(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
25 November 2004 (25.11.2004)

PCT

(10) International Publication Number
WO 2004/102008 A2

(51) International Patent Classification[7]: F15B

(21) International Application Number:
PCT/US2004/013936

(22) International Filing Date: 6 May 2004 (06.05.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/468,088 6 May 2003 (06.05.2003) US

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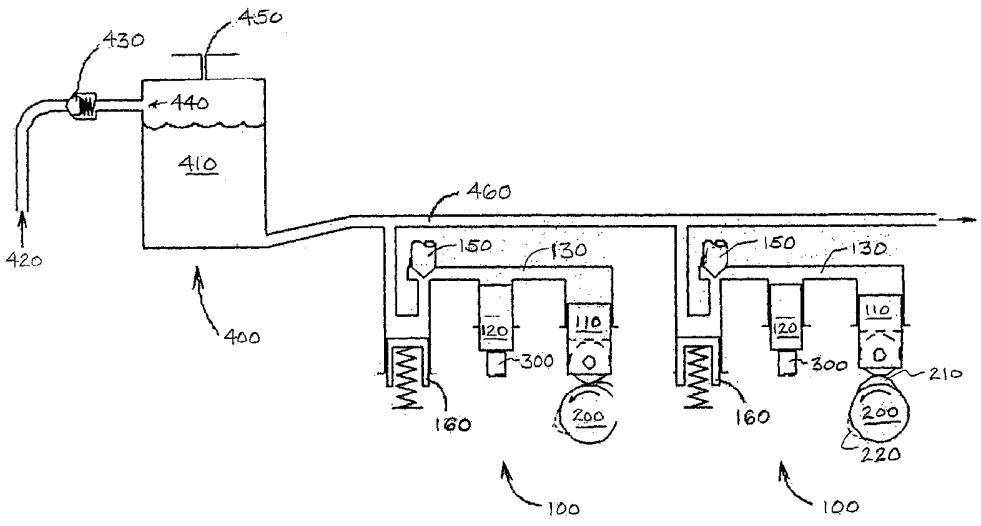
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: SYSTEM AND METHOD FOR IMPROVING PERFORMANCE OF HYDRAULIC ACTUATING SYSTEM



(57) Abstract: A system and method is disclosed for supplying hydraulic fluid to a lost motion system in an internal combustion engine. The system may comprise a reservoir; a gallery circuit connected to the reservoir, wherein the gallery circuit is adapted to be connected to the one or more lost motion systems; and a control valve adapted to provide selective hydraulic communication between the gallery circuit and the one or more lost motion systems.

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SYSTEM AND METHOD FOR IMPROVING PERFORMANCE OF HYDRAULIC ACTUATING SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application relates to and claims priority on United States Provisional Application No. 60/468,088, filed May 6, 2003 and entitled "Hydraulic Circuit to Improve Starting of Hydraulic Actuating System," a copy of which is incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to systems and methods of improving the performance of a hydraulic system. In particular, the present invention relates to a reservoir system and method using same that provides hydraulic fluid to a lost motion system disposed in an internal combustion engine and used to actuate engine valves.

BACKGROUND OF THE INVENTION

[0003] Valve actuation in an internal combustion engine is required in order for the engine to produce positive power, as well as to produce engine braking. During positive power, intake valves may be opened to admit fuel and air into a cylinder for combustion. The exhaust valves may be opened to allow combustion gas to escape from the cylinder.

[0004] During engine braking, the exhaust valves may be selectively opened to convert, at least temporarily, an internal combustion engine of compression-ignition type into an air compressor. This air compressor effect may be accomplished by cracking

open one or more exhaust valves near piston top dead center position for compression-release type braking, or by maintaining one or more exhaust valves in a cracked open position for much or all of the piston motion for bleeder type braking. In doing so, the engine develops retarding horsepower to help slow the vehicle down. This can provide the operator increased control over the vehicle and substantially reduce wear on the service brakes of the vehicle. A properly designed and adjusted engine brake can develop retarding horsepower that is a substantial portion of the operating horsepower developed by the engine in positive power.

[0005] For both positive power and engine braking applications, the engine cylinder intake and exhaust valves may be opened and closed by fixed profile cams in the engine, and more specifically by one or more fixed lobes which may be an integral part of each of the cams. The use of fixed profile cams can make it difficult to adjust the timings and/or amounts of engine valve lift needed to optimize valve opening times and lift for various engine operating conditions, such as different engine speeds.

[0006] One method of adjusting valve timing and lift, given a fixed cam profile, has been to incorporate a "lost motion" device in the valve train linkage between the valve and the cam. Lost motion is the term applied to a class of technical solutions for modifying the valve motion proscribed by a cam profile with a variable length mechanical, hydraulic, or other linkage means. An example of a lost motion system **100** is shown in Fig. 1. The lost motion system **100** may include a master piston **110** hydraulically linked to a slave piston **120** by the hydraulic passage **130**. A check valve **140** allows hydraulic fluid to be supplied to and retained in the hydraulic passage **130**. A control valve **150** permits fluid in the hydraulic passage **130** to be selectively released.

In connection with the lost motion system **100**, a cam **200** may provide the "maximum" (longest dwell and greatest lift) motion needed for engine operating conditions.

[0007] The lost motion system **100** may be included in the valve train linkage, intermediate of the valve **300** to be opened and the cam **200** providing the maximum motion. Cam motion imparted to the master piston **110** may be transferred to the slave piston **120**, and thus the engine valve **300**, when the hydraulic passage **130** is full of fluid. In this manner, the engine valve **300** (e.g., exhaust or intake valve), may be actuated by the lost motion system only when hydraulic fluid is maintained in the hydraulic passage **130**. Selective operation of the control valve **150** allows the lost motion system to subtract or lose part or all of the motion imparted by the cam to the master piston **110** by releasing fluid from the hydraulic passage **130**.

