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(54) **RADIAL ENGINE POWER SYSTEM**

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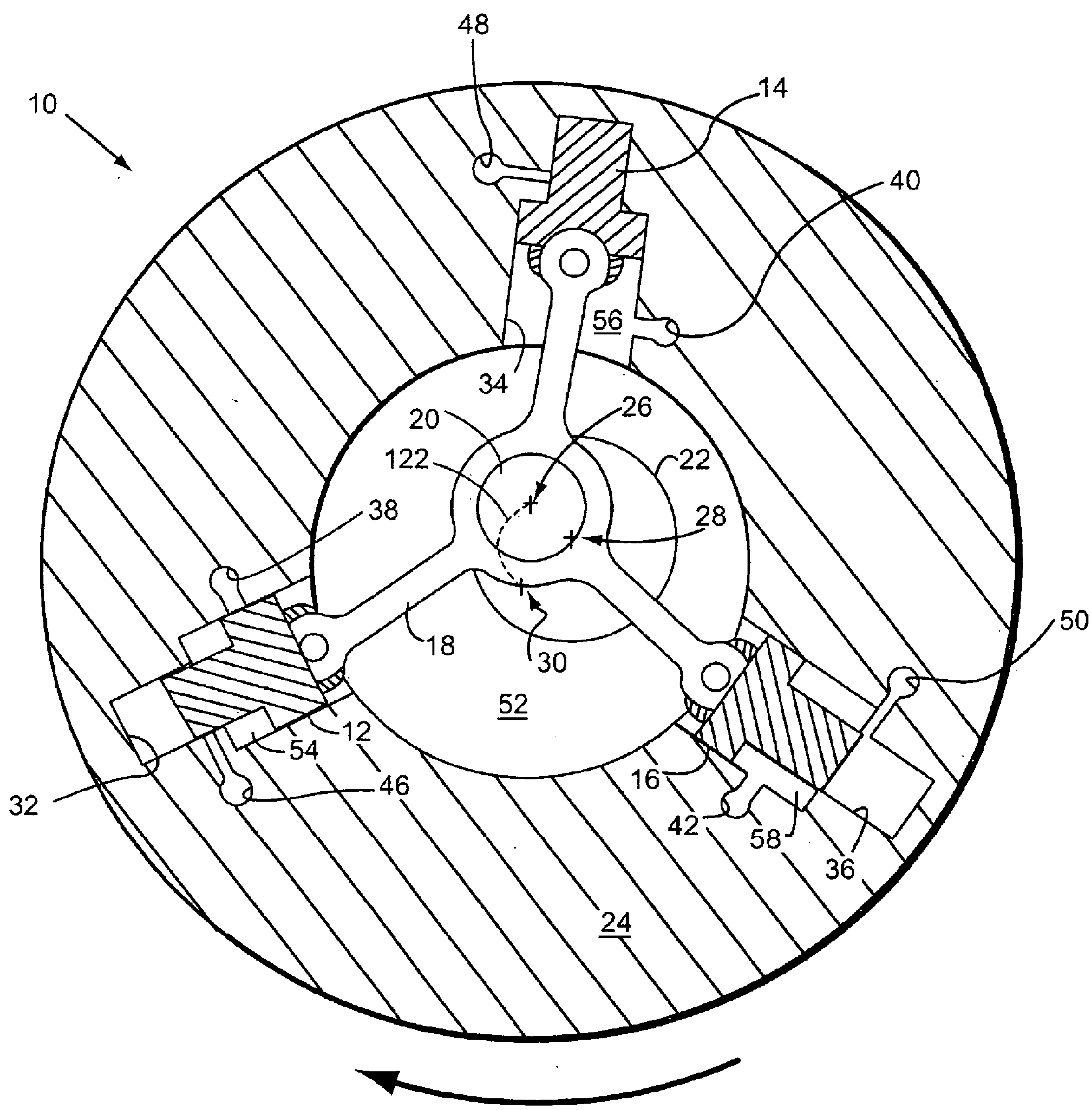
(52) **U.S. Cl.** .... **123/43 R**

(57) **ABSTRACT**

A power plant utilizing a radial rotary engine and incorporating onboard energy storage. The engine is of the type utilized in pre-World War I aircraft, but with certain modifications. The energy storage system exploits the flywheel effect inherent in these engines and optionally also includes auxiliary energy storage in other forms, such as compressed air or electrical. Using a continuously variable transmission enables advantageous use of engine inertia in a coast down mode of driving.



