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(54) Title: **ROCKER LATCH FOR CONTROLLING ENGINE VALVE ACTUATION**

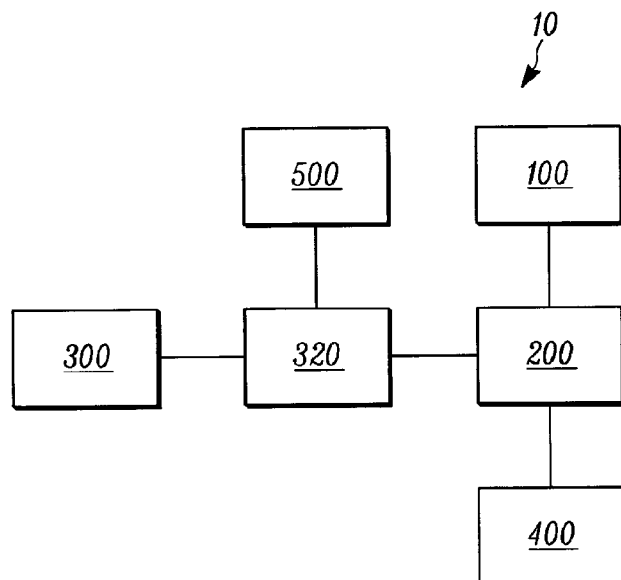


FIG. 1

(57) Abstract: Engine valve actuation systems and methods used to decompress an engine cylinder during engine start-up, shut-down, and for bleeder braking are disclosed. An exemplary system may include a rocker arm pivotally mounted on a rocker shaft, and a structure mounted adjacent to the rocker arm in a fixed position relative to the rocker arm. A latch piston may be slidably disposed between the rocker arm and the structure. The latch piston may be selectively extended to engage both the rocker arm and structure to limit the pivotal motion of the rocker arm and maintain the engine valves in an open condition.



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ROCKER LATCH FOR CONTROLLING ENGINE VALVE ACTUATION

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application relates to, and claims the benefit of the earlier
5 filing date and priority of U.S. Provisional Patent Application No. 61/738,794,
filed on December 18, 2012, and entitled "Rocker Latch For Controlling
Engine Valve Actuation."

FIELD OF THE INVENTION

[0002] The present invention relates generally to systems and methods for
10 controlling engine valves in an internal combustion engine. In particular, the
present invention relates to systems and methods for preventing an engine valve
from closing when acted on by a pivoting rocker arm.

BACKGROUND OF THE INVENTION

[0003] Valve actuation in an internal combustion engine is required in order
15 for the engine to produce positive power, as well as for 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] Internal combustion engines may not only be used to produce positive
20 power, but to also provide bleeder type engine braking. During bleeder engine
braking, in addition to the main exhaust valve event, one or more exhaust
valve(s) may be held slightly open by an amount sufficient to provide bleeder
braking throughout the remaining engine cycles (i.e., the intake, compression,
and expansion cycles for a full-cycle bleeder brake) The initial opening of the
25 exhaust valves in a bleeder braking operation may be in advance of top dead
center (TDC) of the compression stroke, and is preferably near a bottom dead
center (BDC) point between the intake and compression cycles. As such, a
bleeder type engine brake may require much lower force to actuate the valves,
and generate less noise due to continuous bleeding instead of the rapid blow-
30 down of a compression-release type brake. Thus, an engine bleeder brake can

have significant advantages.

5 **[0005]** During start-up and shut-down, an internal combustion engine may shudder and shake as it compresses air at low engine speeds. Moreover, it may be particularly difficult to achieve adequately high cranking speeds, to charge
10 and activate the valve actuation system with hydraulic fluid when the fluid is cold and has a higher viscosity. Holding open an intake and/or exhaust valve during engine start-up may decompress the cylinder so that the piston may move towards a TDC position more easily. An engine decompression system may hold open one or more intake and/or exhaust valves in an engine cylinder during
15 the start-up or shut-down of the engine. Thus, just when the engine is about to shut down, the engine decompression system may be activated to hold the intake and/or exhaust valve(s) open by a lift sufficient to decompress the engine. The valve lift may be controlled so that the piston may not run into the valve, but the lift may be adequate to let the pressure in and out of the cylinder.

20 **[0006]** An engine decompression system of the type described herein may be particularly useful in cold weather conditions, when cranking battery power is lower, cranking time to start-up is increased, the fuel/air mixture is less likely to ignite, and the engine is more difficult to turn over. In addition, engine decompression, which may reduce battery power and starter system requirements, may result in lower weight components, which permit increased
25 fuel efficiency, and avoidance or reduction in the need for additional starting aids. Reduction in start-up time resulting from use of a decompression system may also provide emissions benefits. Decompression shutdown may also result in a randomization of engine stopping angle, which may aid in a more evenly distributed wearing of the starter gear and the flywheel ring gear. Accordingly, advantages such as these, but not limited to the foregoing, may be realized by use of one or more of the embodiments of the invention described herein.

30 **[0007]** Various embodiments of the present invention may meet one or more of the aforementioned needs and provide other benefits as well.

SUMMARY OF THE INVENTION

[0008] Responsive to the foregoing challenges, Applicant has developed

an innovative system for preventing a rocker arm actuated engine valve from closing, said system comprising: a rocker arm pivotally mounted on a rocker shaft; a structure mounted adjacent to the rocker arm in a fixed position relative to the rocker arm; a latch piston slidably disposed between the rocker arm and the structure, and a latch piston actuator operatively connected to the latch piston, wherein said latch piston is adapted to assume an extended position causing the latch piston to engage both the rocker arm and the structure to limit the pivotal motion of the rocker arm, wherein the latch piston actuator is adapted to exert a force on the latch piston to cause the latch piston to assume the extended position or to retract from the extended position, and wherein the latch piston further comprises an engagement surface adapted to maintain the latch piston in the extended position continuously when the latch piston actuator ceases to exert force on the latch piston.

[0009] Applicant has also developed an innovative method of decompressing an internal combustion engine cylinder comprising the steps of: pivoting a rocker arm in a first direction to open an engine valve associated with the engine cylinder and the rocker arm; pivoting the rocker arm in a second direction so that the engine valve moves in a closing direction; exerting an actuation force on a latch piston to cause the latch piston to engage the rocker arm and a structure adjacent to the rocker arm, or to disengage the rocker arm from the structure; maintaining the engine valve in an open position in response to the latch piston engaging the rocker arm and the structure; and maintaining the latch piston in a position in which it engages the rocker arm and the structure after the actuation force on the latch piston ceases to be exerted so that the engine valve maintains an open position.

[0010] Applicant has also developed an innovative method of starting an internal combustion engine, comprising the steps of: maintaining one or more engine valves, in an engine cylinder, in a continuously open state for more than one engine cycle during engine cranking; discontinuing maintaining the one or more engine valves in a continuously open state after an engine parameter has reached a predetermined value; and providing fuel to the engine cylinder for

engine start-up responsive to the discontinuation of maintaining the one or more engine valves in a continuously open state.

[0011] 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

[0012] 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.

10 [0013] Figure 1 is a block diagram of an engine valve actuation system in accordance with an embodiment of the present invention.

[0014] Figure 2 is an isometric view of the rocker latch for controlling engine valve actuation according to an embodiment of the invention.

15 [0015] Figure 3 is an isometric view of the rocker latch for controlling engine valve actuation according to an embodiment of the invention.

[0016] Figure 4 is a partial cross-sectional isometric view of the rocker latch for controlling engine valve actuation according to an embodiment of the invention.

20 [0017] Figure 5 is a partial cross sectional isometric view of a rocker latch for controlling engine valve actuation according to an embodiment of the invention.

[0018] Figure 6 is a cross sectional view of the rocker latch for controlling engine valve actuation according to an embodiment of the invention.

[0019] Figure 7 is a cross sectional view of the rocker latch for controlling engine valve actuation according to an embodiment of the invention.

25 [0020] Figure 8 is a cross sectional view of the rocker latch for controlling engine valve actuation and the rocker according to an embodiment of the invention.

30 [0021] Figure 9 is a cross sectional view of the rocker latch for controlling engine valve actuation and the rocker arm according to an embodiment of the invention.

[0022] Figure 10 is a partial cross sectional view of the rocker latch for

controlling engine valve actuation and the rocker arm according to an embodiment of the invention.