[0008] Other examples of such systems are provided in U.S. patent application serial number Vorih et al., U.S. Pat. No. 5,829,397 (Nov. 3, 1998), Hu, U.S. Pat. No. 6,125,828 (Oct. 3, 2000), and Hu, U.S. Patent No. 5,680,841 (Oct. 28, 1997), which are assigned to the same assignee as the present application, and which are incorporated herein by reference.

[0009] Lost motion systems, while beneficial in many aspects, have also been subject to some drawbacks. The use of hydraulics may result in initial starting difficulties as the result of a lack of hydraulic fluid in the system. With respect to the lost motion system **100** shown in Fig. 1, for example, when the engine in which it is installed is shut off for a period of time, fluid in the hydraulic passage **130** may drain out of the system due to leakage past the master piston **110**, the slave piston **120**, the check valve **140**, and/or the control valve **150**. As a result, when the engine is started there

may be no fluid in the hydraulic passage **130** to enable motion from the cam **200** to be transferred to the engine valve **300**. The oil supply pump (not shown) that provides hydraulic fluid to the passage **130** may not be capable of supplying fluid quickly enough. In some instances, it is possible that the hydraulic passage **130** may not be completely filled until more than a minute after initial cranking of the engine. In a multi-cylinder engine, there may be numerous lost motion systems **100** that must be charged with hydraulic fluid.

[0010] If actuation of the engine valve **300** is required immediately during engine starting, as is often the case with variable valve actuation (VVA) systems, this lack of hydraulic fluid can frustrate and prevent starting, or cause engine damage. It may be particularly difficult to charge the system **100** with hydraulic fluid when the fluid is cold and has a lower viscosity.

[0011] It is therefore an advantage of some, but not necessarily all, embodiments of the present invention to improve upon charging a lost motion valve actuation system with hydraulic fluid.

[0012] Operation of the lost motion system **100** may also be interfered with by the presence of air in the hydraulic passage **130** connecting the master and slave pistons. Air is not a hydraulic fluid, but rather a compressible fluid. Air entrained in the hydraulic passage **130** can cause the hydraulic circuit to compress instead of transferring motion from the master piston **110** to the slave piston **120**. This can result in loss of the cam motion even when it is desired that it not be lost.

[0013] It is therefore an advantage of some, but not necessarily all, embodiments of the present invention to improve upon the venting of air from the hydraulic circuit

connecting the master piston to the slave piston in a lost motion system.

[0014] Additional advantages of various embodiments of the invention are set forth, in part, in the description that follows and, in part, will be apparent to one of ordinary skill in the art from the description and/or from the practice of the invention.

SUMMARY OF THE INVENTION

[0015] Responsive to the foregoing challenges, Applicant has developed an innovative reservoir system for supplying hydraulic fluid to a lost motion system in an internal combustion engine. In one embodiment, the system comprises: a reservoir; a gallery circuit connected to the reservoir, wherein the gallery circuit is adapted to be connected to one or more lost motion systems; and a control valve adapted to provide selective hydraulic communication between the gallery circuit and the one or more lost motion systems.

[0016] Applicant has further developed an innovative method of providing hydraulic fluid to a lost motion system during start up of an internal combustion engine. In one embodiment, the method comprises the steps of: providing hydraulic fluid in a reservoir, the reservoir being disposed relative to the lost motion system to facilitate the flow of hydraulic fluid to the lost motion system under the influence of gravity; blocking hydraulic communication between the reservoir and the lost motion system during application of at least an initial portion of an engine valve event motion to the lost motion system; and providing hydraulic communication between the reservoir and the lost motion system during application of at least a later portion of the engine valve event motion to the lost motion system.

[0017] It is to be understood that both the foregoing general description and the

following detailed description are exemplary and explanatory only, and are not restrictive of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] In order to assist the understanding of this invention, reference will now be made to the appended drawings, in which like reference characters refer to like elements.

[0019] Figure 1 is a cross-section of a lost motion valve actuation system.

[0020] Figure 2 is a cross-section of a lost motion valve actuation system including a system for charging the lost motion valve actuation system with hydraulic fluid in accordance with a first embodiment of the present invention.

[0021] Figure 3 is a cross-section of a lost motion valve actuation system including a system for charging the lost motion valve actuation system with hydraulic fluid in accordance with an alternative embodiment of the present invention.

[0022] Figure 4 is a cross-section of a portion of a lost motion valve actuation system including an orthogonal master-slave piston arrangement in accordance with an alternative embodiment of the present invention.

[0023] Figure 5 is a graph of crank angle position versus cam lobe motion and control valve position which illustrates an example of control valve timing that may be employed in a method embodiment of the present invention.

[0024] Figure 6 is a cross-section of a lost motion valve actuation system including a system for charging the lost motion valve actuation system with hydraulic fluid in accordance with an alternative embodiment of the present invention.

[0025] Figure 7 is a cross-section of a lost motion valve actuation system including a

system for charging the lost motion valve actuation system with hydraulic fluid in accordance with an alternative embodiment of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0026] Reference will now be made in detail to a first embodiment of the present invention, an example of which is illustrated in the accompanying drawings. With reference to Fig. 2, each lost motion system **100** may be disposed between a cam **200** and an engine valve **300**. The cams **200** may include one or more cam lobes **210**, **220**, etc., for imparting an engine valve actuation motion to the lost motion system **100**. The lost motion system **100** is shown to act on a single engine valve **300**, however, it is appreciated that the lost motion system **100** may act on more than one engine valve through a valve bridge in alternative embodiments.