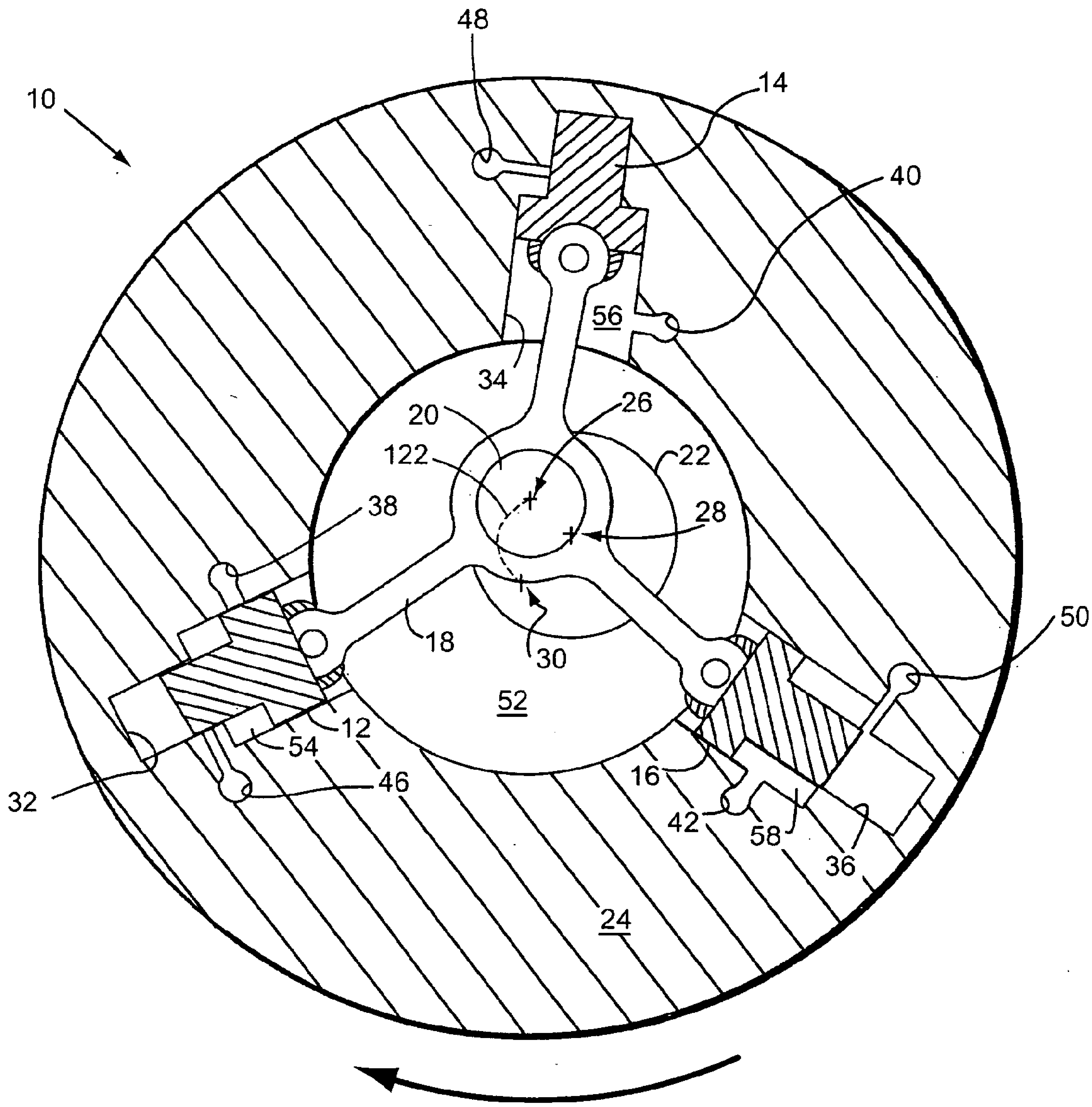

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Fig. 1

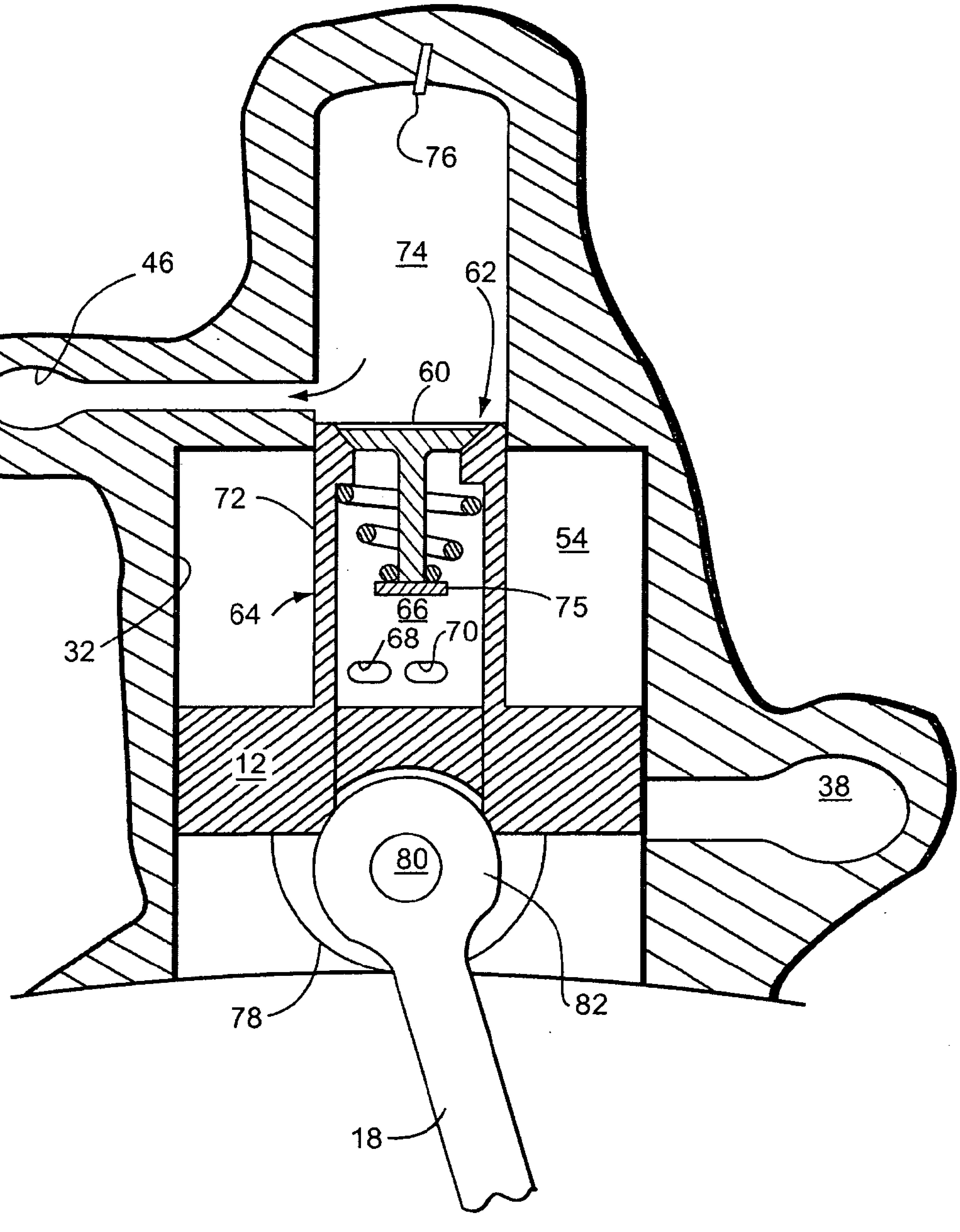