[0023] Figure 11 is a partial cross sectional view of a rocker latch in accordance with an alternative embodiment of the invention.

5 **[0024]** Figure 12 is a partial cross sectional view of a rocker latch in accordance with another alternative, active control, embodiment of the invention.

[0025] Figure 13 is a flow chart illustrating the steps of starting an internal combustion engine while in a partial decompressed state.

[0026] It will be appreciated that for purposes of clarity and where deemed
10 appropriate, reference numerals have been repeated in the figures to indicate corresponding features, and that the various elements in the drawings have not necessarily been drawn to scale in order to better show the features of the invention. The drawings are exemplary only, and should not be construed as limiting the invention.

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DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0027] Reference will now be made in detail to embodiments of the systems and methods of the present invention, examples of which are illustrated in the accompanying drawings. As embodied herein, embodiments of the present
20 invention include systems and methods of actuating one or more engine valves.

[0028] An embodiment of the present invention is shown schematically in Fig. 1 as valve actuation system **10**. The valve actuation system **10** may include a rocker actuator **100**, such as a cam, push tube, or other valve train element, operatively connected to a rocker arm **200**. The rocker actuator **100** may be
25 adapted to selectively apply motion to the rocker arm **200**. The rocker arm **200** may be operatively connected to one or more engine valves **400** or a valve bridge (not shown), which in turn may act on the engine valves. A structure **300**, which is fixed in position relative to the pivoting rocker arm **200**, may be mounted adjacent (*i.e.*, near) to the rocker arm. A latch piston or bar **320** (collectively
30 referred to herein as a latch piston) may selectively extend between the structure

300 and the rocker arm **200** so as to selectively engage either the rocker arm or structure relative to the other. The latch piston **320** may control engine valve actuation by limiting the pivoting motion of the rocker arm **400** relative to the structure **300**.

5 **[0029]** The latch piston **320** may be selectively acted upon by a latch piston actuator **500** such that it extends, or is retracted from extending, between the structure **300** and the rocker arm **200**. When the latch piston **320** is extended, it may prevent the rocker arm from pivoting fully backward under the influence of the engine valve springs. As a result of the impediment to the pivoting motion of
10 the rocker arm **200**, the engine valve(s) **400** may be maintained slightly open throughout the full cycle of the engine. The engine valves **400** may comprise one or more exhaust valves, intake valves, or auxiliary valves. The selective extension of the latch piston **320** may cause the engine valves **400** to produce an engine valve event, including, but not limited to, a bleeder braking event
15 and/or engine decompression.

[0030] In a first embodiment, the latch piston **320** may be switched between the modes of preventing the rocker arm **200** from pivoting into an engine valve closed position and not preventing the rocker arm from pivoting into an engine valve closed position in response to input from a latch piston actuator **500**. The
20 latch piston actuator **500** may comprise any hydraulic, electro-magnetic, mechanical, pneumatic or gas actuation device or system capable of extending the latch piston **320** between the structure **300** and the rocker arm **200** to hold open one or more engine valves for initial engine start-up, shut-down, or bleeder braking. For example, in one embodiment of the present invention, the latch
25 piston actuator **500** may control a supply valve to supply activation fluid, such as hydraulic fluid or air or gases, to selectively extend the latch piston **320**. The latch piston actuator **500** may include a means for electronic control, which may include, for example, a microprocessor, linked to other engine component(s), to determine and select the appropriate times at which to extend the latch piston
30 **320**.

[0031] Engine decompression events may be optimized at a plurality of

engine operating conditions (e.g., speeds, loads, etc.) based upon information collected from the engine component(s). The information collected may include, without limitation, engine speed, vehicle speed, oil temperature, manifold (or port) temperature, manifold (or port) pressure, cylinder temperature, cylinder pressure, particulate information, and/or crank angle.

[0032] A first embodiment of the present invention is shown in Fig. 2, in which like reference characters refer to like elements. With reference to Figs. 2-9, the structure **300**, may be provided in the form of a housing **305** mounted in a fixed position adjacent to the rocker arm **200**. In the embodiment illustrated, the structure **300** may be mounted on a rocker shaft **250**, however, it is appreciated that it could be mounted to the engine cylinder head, or other surface so long as it is fixed in position relative to the pivoting motion of the rocker arm **200**. As shown in Figs. 2 and 3, the housing **305** may include a finished surface **350** that is adapted to wrap around the rocker shaft. The finished surface **350** may be shaped such that it forms a close fit around the rocker shaft.

[0033] As shown in Figs. 4, 6, and 7, the housing **305** may contain a latch piston bore **310**, and a bolt bore or hole **330** which intersect with each other. As shown in Figs. 5-7, the latch piston bore **310** may have an open end and a closed end that terminates in the housing **305**. As shown in Figs. 3, 4, and 9, both ends of the bolt hole **330** may be open such that a bolt **390** may pass through the bolt hole to fixedly secure the housing **305** on to the rocker shaft **250**. The bolt **390** may pass through the rocker shaft **250** to fixedly secure the housing **305** on to the bearing cap or the engine cylinder head.

[0034] With reference to Figs. 2-7, a latch piston **320** may be slidably disposed within the latch piston bore **310** such that an end of the latch piston extends out of the latch piston bore **310** toward the rocker arm **200**. The latch piston **320** may have a shoulder separating the narrow and broad ends of the latch piston. A piston retaining ring **370** may be located near the open end of the latch piston bore **310**. The piston retaining ring **370** may have a central opening through which the narrow end of the latch piston **320** extends. A spring **360** may extend between the piston retaining ring **370** and the shoulder of the

latch piston **320** to bias the latch piston into the latch piston bore **310**.

[0035] The diameter of the narrow end of the latch piston **320** may taper linearly, progressively, or less than linearly from the shoulder of the latch piston **320** to its terminus. As shown in Fig. 9, the narrow end of the latch piston **320** may selectively contact a boss **210** disposed on the rocker arm **200**. As shown in Fig. 8, in an alternate embodiment, a lash adjustment screw **220** may extend from the boss **210** and the narrow end of the latch piston **320** may contact the lash adjustment screw **220** to interrupt or limit the pivoting motion of the rocker arm **200**. The narrow end of the latch piston **320** may have a contact surface adapted to engage the rocker arm boss **210** or adjustment screw **220**. Specifically, the narrow end of the latch piston **320** may be provided with a surface adapted to engage the rocker arm boss **210** or adjustment screw **220** such that the contact between the two causes the latch piston to be maintained in its extended position even when the latch piston actuator **500** ceases to exert its full actuation force on the latch piston. The latch piston may be maintained in its extended position as a result of the force of the engine valve springs acting through the rocker arm **200** to jam the latch piston **320** into the wall of the latch piston bore **310**. Alternatively, with reference to Fig. 11, the latch piston **320** may include an engagement structure **322** which may interlock with a mating engagement structure **212** provided on the rocker arm boss **210** or adjustment screw (not shown). Thus, the narrow end of the latch piston **320** shown in Figs. 9 and 11, may remain engaged against the rocker arm boss **210** or adjustment screw **220** even after the engine shuts down and the latch piston actuator **500** ceases to exert its full actuation force on the latch piston. As a result, one or more cylinders of the engine may be in a decompressed state at the initiation of engine start-up.

[0036] As shown in Figs. 8 and 9, a bolt **390** may be inserted into the bolt hole **330** to removably attach the housing **305** on to the rocker shaft **250**. With reference to Fig. 3, a recess **380** having a flat surface may be adapted to buttress the latch piston **320** against the bolt **390** disposed in the bolt hole **330**, thereby preventing the latch piston **320** from rotating within the latch piston bore

310.

[0037] As shown in Figs. 3, 4, 5, and 9, a dowel ring **340** may be disposed around one open end of the bolt hole **330**, which is on the finished surface **350** side of the housing **305**. The dowel ring **340** may fit into the counter bore **345** on the rocker shaft **250** to align the rocker latch **300** on the rocker shaft **250**. The dowel ring **340** may be press fit in the open end of the bolt hole **330** on the finished surface **350** side of the housing **305** to locate the housing **305** on the rocker shaft **250**. As shown in Fig. 3, the dowel ring **340** may have a split to enable it to be inserted into and removed from the counter bore **345** on the rocker shaft **250**.

