:

1. In an hydraulically operated valve positioned to control flow of fluid with respect to an internal combustion engine cylinder in combination: a cylinder having a piston therein connected to a valve member and movable between open and closed positions of the valve member; means comprising a valve sleeve member cooperable with said cylinder, said valve sleeve member and cylinder having mutually cooperable porting providing for flow of hydraulic fluid to and from opposite sides of said piston for moving said valve member through its stroke in opposite directions, control means for controlling the position of opening and closing of the valve with respect to crankshaft angle comprising means responsive to crankshaft position and means responsive to at least one variable which is related to an engine operating condition.

2. A device as in claim **1**, including means to reciprocate said sleeve member relative to said cylinder, to cause said piston to reciprocate.

3. A device as in claim **2**, wherein said cylinder has ports for admitting hydraulic fluid to one side of said piston for moving it in one direction and ports for relieving pressure from one side of said piston, said cylinder having ports for admitting fluid to the opposite side of said piston and ports for withdrawing fluid from the opposite side of said piston, said sleeve member being operative to control all of said ports for causing said piston to reciprocate.

4. A device as in claim **3**, wherein said sleeve member has ports positioned to be moved into alignment with ports in said cylinder and to moved out of alignment with ports in said cylinder for controlling the flows.

5. A device as in claim **3**, wherein said ports include a port in an end wall of said cylinder and said sleeve member having a part cooperating with said end wall port.

6. A device as in claim **1**, including an electromagnetic winding associated with said sleeve member for causing said sleeve member to reciprocate relative to said cylinder.

7. A device as in claim **6**, including a further cylinder spaced outwardly from said sleeve member and adapted to accommodate a flux circuit for flux from said electro-magnetic winding.

8. A device as in claim **7**, wherein said electromagnetic winding is of ring shape and is positioned around a part of said further cylinder.

9. A device as in claim **6**, including spring means for urging said sleeve member in one direction.

10. A device as in claim **7**, including a pair of electromagnetic windings and a permanent magnet associated with said sleeve whereby reciprocation of said sleeve may be produced by energization of said windings.

11. A device as in claim **10**, including a second pair of electro-magnetic windings coupled with said first pair whereby said device is adapted to pulse type digital control from a driving circuit having connections to all four windings.

12. A device as in claim **6**, wherein said sleeve member is constructed of material so as to constitute an armature.

13. A device as in claim **6**, wherein said sleeve member has an end closure which is constructed of material so as to constitute an armature.

14. A device as in claim **10**, wherein said first pair of electro-magnetic windings are spaced axially from each other with a permanent magnet positioned between them.

15. A device as in claim **11**, wherein said second pair of windings is positioned to surround the first pair of windings respectively to provie magnetic coupling therewith.

16. A valve as in claim **1**, said valve being positioned and constructed to receive engine lubricating oil to drive the piston and to discharge lubricating oil into the engine crankcase.

* * * * *