Fig. 2

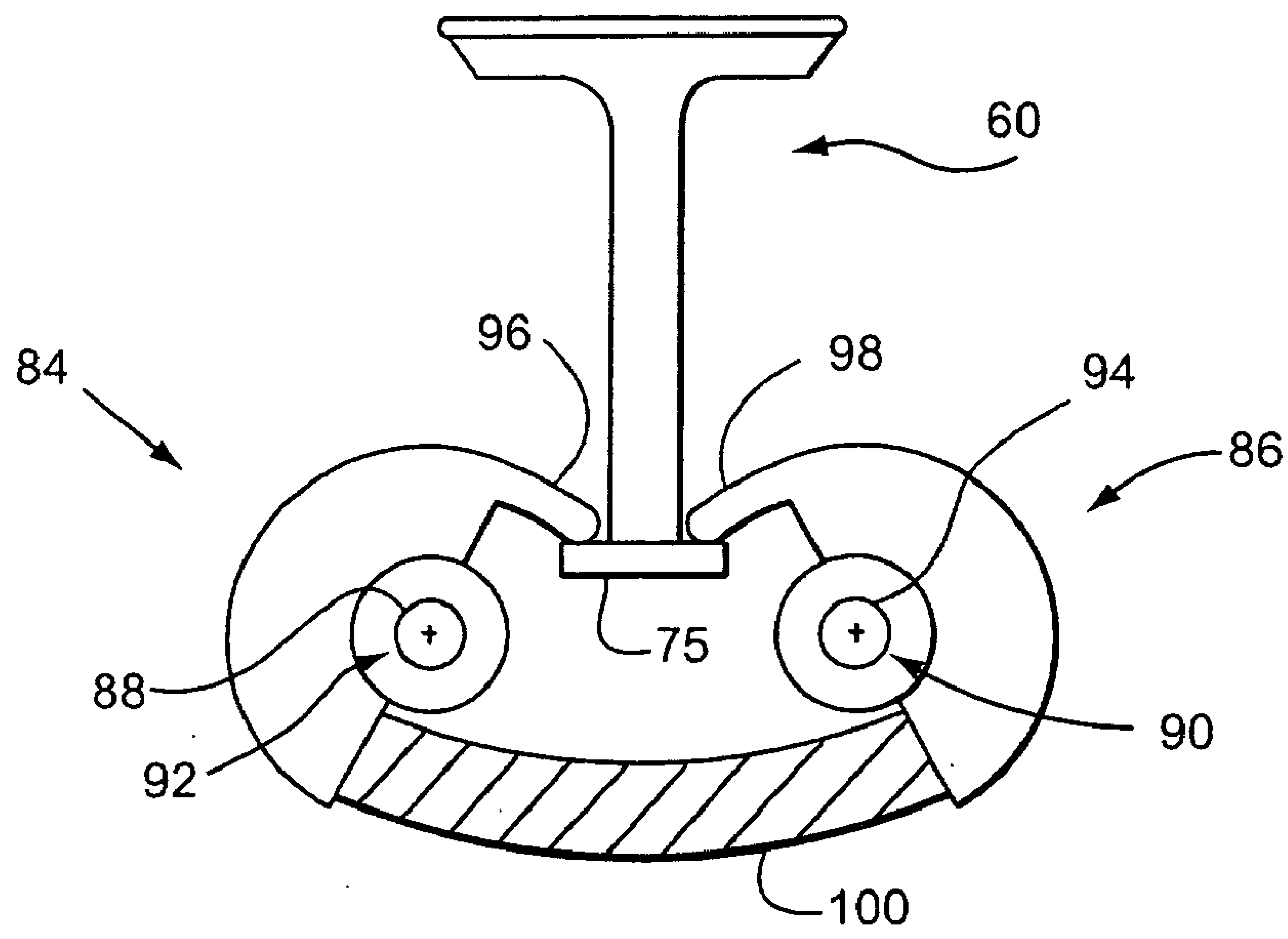
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Fig. 3