[0038] Hydraulic fluid may be supplied to the housing **305** from a hydraulic fluid supply (not shown). The hydraulic fluid supply may be connected to the housing **305** through a control valve (not shown). As shown in Figs. 8 and 9, hydraulic fluid may flow from the hydraulic fluid supply through a fluid supply/drain passage **260** formed in the rocker shaft **250** to the bolt hole **330**. The bolt hole **330** may be oversized such that the hydraulic fluid may wash up around the bolt **390** to flow into and out of the latch piston bore **310** at the intersection of the latch piston bore and the bolt hole. The control valve may regulate the supply of hydraulic fluid to and from the bolt hole **330**. Other hydraulic arrangements for supplying hydraulic fluid to the housing **305** are considered well within the scope and spirit of the present invention.

[0039] As noted above, the fluid supplied may be hydraulic fluid or any other suitable fluid. For example, in an alternate embodiment, the latch piston **320** may be actuated by pneumatic air or gases that are supplied to the latch piston bore **310**. The pneumatic air/gases may be supplied to the housing **305** through a control valve (not shown). In another alternate embodiment, shown in Fig. 10, the latch piston **320** may be slidably disposed in a latch piston bore **310** formed in the rocker arm **200**. As described above, a spring **360** and piston retaining ring **370** may bias the latch piston **320** into the latch piston bore **310**. A key **395** may be disposed in a bore or hole formed in the rocker arm such that the key **395** may allow the latch piston **320** to slide along the axis of the latch piston bore

310, but may prevent the latch piston 320 from rotating in the latch piston bore 310.

[0040] In the Fig. 10 embodiment, the structure 300 may be attached to the rocker shaft, rocker cap, rocker shaft cap, cylinder head or other structure which is fixed in position relative to the pivoting motion of the rocker arm 200. The structure 300 may include a boss 610 that is adapted to be selectively engaged by the latch piston 320, as shown in Fig. 10. In an alternate embodiment, a lash adjustment screw (see Fig. 8) may extend from the boss 610 and the narrow end of the latch piston 320 may selectively engage the lash adjustment screw to interrupt or limit the pivoting motion of the rocker arm 200. The Fig. 10 embodiment may be operated in like fashion to the embodiment illustrated in Figs. 2-9.

[0041] In yet another alternative embodiment, described generally as an active control embodiment, the latch piston 320 may be normally biased into an extended position in which it engages both the structure 300 and the rocker arm 200 to keep an engine valve open. With reference to Fig. 12, in which like reference characters refer to like elements and which illustrates an active control embodiment of the invention, the structure 300 may include a latch piston bore 310 in which a latch piston 320 is slidably disposed. A spring 362 may bias the latch piston 320 out of the latch piston bore 310 towards a rocker arm (not shown). Specifically, the spring 362 may normally bias the latch piston 320 out of the latch piston bore 310 towards a rocker arm when no hydraulic fluid pressure is actively supplied to the system.

[0042] A bolt 390 (or alternatively, a key 395 shown in other embodiments) may be provided in the bolt hole 330. The bolt 390 (or key 395) may engage a recess provided in the latch piston 320 to prevent it from rotating in the latch piston bore 310. The bolt hole 330 may be sized to permit hydraulic fluid to be supplied to the latch piston bore 310 through the bolt hole, as explained above, under the control of a controller. The latch piston 320 may be provided with a force receiving surface 324, such as a shoulder, upon which the force of hydraulic fluid supplied through the bolt hole 330 may act on the latch piston 320

to push it into the latch piston bore **310** against the bias of the spring **362**. The supply of hydraulic fluid pressure (or other force) to the latch piston **320** causes it to disengage the rocker arm in the active control embodiment, as opposed to engage the rocker arm in the previously described embodiments.

5 **[0043]** Operation of an embodiment of the present invention will now be described. With regard to Figs. 2-9, the embodiment shown therein may provide cylinder decompression during engine start-up, shut-down, or bleeder braking by holding open one or more engine valves (not shown) as a result of the latch piston **320** being selectively extended between the structure **300** and the
10 rocker arm **200**. As shown in Fig. 6, when no decompression is required, the latch piston **320** may be biased into the latch piston bore **310** by the spring **360** so that the rocker arm may pivot freely without contacting the latch piston.

[0044] As shown in Fig. 7, when hydraulic fluid is supplied to the latch piston bore **310**, the hydraulic fluid pressure may overcome the bias of the spring **360**
15 and push the latch piston **320** out of the latch piston bore such that the narrow end of the latch piston engages rocker arm boss **210** or adjustment screw **220**. In the exemplary embodiment, the latch piston **320** may be pushed out of the latch piston bore **310** almost simultaneously when the rocker arm **200** lifts above the height required for the latch piston **320** to extend. As shown in Fig. 8, the
20 projecting latch piston **320** may interrupt the rotation of the rocker arm **200** and prevent it from pivoting back completely, thereby holding the engine valve open, for example, by an amount sufficient to provide engine decompression and/or bleeder braking. During engine operation, the hydraulic fluid acting on the latch piston **320** causes it to hold the rocker arm **200** open unless the controller **500**
25 turns off the hydraulic fluid supply.

[0045] When the engine shuts down while the controller **500** maintains hydraulic fluid supply, the oil pressure drops, and, over time, the hydraulic fluid pressure in the latch piston bore **310** may abate, such that sufficient hydraulic fluid is not present in the latch piston bore to overcome the bias of spring **360**.
30 Nevertheless, at this time, the rocker arm **200** is being pushed against the latch piston **320** by the bias of the valve spring (not shown). The force exerted by the

valve spring may be sufficient to press the rocker arm **200** upward with sufficient force to prevent the bias of the spring **360** from pushing the latch piston **320** out of engagement with the rocker arm. In other words, the bias of the valve spring locks the latch piston **320** and the rocker arm **200** together, as explained above.

- 5 Thus, the rocker arm **200** may be held open to allow the engine to partially decompress during subsequent engine start-up.

[0046] In the embodiments shown in Figs. 2-10, if the engine has six cylinders, for example, when the engine shuts down, rocker arms for four out of the six cylinders may be latched into an open decompressed state by the process described above. The remaining two rocker arms may be in some intermittent stage of opening engine valves, or the engine valves may be closed, so that when the hydraulic pressure ceases to be exerted on the latch pistons associated with these rocker arms, the spring **360** may retract the latch pistons, and these valves may close (or remain closed if closed already) under bias of the valve springs upon engine start-up. When the engine is restarted the four rocker arms that are latched open may partially decompress the engine to improve starting speed and potentially provide the benefits described above.

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[0047] When the engine restarts, the rocker arms **200** that are latched open may allow the engine to decompress so that the starter can get the engine moving and prevent the engine from shuddering. As the engine spins through its start-up cycle, the camshaft may relieve the pressure exerted by the rocker arms **200** on the latch pistons **320** and may permit the springs **360** to retract the latch pistons **320** into the housings **305**. Latch piston retraction and engine compression may occur within two (2) engine rotations. Latch piston retraction and engine compression occurring in more or less than two (2) engine revolutions are also considered well within the scope and spirit of the present invention.

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[0048] The embodiment shown in Figs. 2-10 may also provide bleeder type engine braking during engine operation by holding open one or more exhaust valves. As described above, the rocker arm for one or more exhaust valve(s) may be held open by the latch piston **320** of the rocker latch **300**. The one or

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more exhaust valve(s) may be held slightly open throughout the remaining engine cycles (full-cycle bleeder brake) or during a portion of the remaining engine cycles (partial-cycle bleeder brake). Likewise, the embodiment shown in Figs. 2-10 may also provide exhaust gas recirculation by holding the valves open
5 for the exhaust gases to recirculate.

[0049] For systems with active control capability, an example of which is described above in connection with Fig. 12, the engine control system can include a start-up control strategy which enables closed loop feedback of the engine based on one or more engine parameters. For example, with reference
10 to Figs. 12 and 13, when an active control embodiment of the invention is employed and the engine is at rest, in a shut-down state or potentially as a result of engine stall, the latch piston **320** may be extended into a position in which it engages both the structure **300** and a rocker arm under the influence of the spring **362**. As a result, one or more of the engine valves may be latched into an
15 open position.