[0027] In one embodiment of the present invention, as shown in Fig. 2, each lost motion system **100** may include a master piston **110** hydraulically linked to a slave piston **120** by a hydraulic passage **130**. A control valve **150** is disposed in the hydraulic passage **130** so that it may selectively block or unblock the hydraulic passage. Electronic or mechanical control of the control valve **150** permits fluid to enter the hydraulic passage **130** when the control valve **150** is in an open position (as shown). When the control valve **150** is closed (downward as shown in Fig. 2), hydraulic fluid is trapped in the passage **130**, thereby hydraulically locking the master piston **110** to the slave piston **120**. Reopening the control valve **150** may also allow fluid in the passage **130** to be selectively released, thereby unlocking the master piston **110** from the slave piston **120**.

[0028] An optional accumulator piston **160** may assist in maintaining low pressure fluid in the vicinity of the hydraulic passage **130** so that it may be drained and refilled rapidly. The optional accumulator piston **160** may be particularly useful when the lost motion system **100** is used to provide variable valve actuation. In the instances where variable valve actuation is provided, the control valve **150** may be a high-speed trigger valve. High-speed trigger valves may be capable of being opened and closed one or more times per engine cycle to enable locking and unlocking the master piston **110** from the slave piston **120** one or more times per engine cycle.

[0029] Hydraulic fluid may be supplied to the hydraulic passage **130** by the reservoir system **400**. The reservoir system **400** may include a reservoir **410**, a low pressure feed **420**, an optional check valve **430**, an inlet port **440**, an air bleed opening **450**, and a common gallery circuit **460**. Hydraulic fluid, such as, for example, engine oil, may be provided from the low pressure feed **420** to the reservoir **410**. The optional check valve **430** may prevent hydraulic fluid in the reservoir **410** from flowing back to the low pressure feed **420**.

[0030] In one embodiment of the present invention, the reservoir system **400** may include an air bleed opening **450** near the top of the reservoir **410**. The air bleed **450** may allow air entrained in the hydraulic fluid that enters the reservoir **410** from the low pressure feed **420** to exit the system before it enters the one or more lost motion systems **100**. The air bleed opening **450** may be sized to allow small quantities of air to exit from the reservoir system **400** freely, while still offering restriction to the exit of hydraulic fluid, even at relatively high pressure. The air bleed **450** may also allow air to enter the reservoir **410** to make up for hydraulic fluid that is fed by the reservoir to the

gallery circuit **460**. This may prevent a vacuum effect from preventing hydraulic fluid from flowing out of the reservoir **410** under a relatively small gravitational force. Still further, the air bleed **450** may permit air that does become entrained in the hydraulic fluid of the lost motion systems **100** to bubble up and out of these systems over time.

[0031] The inlet port **440** may be located near the top of the reservoir **410**. Placement of the inlet port **440** near the top of the reservoir **410** may enhance the ability of the reservoir system **400** to allow air entrained in the fluid provided by the low pressure feed **420** to exit through the air bleed **450**.

[0032] The gallery circuit **460** may provide hydraulic fluid from the reservoir system **400** to each of the possible plurality of lost motion systems **100**. The reservoir system **400** may be located at any point along the expanse of the gallery circuit **460**. The upper level of hydraulic fluid in the reservoir **410** may be above the level of the hydraulic passages **130** so that gravity can facilitate the flow of hydraulic fluid from the reservoir to the hydraulic passages.

[0033] It is appreciated that in alternative embodiments, more than one reservoir system could be provided to service the lost motion systems **100** included in the engine. In fact, each lost motion system **100** may benefit from incorporating a reservoir system **400** local to the lost motion system. These local reservoir systems **400** may be integrally incorporated into the housing of each lost motion system **100**.

[0034] It is appreciated that the low pressure feed **420** need not connect directly to the reservoir **410**. With reference to Fig. 3 for example, the low pressure feed **420** may connect to the gallery circuit **460** directly, instead of connecting through the reservoir **410**.

[0035] In one embodiment, as shown in Fig. 6, the lost motion system **100** may further comprise an optional passage **170** for bypassing the control valve **150**, and an optional check valve **175** disposed in the passage **170**. The optional passage **170** and check valve **175** may permit hydraulic fluid to enter and refill the hydraulic passage **130** when there is insufficient time to open the control valve **150** between engine valve events, for example, in a variable valve actuation system.

[0036] With renewed reference to Fig. 2, operation of the lost motion system **100** may begin by filling the reservoir **410** with hydraulic fluid from the low pressure feed **420**. The optional check valve **430** permits hydraulic fluid flow into the reservoir **410** from the low pressure feed **420**, but does not permit a substantial amount of fluid to flow back to the low pressure feed from the reservoir.

[0037] As will be apparent to those of ordinary skill in the art, the control valve **150** may be normally open, or normally closed. For illustrative purposes, as shown in Fig. 2, an embodiment of the present invention including a normally open control valve **150** will be described. Embodiments of the present invention may use either a normally open or a normally closed control valve **150**.

[0038] At the time that the engine is shut down, the reservoir **410** may contain a substantial amount of hydraulic fluid. At this time each of the control valves **150** open, thereby connecting the hydraulic passage **130** from the gallery circuit **460** and the reservoir **410**, as shown in Fig. 2. Over time, hydraulic fluid may leak out of the hydraulic passage **130** due to leakage past the master piston **110** and the slave piston **120**. Hydraulic leakage may also occur past the accumulator **160**. Features of various embodiments of the present invention, however, may limit the amount of leakage past

these and other system components, which could deplete the level of hydraulic fluid in the reservoir **410**. First, the accumulator **160** may be disposed so that it is inverted as compared to its position shown in Fig. 2. The accumulator **160** position in Fig. 2 is provided for ease of illustration, and is not intended to show the only, or even preferred, positioning of the accumulator. Second, the master piston **110** and/or the slave piston **120** may be inverted to limit the drainage of hydraulic fluid. Third, the reservoir **410** may be provided with a sufficiently great amount of hydraulic fluid that it will continue to retain a useful amount of fluid over a prolonged period even if a low to moderate level of fluid leakage occurs past the accumulator **160**. Fourth, the bottom of the reservoir **410** may be positioned below the level of the gallery circuit **460** such that the fluid in the reservoir **410** is prevented from being entirely drained out. Fifth, the reservoir feed **440** may be positioned at the top of the reservoir **410** to prevent hydraulic fluid drainage into the engine should the check valve **430** fail or be absent. Some, but not necessarily all, embodiments of the present invention may include one or more of these features.