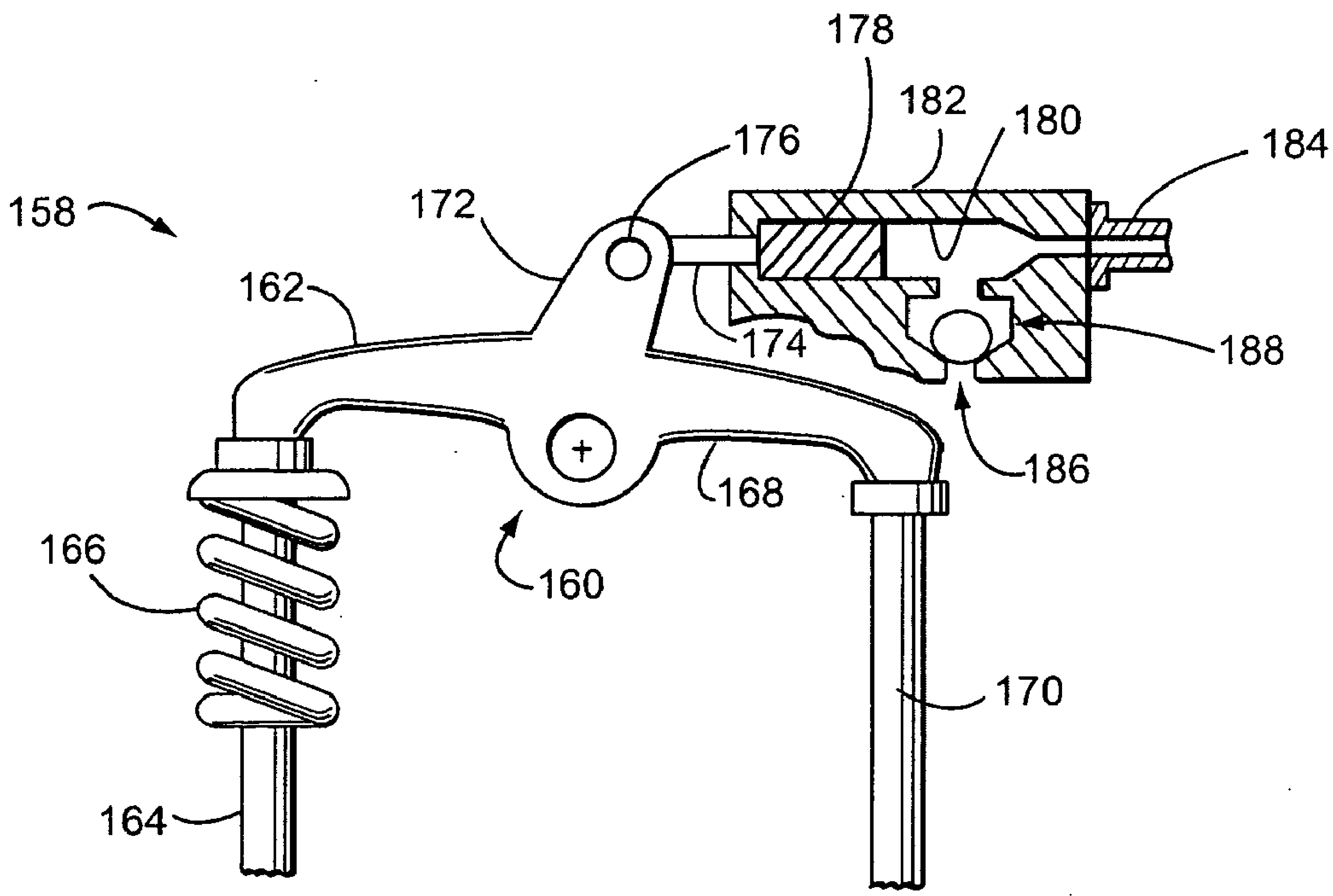
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Fig. 8