[0050] With reference to Fig. 13, engine start-up may be initiated by turning the engine key into an on position in step **600**. Turning the engine key on may cause the latch piston to be extended to engage the structure **300** and a rocker arm in step **602** if the latch piston is not already extended as a result of the
20 engine being shut down. Turning the key on may also cause the controller to measure one or more engine parameters, referenced above, in step **604** and cause the starter to crank the engine in step **606**. If the one or more measured engine parameters are determined to meet or exceed threshold values in step **608**, hydraulic fluid may be provided to the active control latch piston **320** to
25 cause the latch piston to disengage the rocker arm and enable engine compression in the associated engine cylinder in step **612**. If the engine parameter value is not met or exceeded, then the controller may determine in step **610** whether a time duration threshold has been exceeded. If a time threshold value is exceeded, then hydraulic fluid may be provided to the active
30 control latch piston **320** to cause the latch piston to disengage the rocker arm and enable engine compression in the associated engine cylinder in step **612**. If

neither the engine parameter threshold value nor the time threshold value have been met or exceeded in steps **608** and **610**, the engine may continue to be cranked in step **606** in a decompressed, or partially decompressed, state. Once the engine compression is enabled in step **612**, fuel may be supplied in step **614** and engine start completed in step **616**.

[0051] With continued reference to Fig. 13, the monitored engine parameter(s) may include one or more of coolant temperature, intake manifold air temperature, oil pressure, fuel pressure, engine speed, exhaust temperature, metal temperature, intake manifold pressure, cylinder pressure, cylinder temperature, engine speed variation, starter motor current draw, battery voltage, alternator current, transmission oil pressure. The control sequence illustrated in Fig. 13 can also be modified to include a step of verifying that the engine is in a decompressed state prior to starting cranking.

[0052] In alternative embodiments of the present invention, the engine cylinder associated with a described engine valve actuation system **10** may be further provided with heated cylinder inlet air for improved engine start-up while using engine decompression. The heated inlet air may be provided by an electric resistance heater or combustion oil flame burner, for example. A temperature sensor may be provided for measuring ambient temperature, or engine temperature.

[0053] 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, pneumatic fluid may be used instead of a hydraulic fluid in the above embodiments without departing from the invention's intended scope. Further, instead of the bolt, the housing could be anchored on the rocker shaft using any other commercially available means without departing from the invention's intended scope.

WHAT IS CLAIMED IS:

1. A system for preventing a rocker arm actuated engine valve from closing, said system comprising:
 - a rocker arm pivotally mounted on a rocker shaft;
 - 5 a structure mounted adjacent to the rocker arm in a fixed position relative to the rocker arm;
 - a latch piston slidably disposed between the rocker arm and the structure, and
 - a latch piston actuator operatively connected to the latch piston,
 - 10 wherein said latch piston is adapted to assume an extended position causing the latch piston to engage both the rocker arm and the structure to limit the pivotal motion of the rocker arm,
 - wherein the latch piston actuator is adapted to exert a force on the latch piston to cause the latch piston to assume the extended position or to retract
 - 15 from the extended position, and
 - wherein the latch piston further comprises an engagement surface adapted to maintain the latch piston in the extended position continuously when the latch piston actuator ceases to exert force on the latch piston.
- 20 2. The system of claim 1, wherein the latch piston is slidably disposed in a latch piston bore provided in the structure.
3. The system of claim 1, wherein the latch piston is slidably disposed in a latch piston bore provided in the rocker arm.
- 25 4. The system of claim 1, wherein the latch piston actuator exerts a hydraulic force on the latch piston.
5. The system of claim 1, wherein the latch piston actuator exerts a
- 30 mechanical force on the latch piston.

6. The system of claim 1, wherein the latch piston actuator exerts a gas pressure force on the latch piston.
7. The system of claim 1, wherein the latch piston is biased towards a position in which it does not engage both the rocker arm and the structure when the latch piston actuator is not exerting a force on the latch piston.
8. The system of claim 1, wherein the latch piston actuator force exerted on the latch piston is electromagnetically generated.
9. The system of claim 1, wherein the latch piston is biased towards a position in which it engages both the rocker arm and the structure when the latch piston actuator is not exerting a force on the latch piston.
10. The system of claim 1, further comprising:
a bore in the structure; and
a bolt or key extending into the bore,
wherein the bore is sized to receive the bolt or key and permit fluid to flow through the bore to the latch piston.
11. The system of claim 1 further comprising:
a bore in the structure, said bore provided adjacent to the latch piston;
a bolt or key extending into the bore; and
a recess provided on the latch piston, said recess adapted to engage the bolt or key to prevent rotation of the latch piston.
12. The system of claim 1, wherein the rocker arm or the structure includes an adjustment screw for adjusting the position of a point of engagement between the rocker arm and the structure.
13. The system of claim 1, further comprising an engagement structure provided on the latch piston.

14. A method of decompressing an internal combustion engine cylinder comprising the steps of:
- pivoting a rocker arm in a first direction to open an engine valve
 - 5 associated with the engine cylinder and the rocker arm;
 - pivoting the rocker arm in a second direction so that the engine valve moves in a closing direction;
 - exerting an actuation force on a latch piston to cause the latch piston to engage the rocker arm and a structure adjacent to the rocker arm, or to
 - 10 disengage the rocker arm from the structure;
 - maintaining the engine valve in an open position in response to the latch piston engaging the rocker arm and the structure; and
 - maintaining the latch piston in a position in which it engages the rocker arm and the structure after the actuation force on the latch piston is reduced so
 - 15 that the engine valve maintains an open position.
15. The method of claim 14, wherein the latch piston is maintained in the position in which it engages the rocker arm and the structure for more than one engine cycle while the internal combustion engine is shut down.
- 20 16. The method of claim 14, wherein the latch piston is maintained in the position in which it engages the rocker arm and the structure as a result an engagement structure provided on the latch piston.
- 25 17. The method of claim 14, wherein the latch piston disengages from extending between the rocker arm and the structure in response to the actuation force.
- 30 18. The method of claim 14, wherein the latch piston is maintained in the position in which it engages the rocker arm and the structure while the internal combustion engine is cranked until engine oil pressure or engine fuel pressure

reaches a desired level.

19. The method of claim 14, wherein the latch piston is maintained in the position in which it engages the rocker arm and the structure while the internal
5 combustion engine is cranked until the inlet air temperature reaches a desired set point.

20. The method of claim 14, wherein the latch piston extends between the rocker arm and the structure in response to the actuation force.

10

21. A method of starting an internal combustion engine, comprising the steps of:

maintaining one or more engine valves in an engine cylinder in a continuously open state for more than one engine cycle during engine cranking;

15 discontinuing maintaining the one or more engine valves in the continuously open state after an engine parameter has reached a predetermined value; and

providing fuel to the engine cylinder for engine start-up responsive to the discontinuation of maintaining the one or more engine valves in the continuously
20 open state.

22. The method of claim 21, wherein the engine parameter is selected from the group consisting of: engine cranking time, and engine temperature.

25 23. The method of claim 21, further comprising the steps of:
providing heated air to the engine cylinder while maintaining the one or more engine valves in a continuously open state for more than one engine cycle during engine cranking.