[0039] At the time of engine start up, the hydraulic passage **130** may be so depleted of hydraulic fluid that displacement of the master piston **110** fails to result in sufficient displacement of the slave piston **120** to produce a desired actuation of engine valve **300**. Hydraulic fluid may be supplied by the reservoir **410** to the hydraulic passage **130** at this time. The supply of fluid to the hydraulic passage **130** may begin by opening the control valve **150**. By opening the control valve **150**, fluid is permitted to flow from the reservoir **410**, through the gallery circuit **460** to the hydraulic passage **130**. The gallery circuit **460** may be located relative to the individual lost motion systems **100** so that gravity encourages the flow of fluid from the gallery circuit to the individual lost motion

systems.

[0040] The flow of fluid into each of the hydraulic passages **130** may be further encouraged by the pumping action of the master piston **110** in conjunction with selective control of the control valve **150**. As the master piston **110** pumps downward with each revolution of the cam **200**, the control valve **150** may be open so that fluid may be drawn into the hydraulic passage **130** by the vacuum created by the master piston. As the master piston **110** pumps back upward under the influence of the main exhaust lobe on the cam **200**, the control valve **150** may be maintained closed so that the master piston **110** does not drive fluid back out of the hydraulic passage **130**. This cycle may be repeated until the passage **130** and accumulator **160** are refilled with fluid.

[0041] In addition, the high pressure generated in the master-slave circuit may force any air in the circuit out past the close clearance between the master piston **110** and the slave piston **120** and their respective bores. In one embodiment of the present invention, as shown in Fig. 4, the master piston **110** may be disposed in a direction substantially orthogonal or perpendicular to the orientation of the slave piston **120**, such that any air in the circuit may be located at the piston/bore interface and may be readily forced out.

[0042] An example of the control valve timing that may be used to further enhance the refilling of the lost motion system **100** is provided in Fig. 5. The cam may be provided with one or more cam lobes that provide a main exhaust motion **500** and a compression release motion **510**, for example. The control valve position may be maintained in an open position until just prior to the main exhaust motion **500**. At this time the control valve may be closed, and maintained closed until approximately the

mid-point of the main exhaust motion **500**, at which time the control valve may be re-opened. This timing may be used during the first part of cranking (engine start-up) to facilitate refilling of the circuits, after which time the normal starting valve motion may be generated. It is contemplated that the control valve timing of embodiments of the present invention may be used in conjunction with other engine valve events, such as, a main intake valve event and an engine braking valve event.

[0043] It will be apparent to those skilled in the art that variations and modifications of the present invention can be made without departing from the scope or spirit of the invention. For example, as shown in Fig. 7, the one or more lost motion systems **100** may include a collapsible tappet assembly **180** operatively connected to a rocker arm **182**, which, in turn, is operatively connected to one or more engine valves **300**. Other embodiments of the one or more lost motion systems **100** for selectively losing part or all of the motion imparted to the system **100** are considered well within the scope and spirit of the present invention.

WHAT IS CLAIMED IS:

1. A system for supplying hydraulic fluid to one or more lost motion systems in an internal combustion engine, comprising:

a reservoir;

a gallery circuit connected to said reservoir, wherein said gallery circuit is adapted to be connected to the one or more lost motion systems; and

a control valve adapted to provide selective hydraulic communication between said gallery circuit and the one or more lost motion systems.

2. The system of Claim 1 further comprising an air bleed opening provided in said reservoir.

3. The system of Claim 1 wherein said gallery circuit is disposed relative to the one or more lost motion systems to facilitate the flow of hydraulic fluid from said gallery circuit to the one or more lost motion systems under the influence of gravity.

4. The system of Claim 1 wherein said reservoir is disposed relative to the one or more lost motion systems to facilitate the flow of hydraulic fluid from said reservoir to the one or more lost motion systems under the influence of gravity.

5. The system of Claim 1 further comprising means for selectively opening said control valve during an engine start up period.

6. The system of Claim 1 further comprising a hydraulic fluid supply passage for supplying hydraulic fluid to the reservoir system.

7. The system of Claim 6, wherein said fluid supply passage connects to an inlet port in said reservoir.

8. The system of Claim 7, wherein the inlet port is disposed proximate the top of said reservoir.

9. The system of Claim 6, wherein said fluid supply passage connects to said gallery circuit.

10. The system of Claim 6, a check valve disposed in said fluid supply passage.

11. The system of Claim 1, wherein the lost motion system comprises:

a master piston;

a slave piston; and

a hydraulic passage operatively connecting said master piston to said slave piston.

12. The system of Claim 11, wherein said master piston is disposed in a direction substantially orthogonal to the direction of said slave piston.

13. The system of Claim 11, wherein at least one of said master piston and said slave piston is inverted.

14. The system of Claim 11, further comprising an accumulator piston disposed proximate said hydraulic passage.

15. The system of Claim 11, wherein the level of hydraulic fluid in said reservoir is above the level of said hydraulic passage.

16. The system of Claim 11, further comprising:

a bypass passage providing hydraulic fluid bypass of said control valve; and

a check valve disposed in said bypass passage.

17. A hydraulic actuating system in a multi-cylinder internal combustion engine, said system comprising:

a plurality of lost motion systems, wherein one lost motion system is provided for each cylinder in the multi-cylinder engine;

a reservoir;

a gallery circuit connected to said reservoir, wherein said gallery circuit is adapted to be connected to said plurality of lost motion systems; and

a control valve adapted to provide selective hydraulic communication between said gallery circuit and said plurality of lost motion systems.