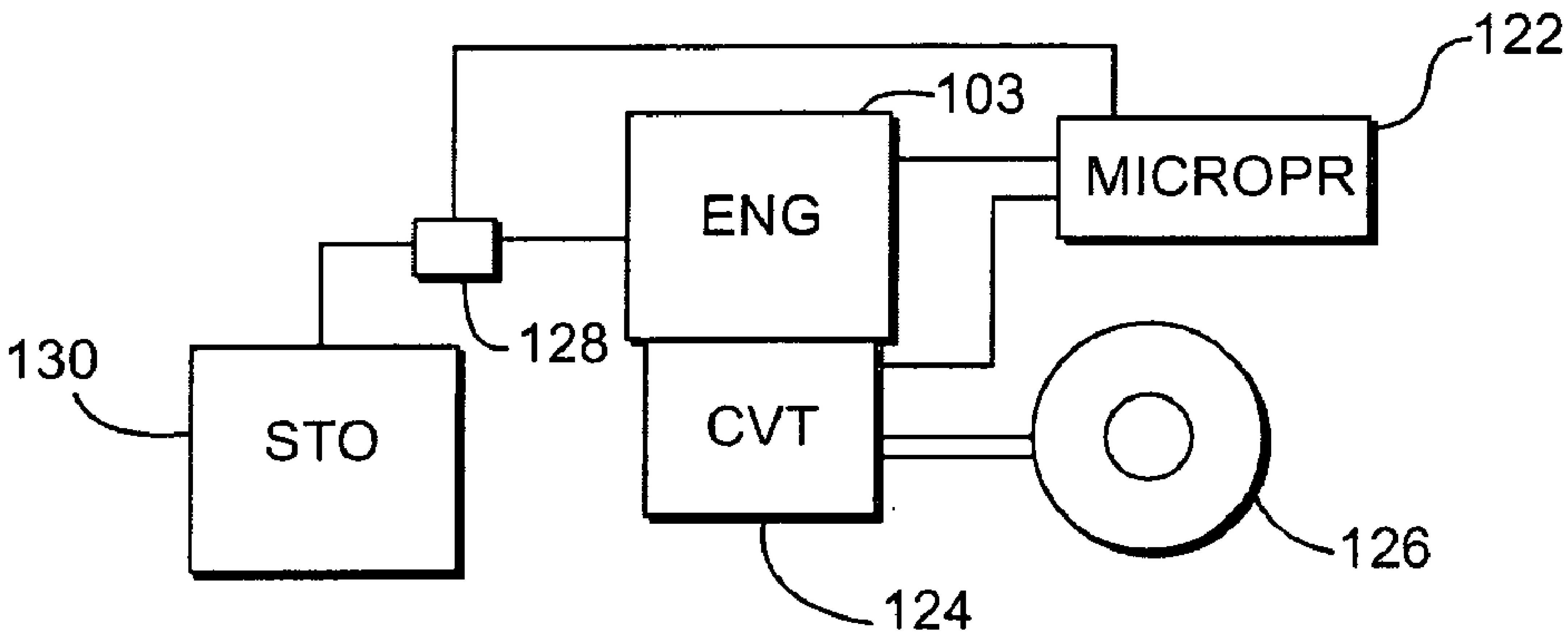

Fig. 6

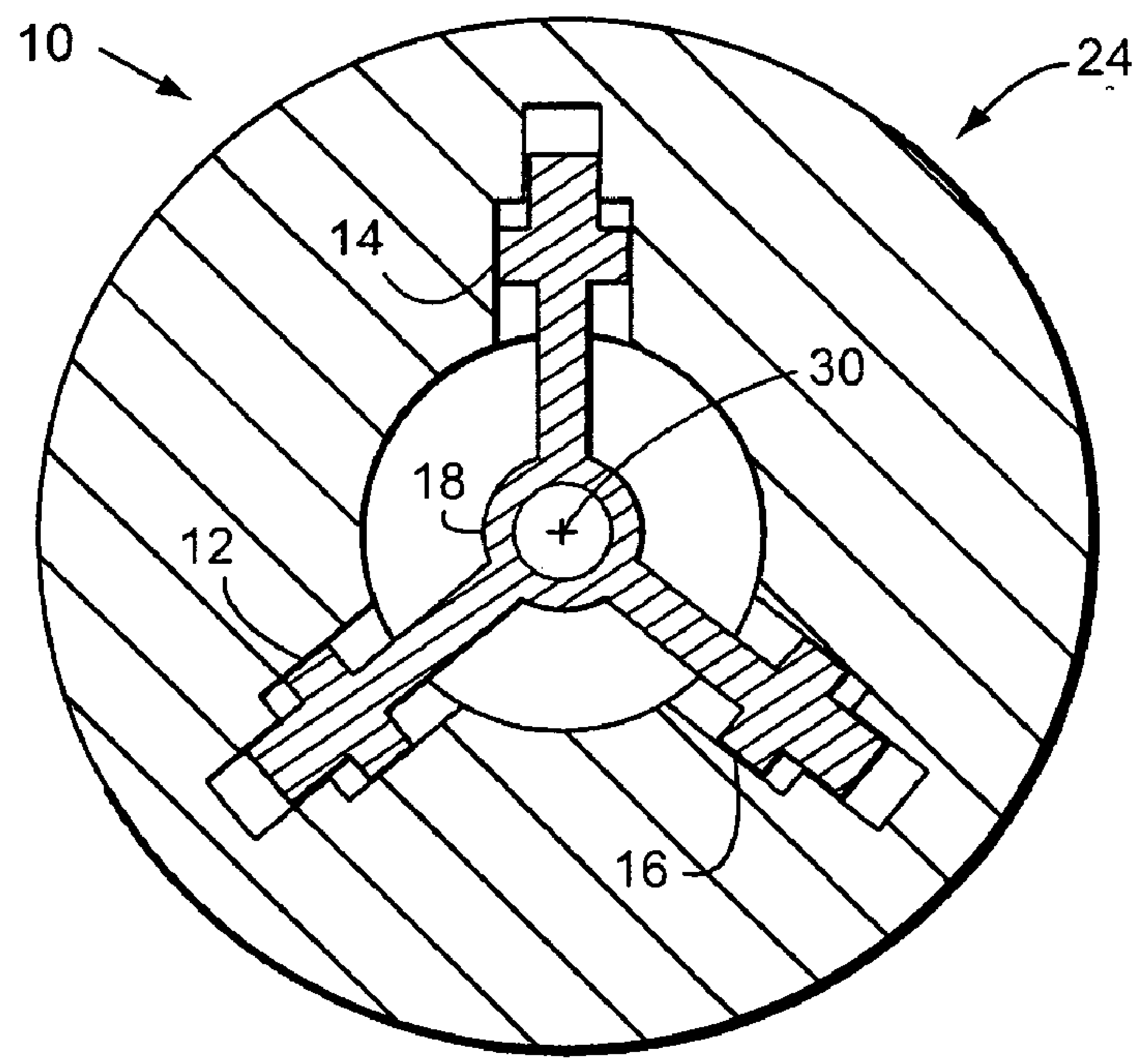

Fig. 4