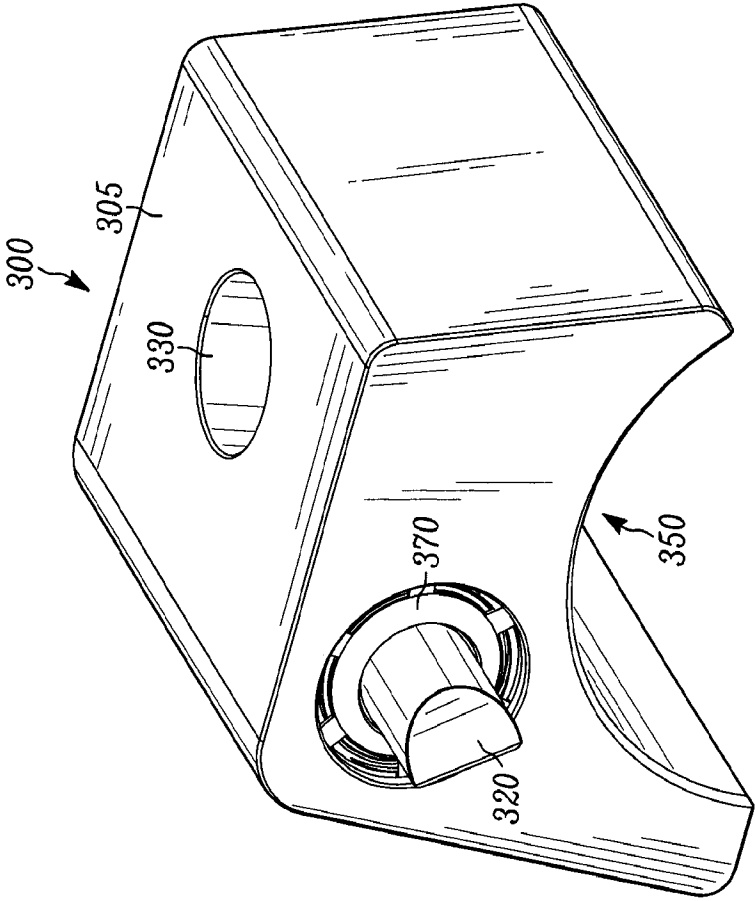


FIG. 2

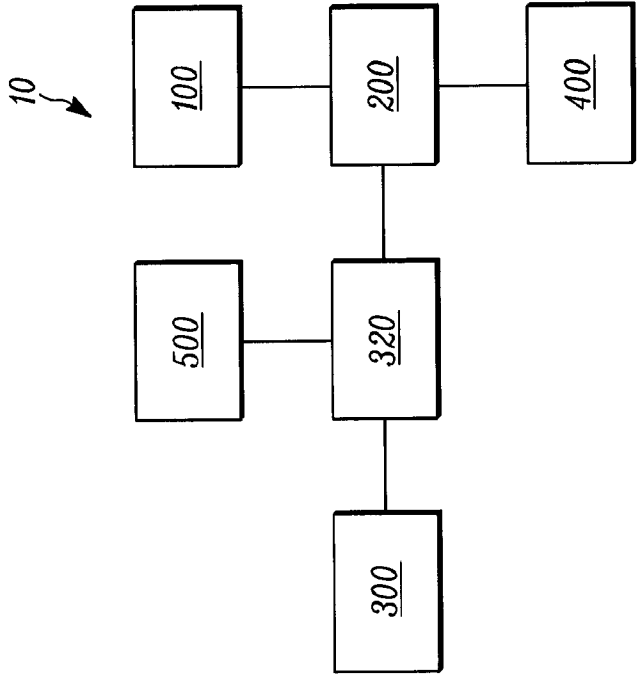


FIG. 1

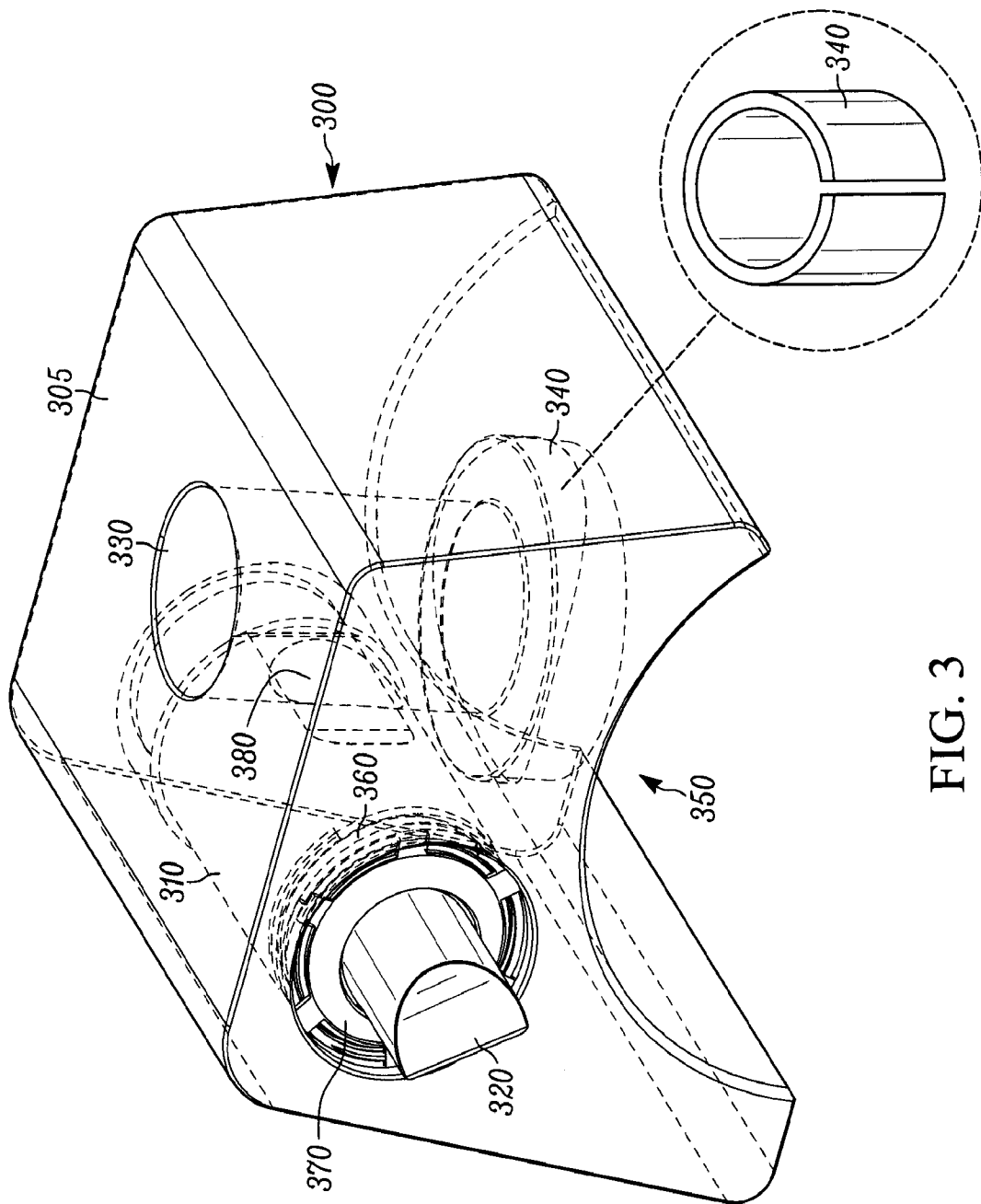


FIG. 3

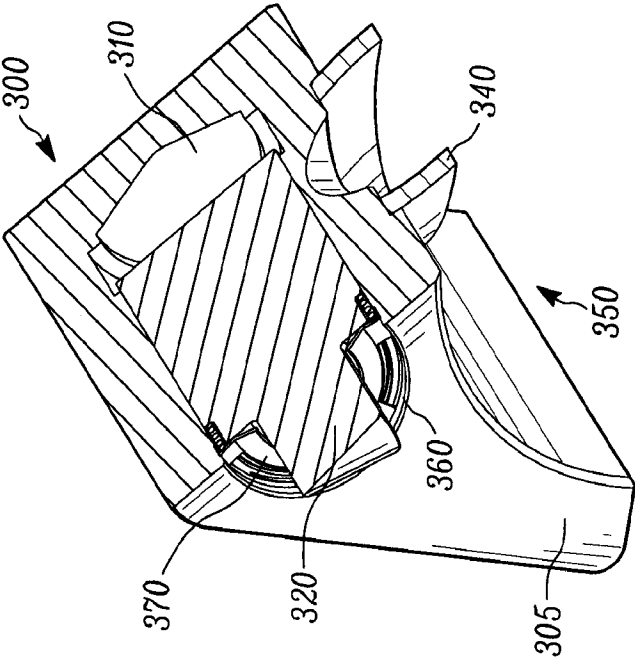


FIG. 5