18. The system of Claim 17, further comprising means for selectively opening said control valve during an engine start up period.

19. The system of Claim 17, wherein said gallery circuit is disposed relative to said lost motion systems to facilitate the flow of hydraulic fluid from said gallery circuit to said lost motion systems under the influence of gravity.

20. The system of Claim 17, wherein said reservoir is disposed relative to said lost motion systems to facilitate the flow of hydraulic fluid from said reservoir to said lost motion systems under the influence of gravity.

21. A method of providing hydraulic fluid to a lost motion system during start up of an internal combustion engine, said method comprising the steps of:

providing hydraulic fluid in a reservoir, the reservoir being disposed relative to the lost motion system to facilitate the flow of hydraulic fluid to the lost motion system under the influence of gravity;

blocking hydraulic communication between the reservoir and the lost motion system during application of at least an initial portion of an engine valve event motion to the lost motion system; and

providing hydraulic communication between the reservoir and the lost motion system during application of at least a later portion of the engine valve event motion to the lost motion system.

22. The method of Claim 21, wherein the engine valve event comprises a main exhaust event.

23. The method of Claim 21, further comprising the step of venting air from the reservoir through an air bleed opening provided in said reservoir.

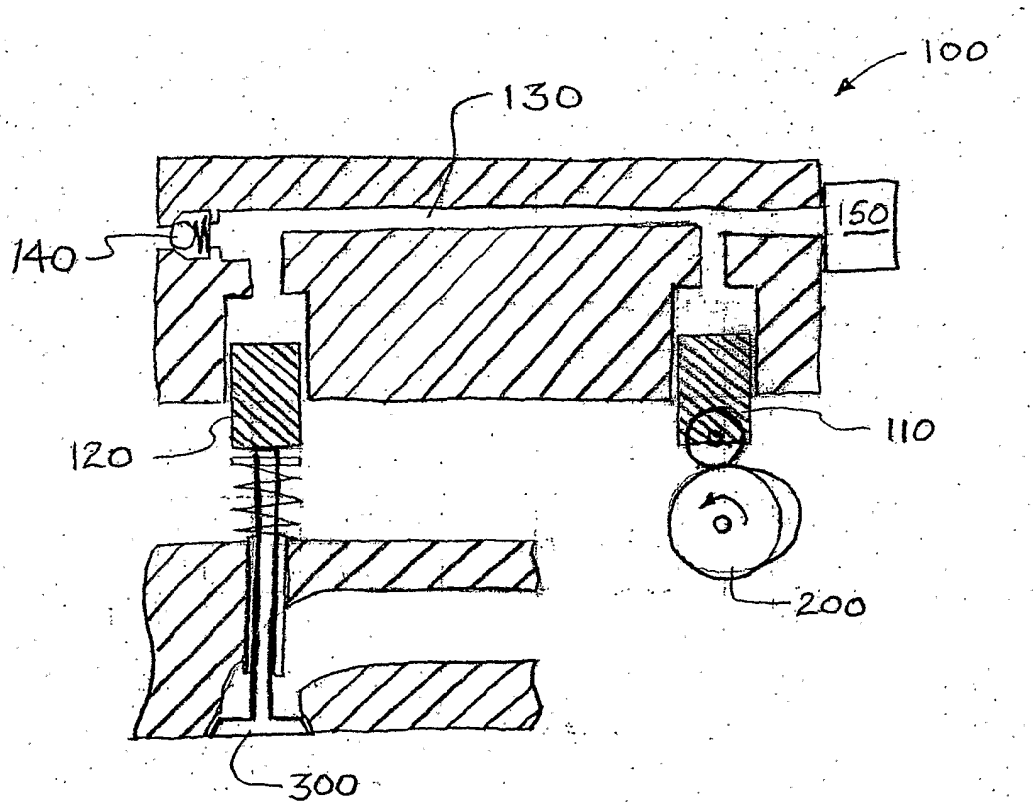


FIG. 1

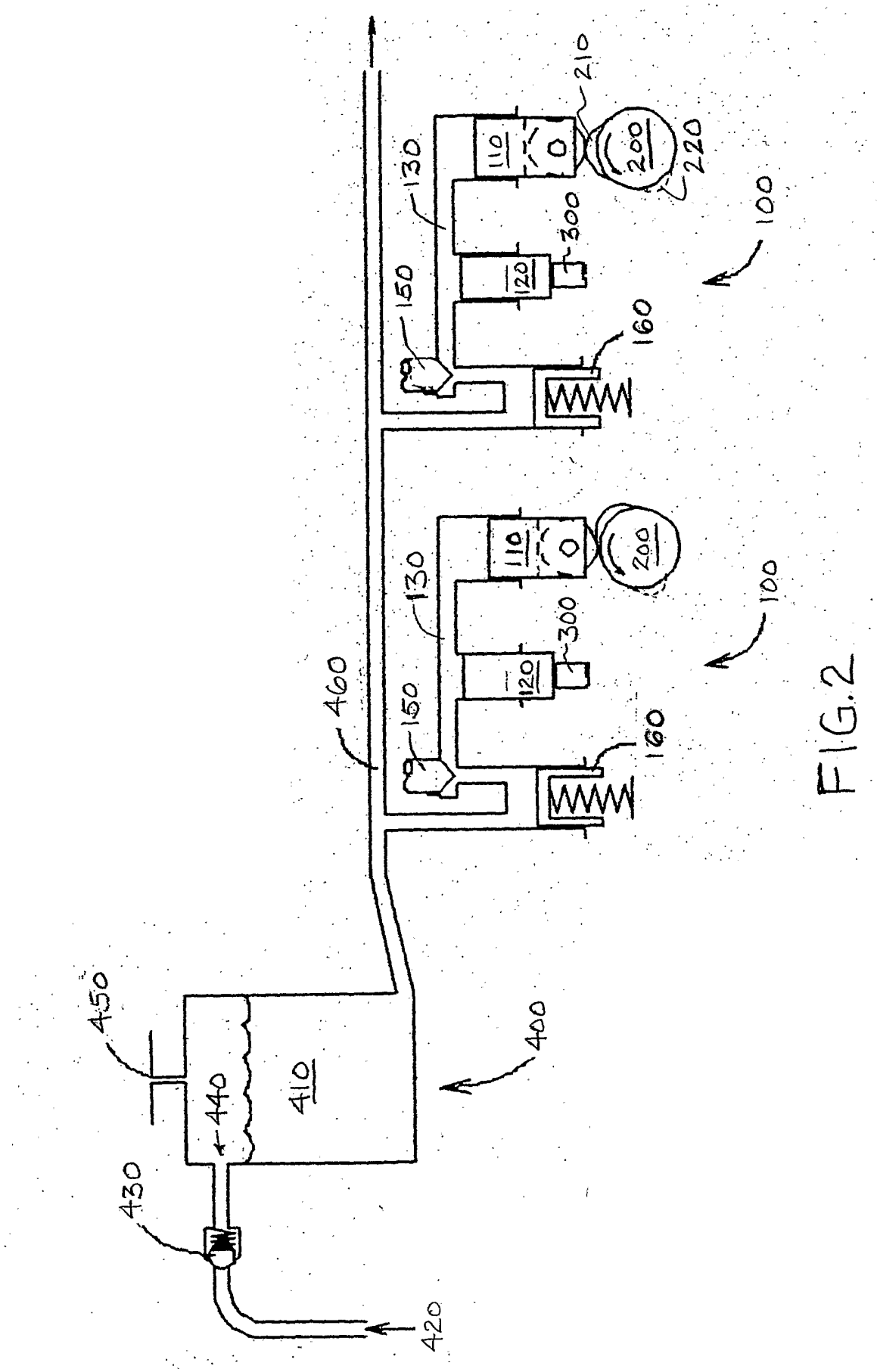


FIG.2

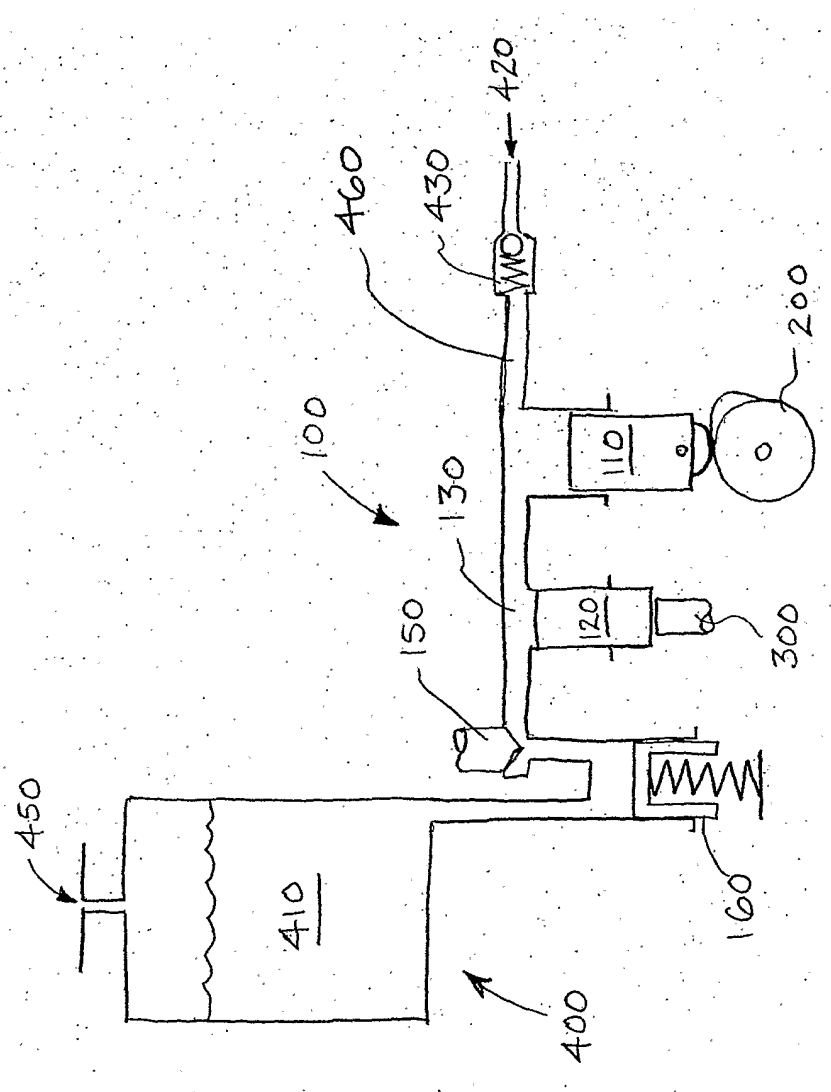


FIG. 3

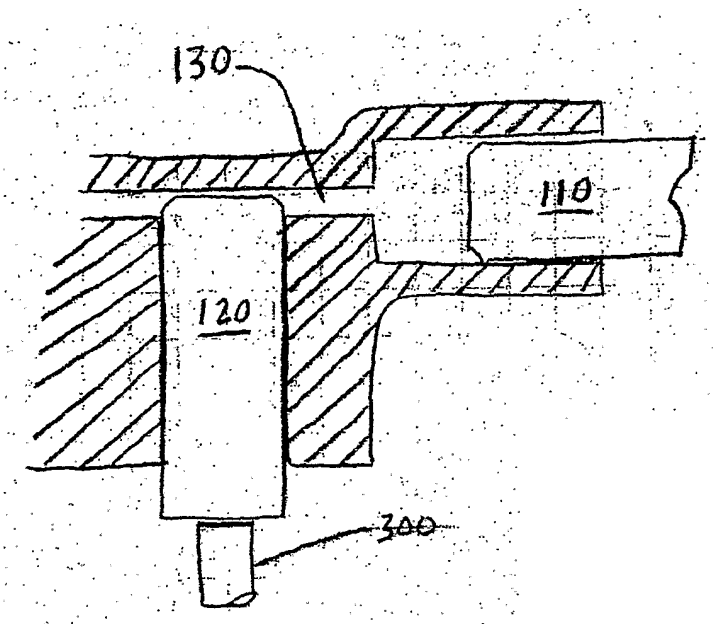

130
110
120
300

FIG. 4

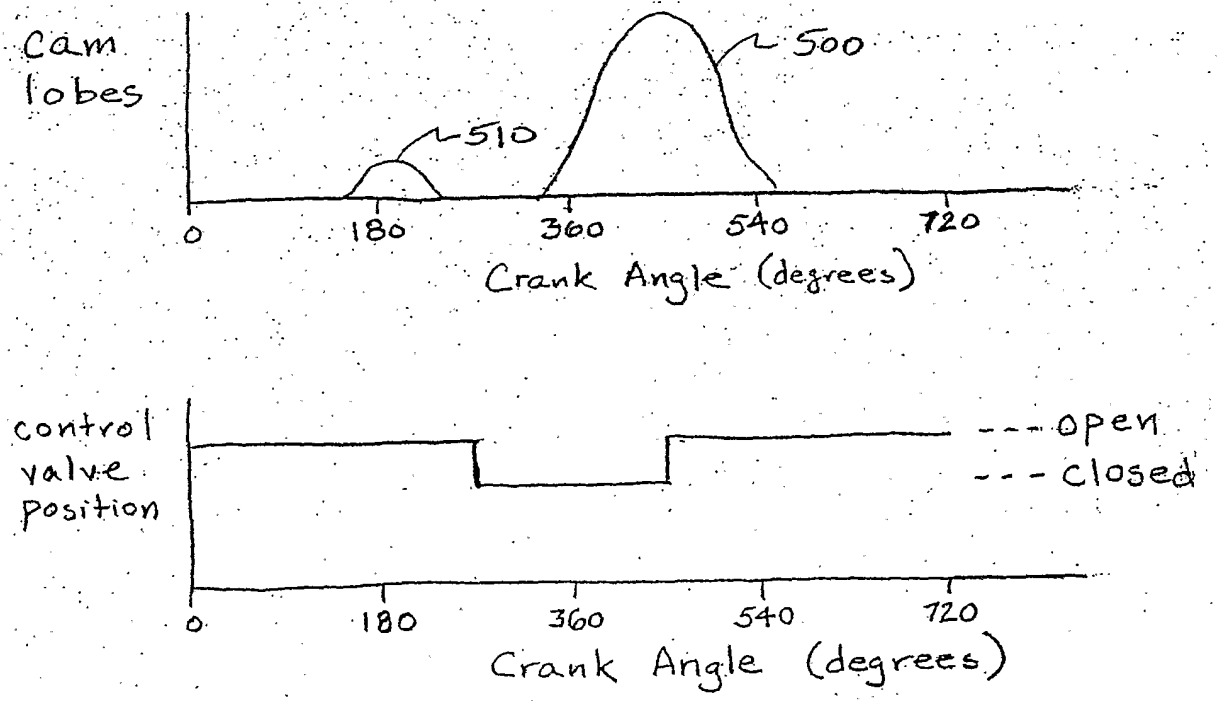

cam lobes
500
510
0
180
360
540
720
Crank Angle (degrees)
control valve position
--- open
--- closed
0
180
360
540
720
Crank Angle (degrees)