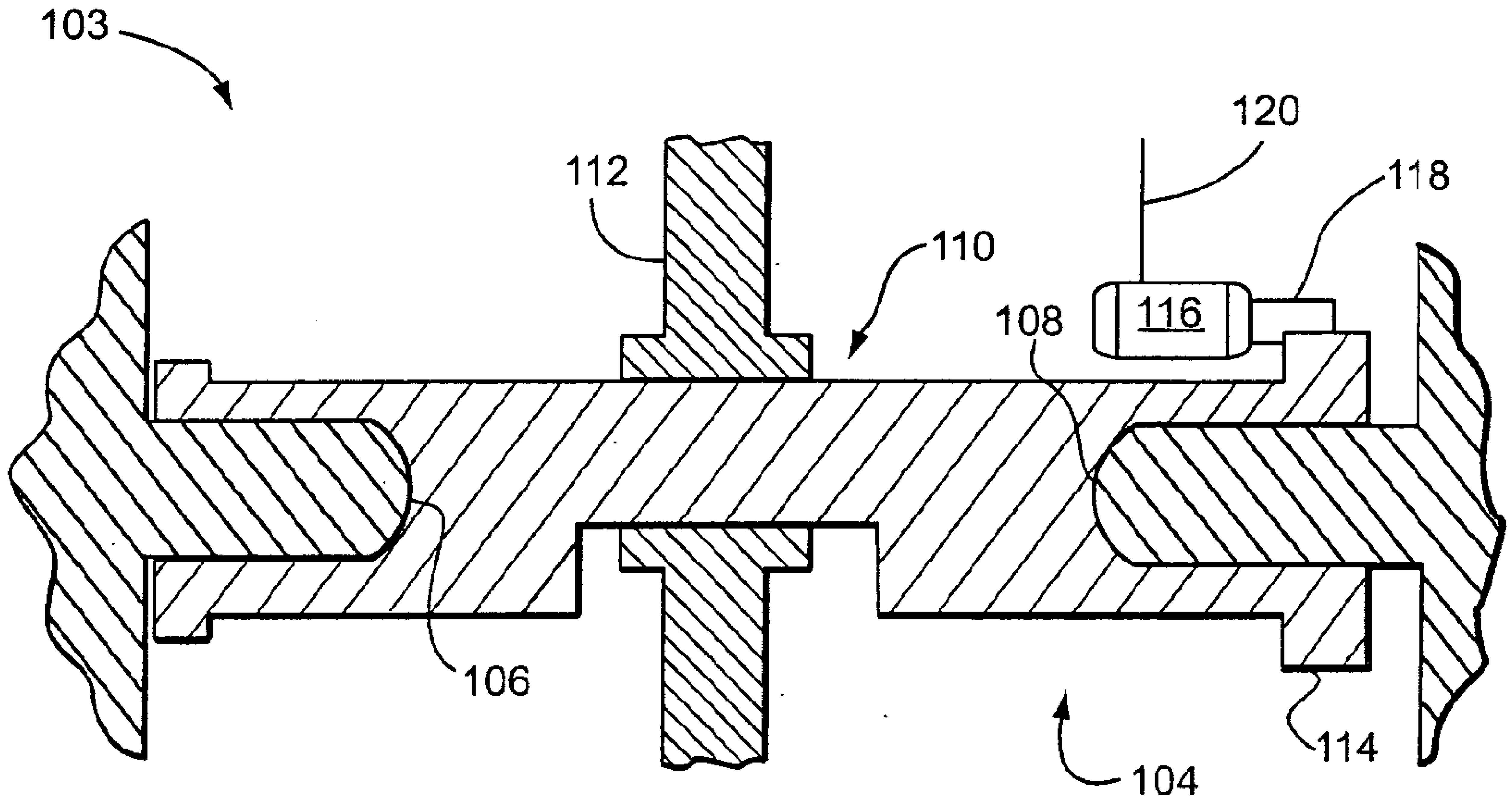
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Fig. 5