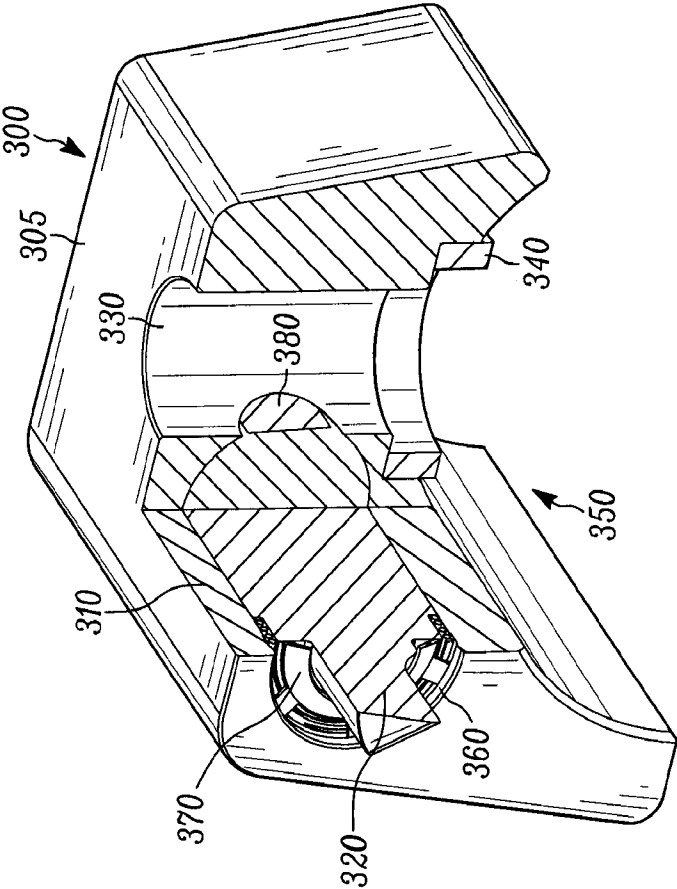


FIG. 4

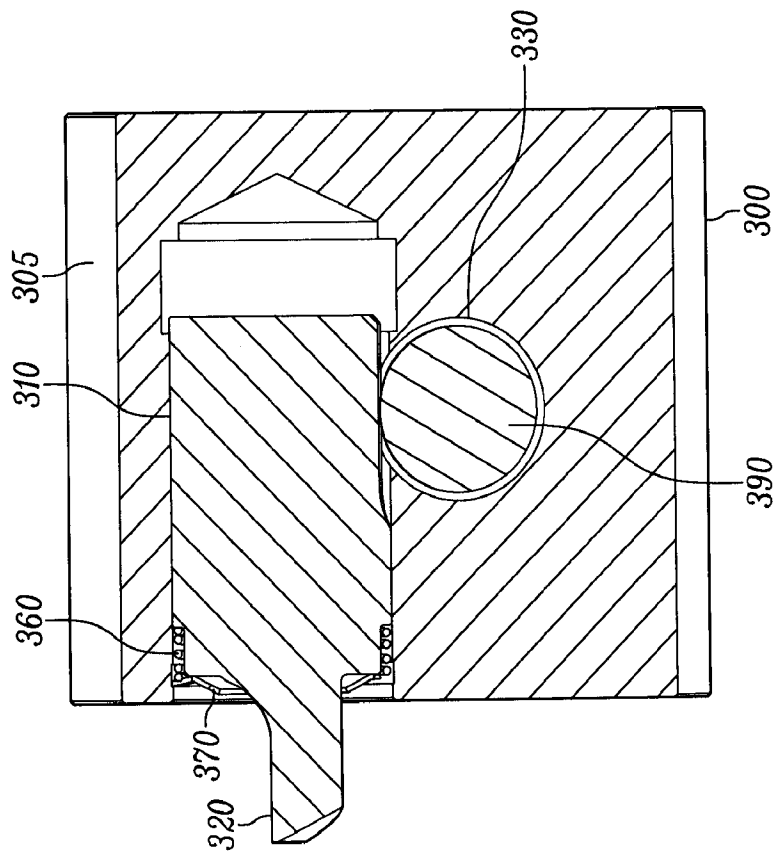


FIG. 7

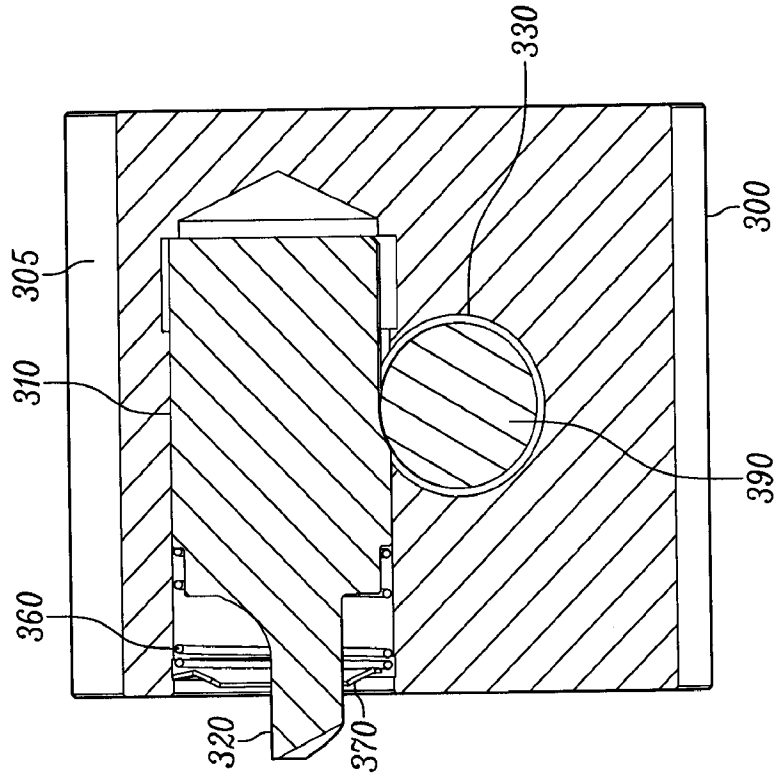
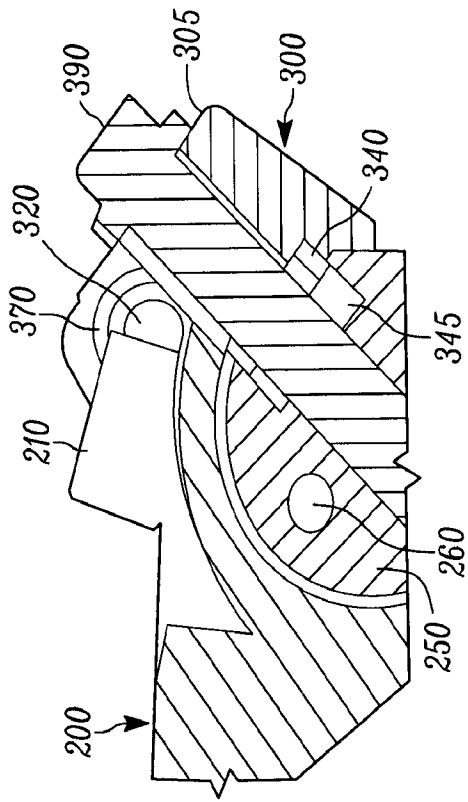
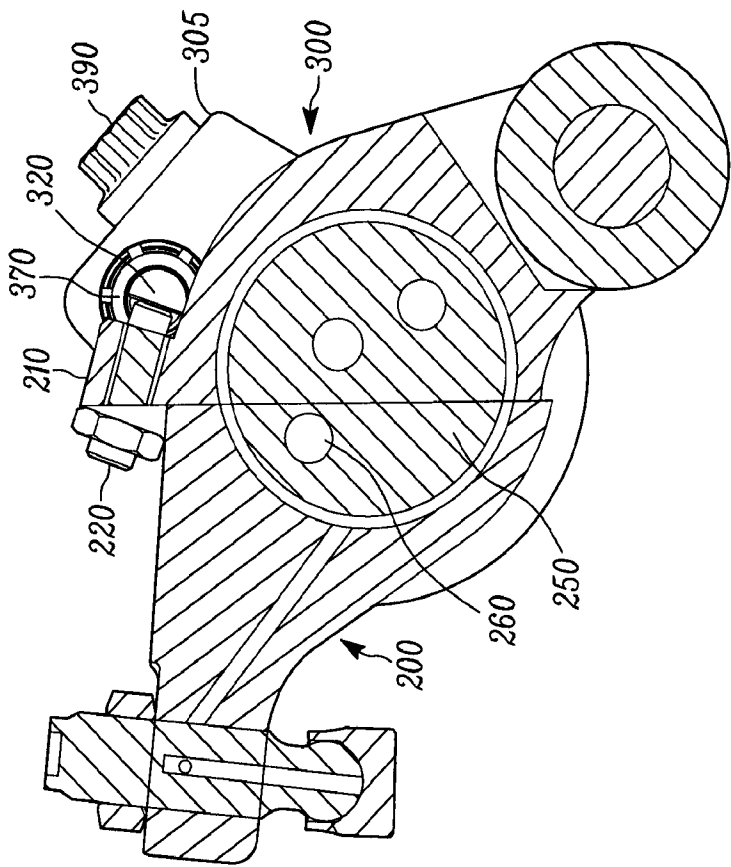