FIG. 5

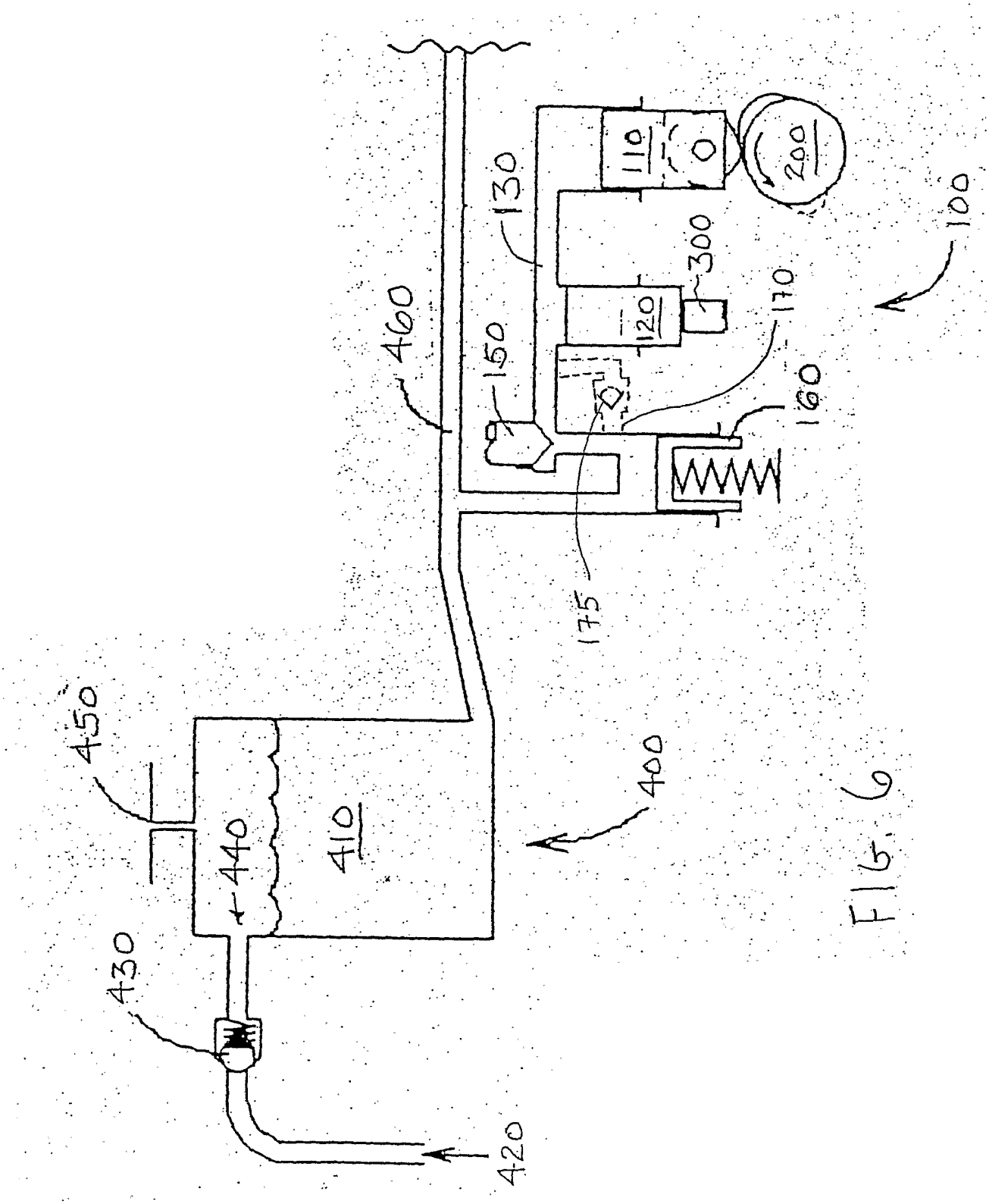

110
200
130
300
120
170
460
150
160
175
100
450
440
410
400
430
420

FIG. 6

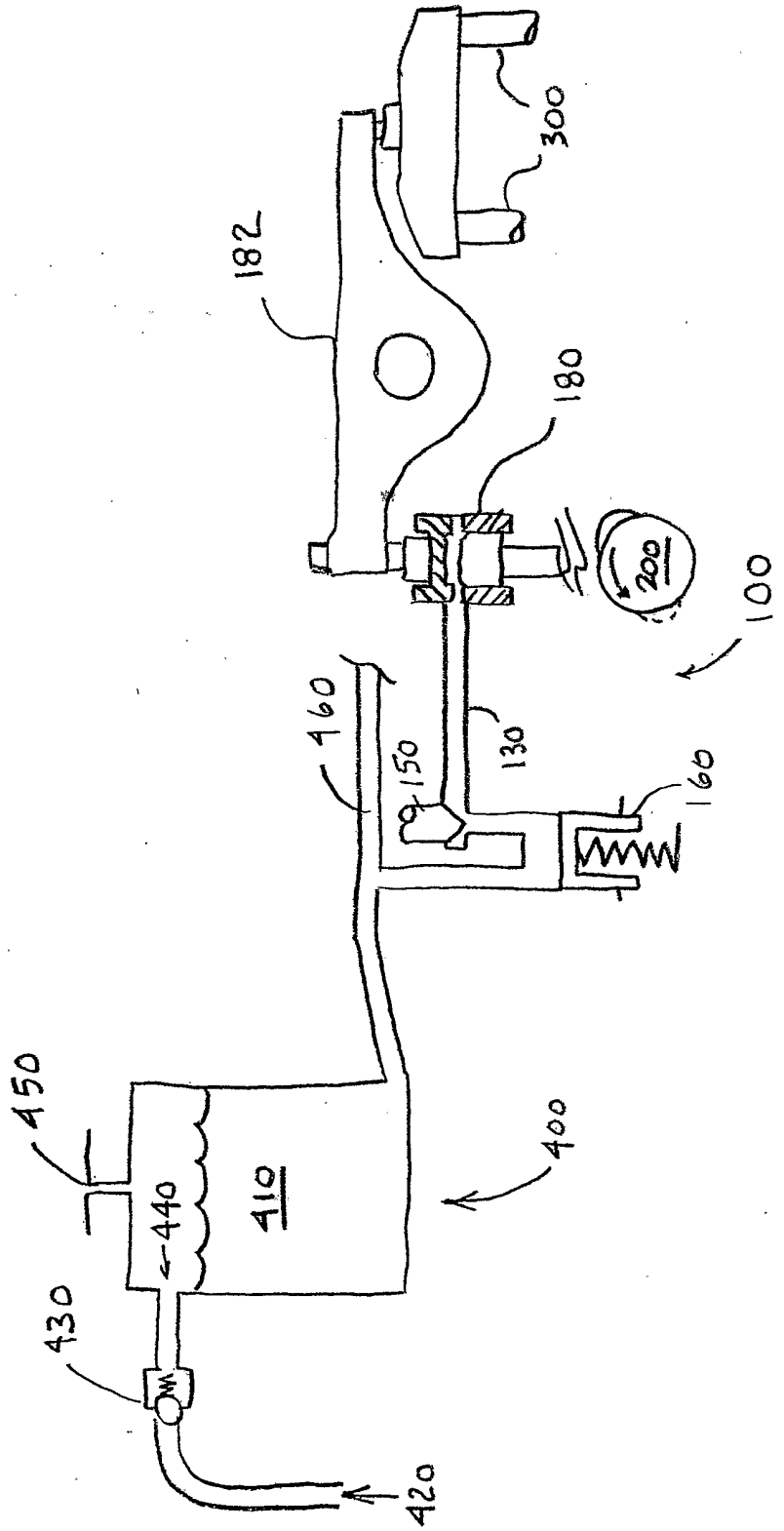


FIG. 7