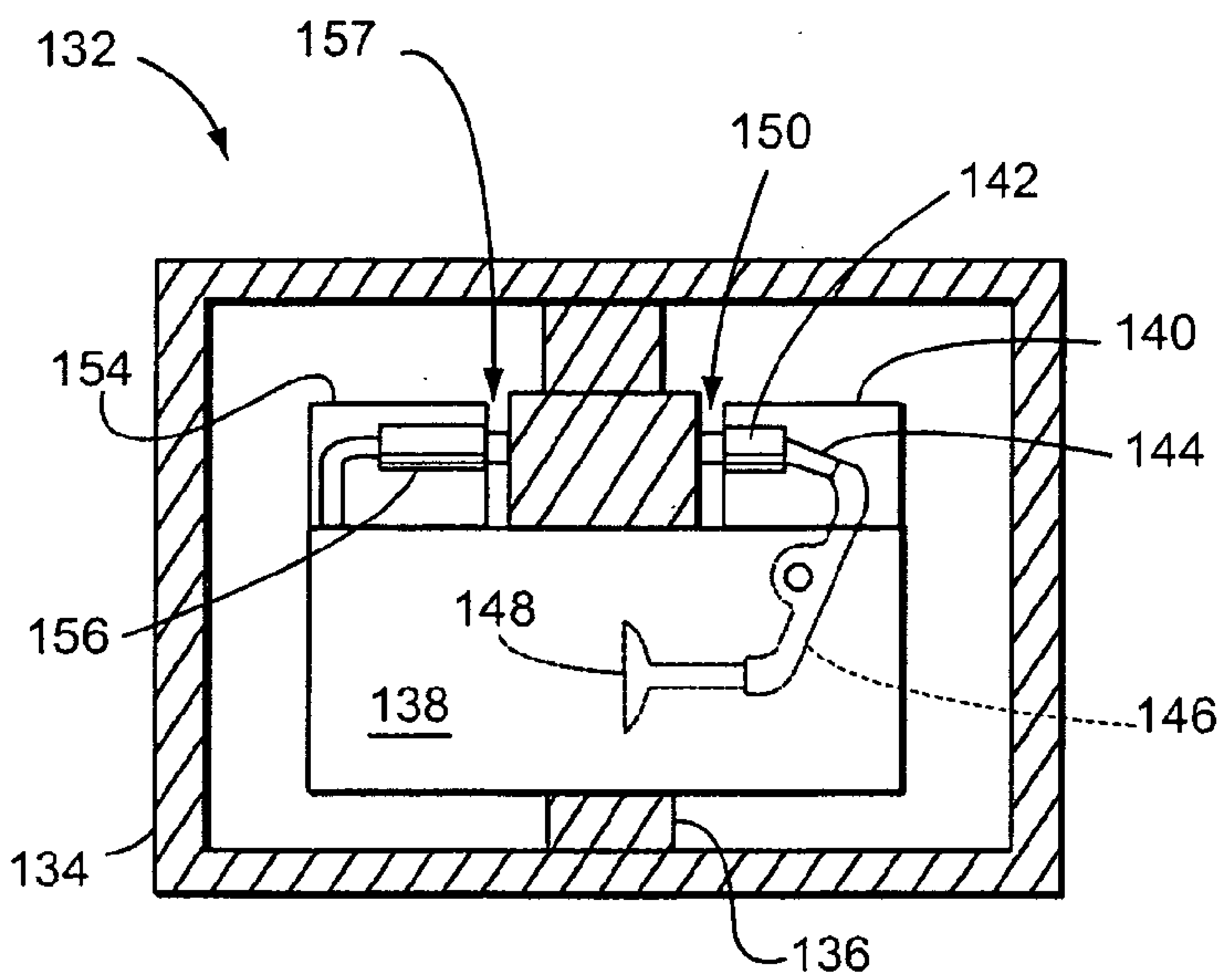
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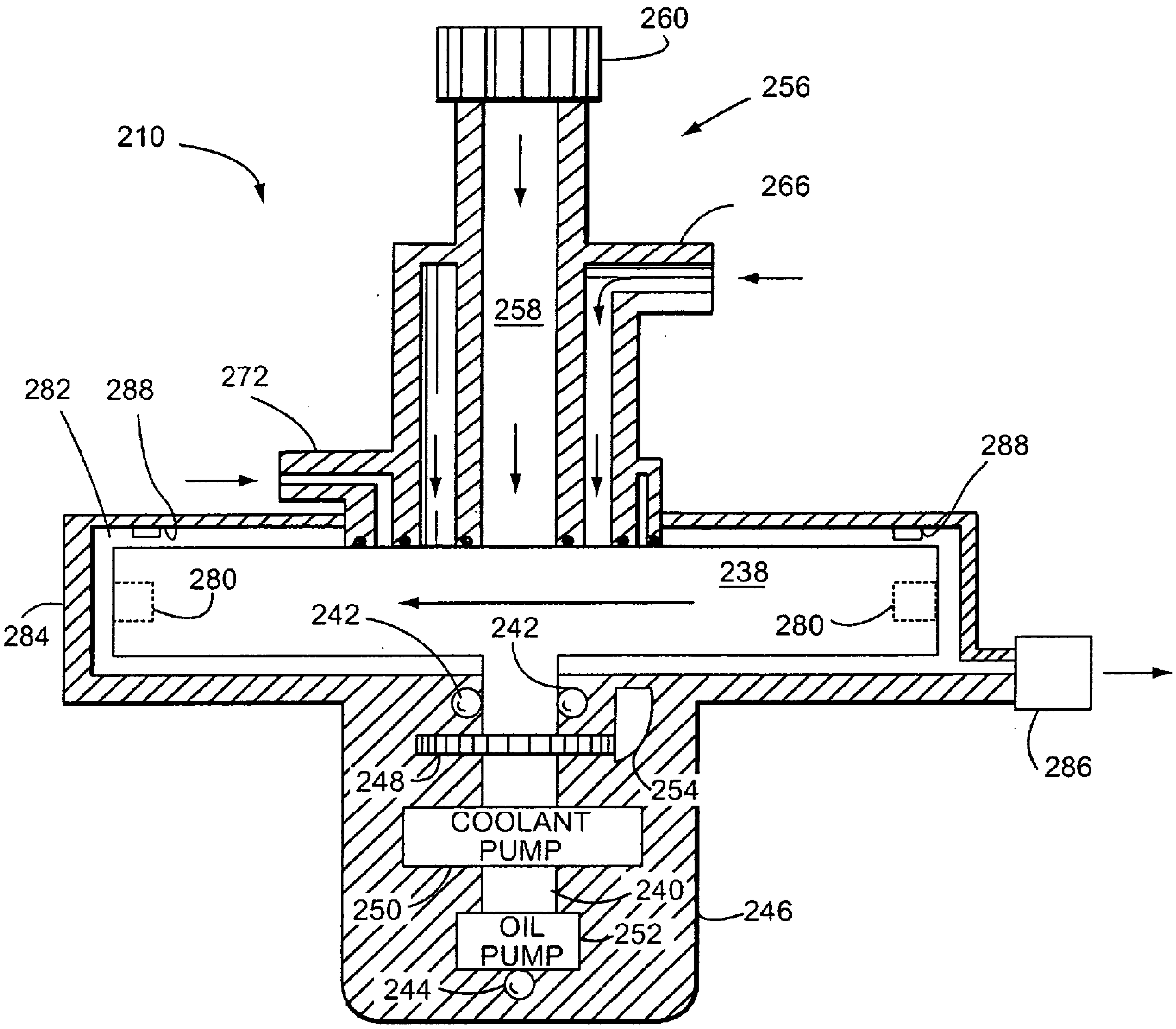
Fig. 7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272
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286
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COOLANT PUMP
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250
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OIL PUMP
252
244