FIG. 6



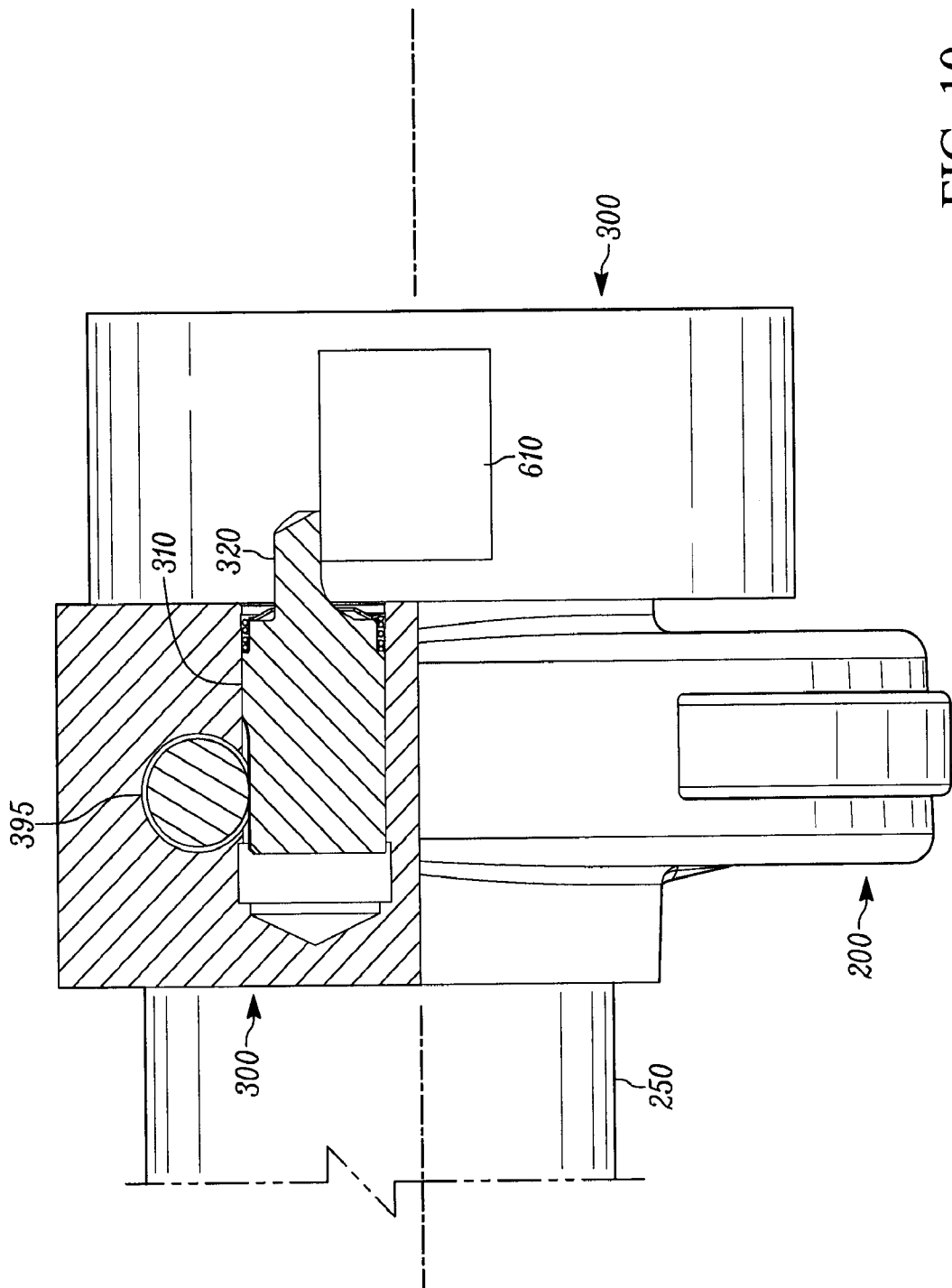


FIG. 10

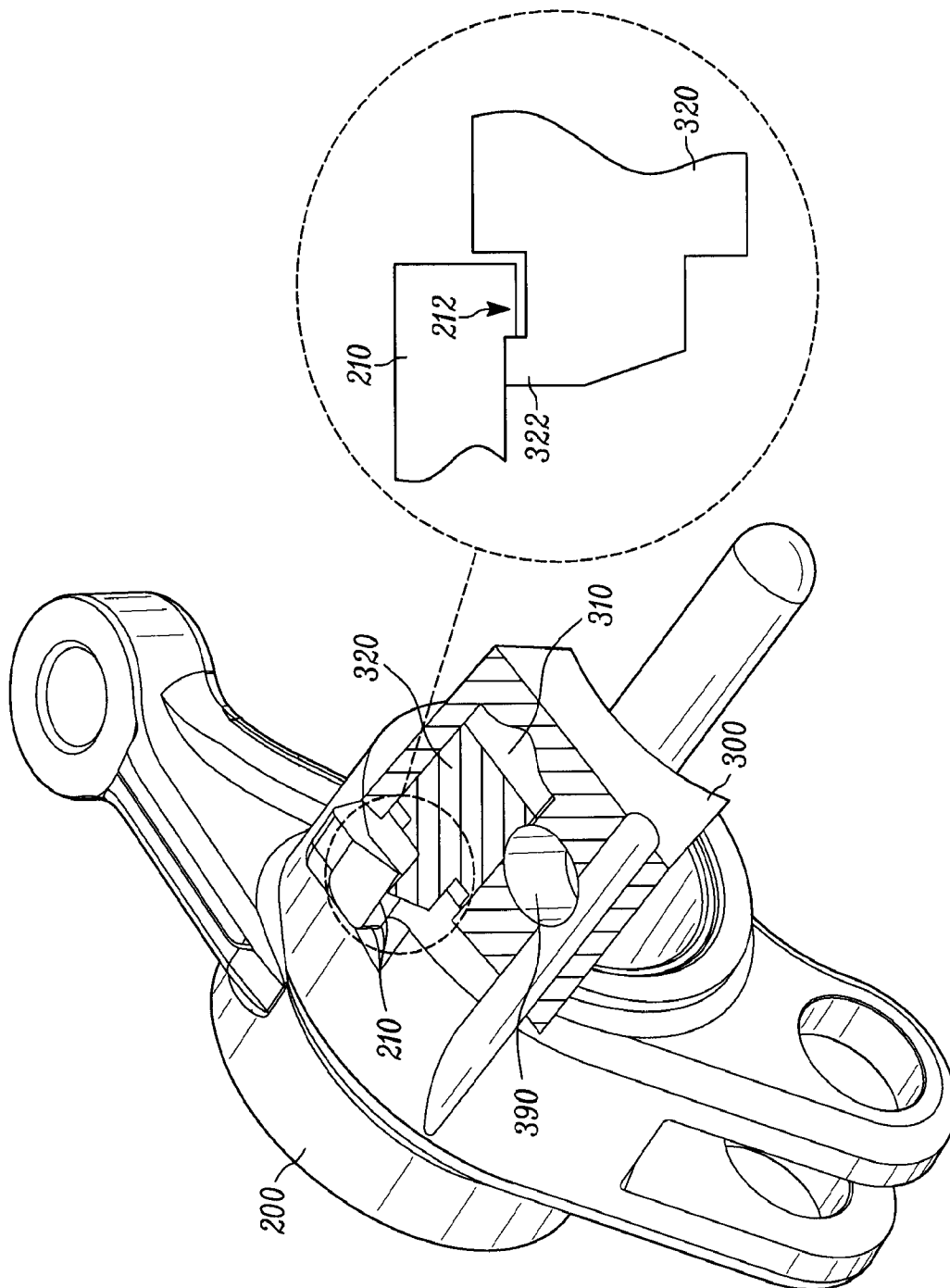


FIG. 11

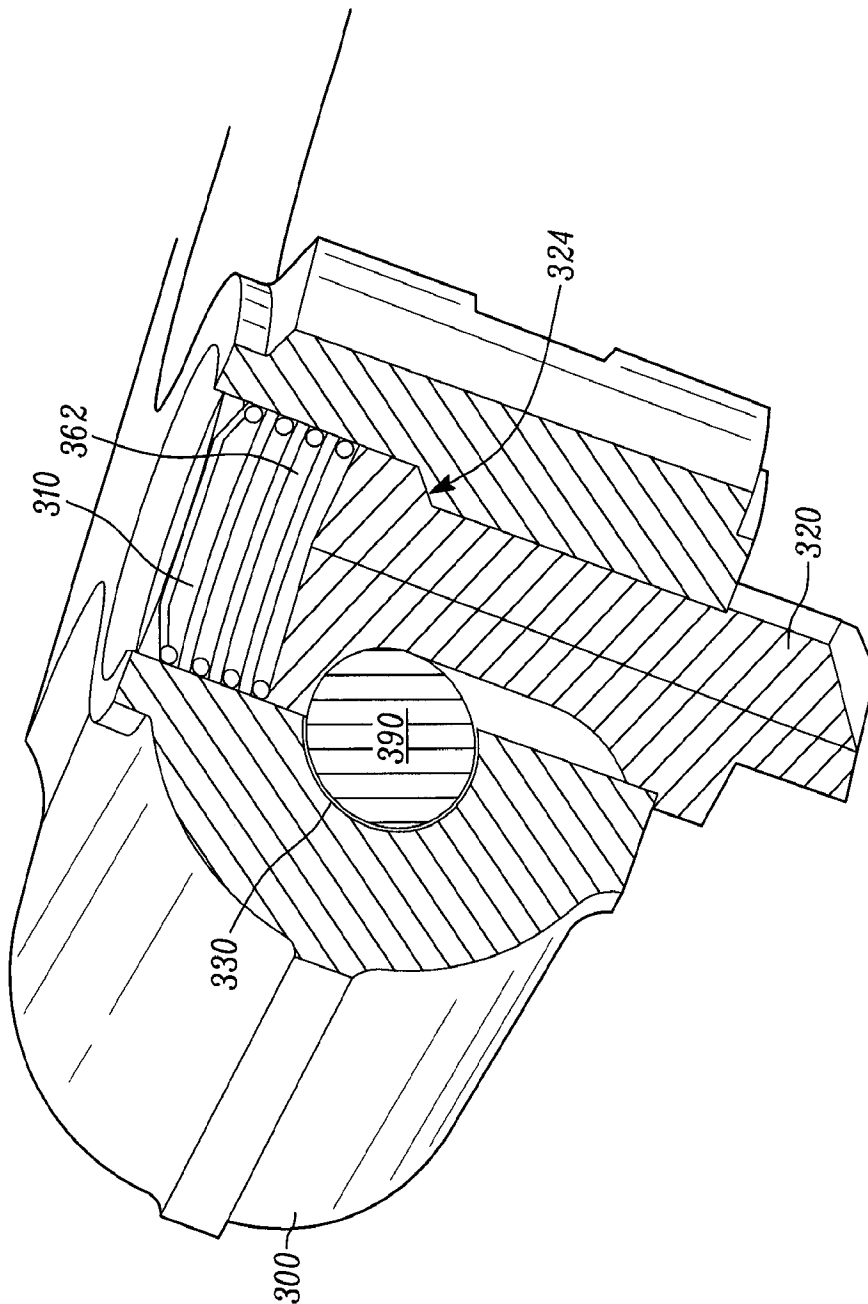


FIG. 12

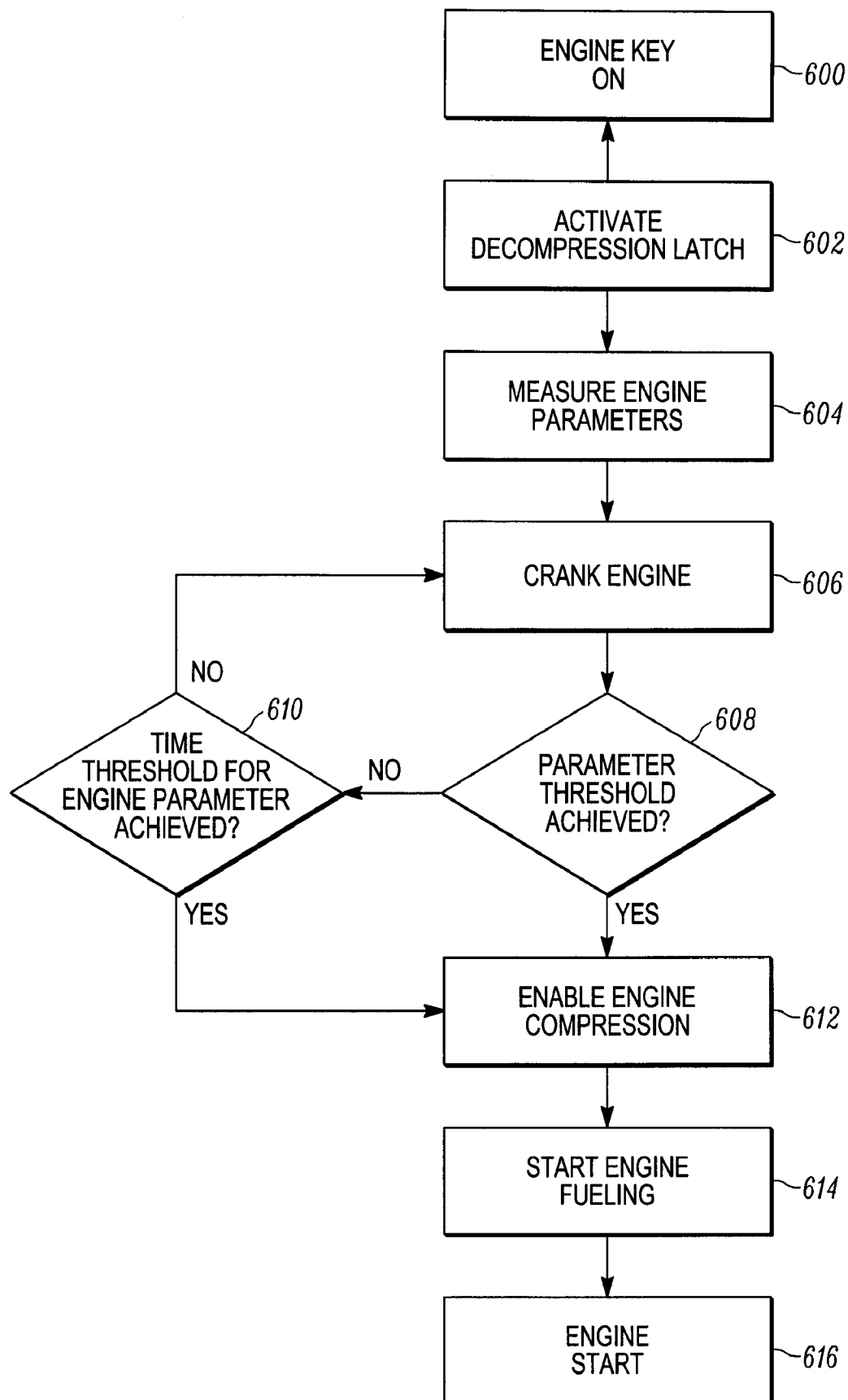


FIG. 13

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2013/076136

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - F01L 1/18 (2014.01)

USPC - 123/90.39

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) - F01L 1/18, 13/00, 13/06, 13/08 (2014.01)

USPC - 74/559; 123/90.1, 90.15, 90.16, 90.39, 90.44, 90.46, 182.1, 320; 188/273

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

CPC - F01L 13/08 (2014.02)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PatBase, Google Scholar

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6,655,349 B1 (CAVANAGH) 02 December 2003 (02.12.2003) entire document	1-14, 16, 17, 20
Y	GB 355,812 A (RICARDO) 31 August 1931 (31.08.1931) entire document	1-14, 16, 17, 20
Y	US 2008/0223325 A1 (MEISTRICK) 18 September 2008 (18.09.2008) entire document	3, 12
A	US 6,092,496 A (BHARGAVA et al) 25 July 2000 (25.07.2000) entire document	1-23
A	US 4,648,362 A (KASTLUNGER) 10 March 1987 (10.03.1987) entire document	1-23

☐ Further documents are listed in the continuation of Box C.


* Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

15 April 2014

Date of mailing of the international search report

20 MAY 2014

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