Fig. 9

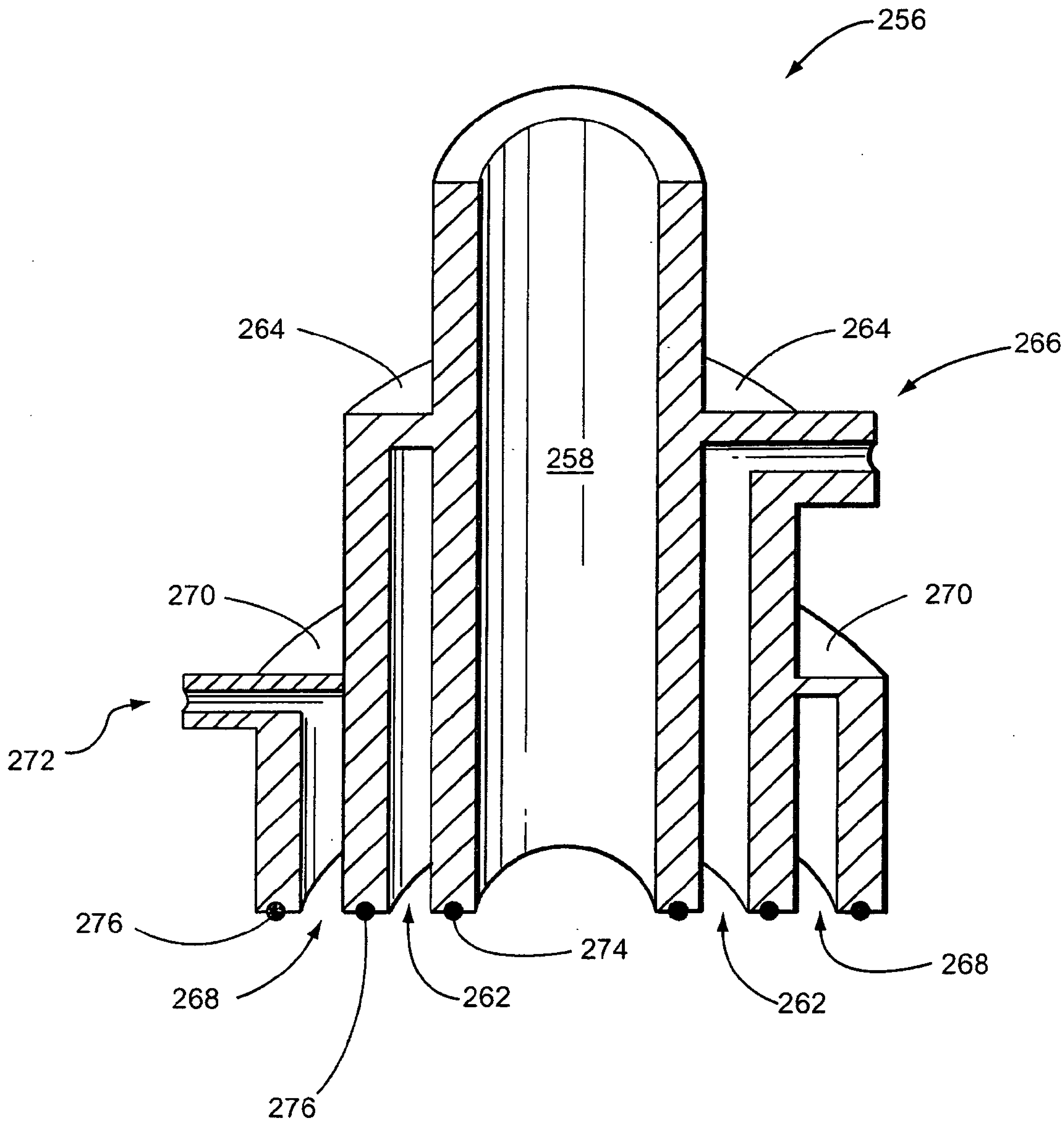

Fig. 10

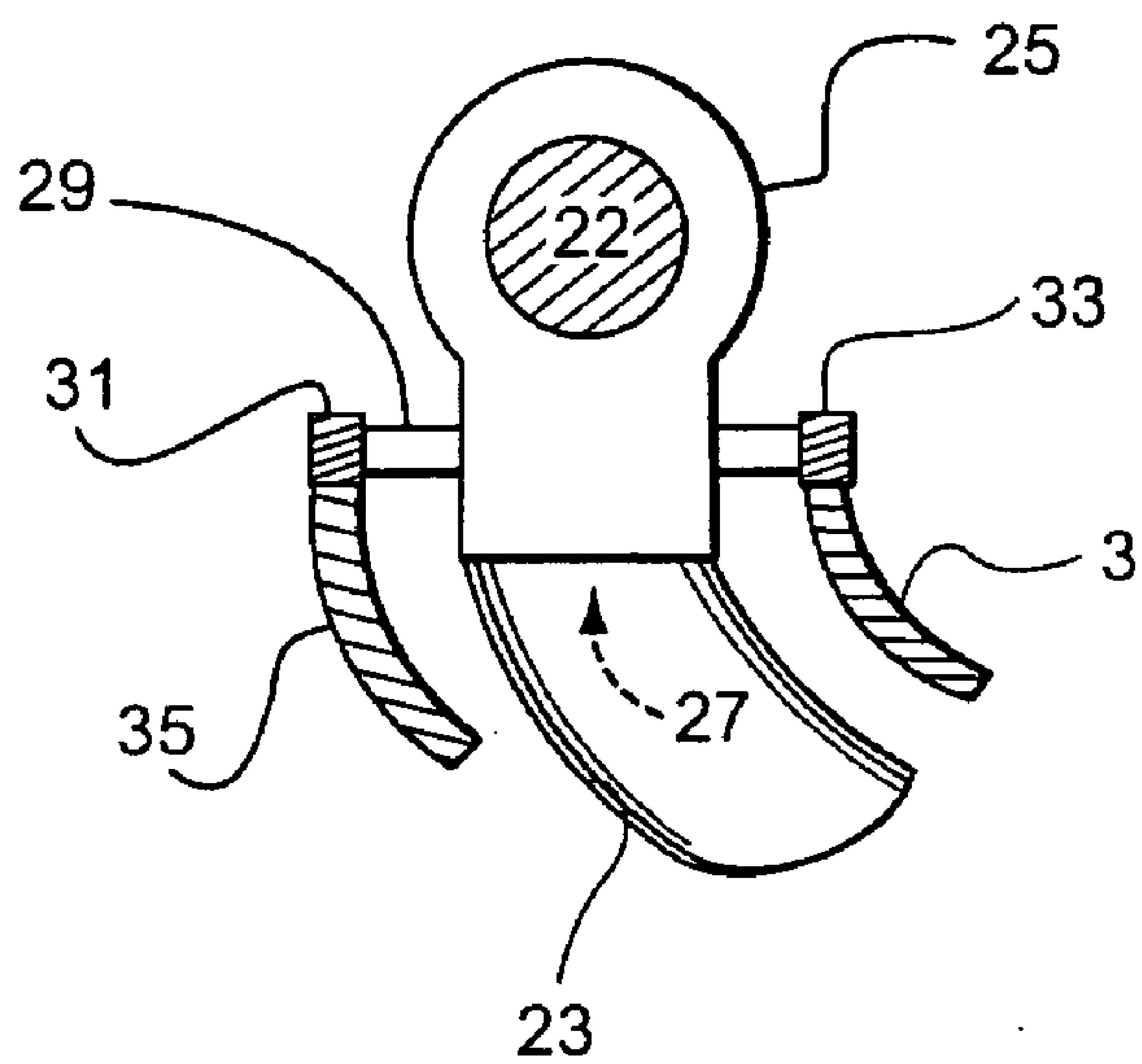
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Fig. 11

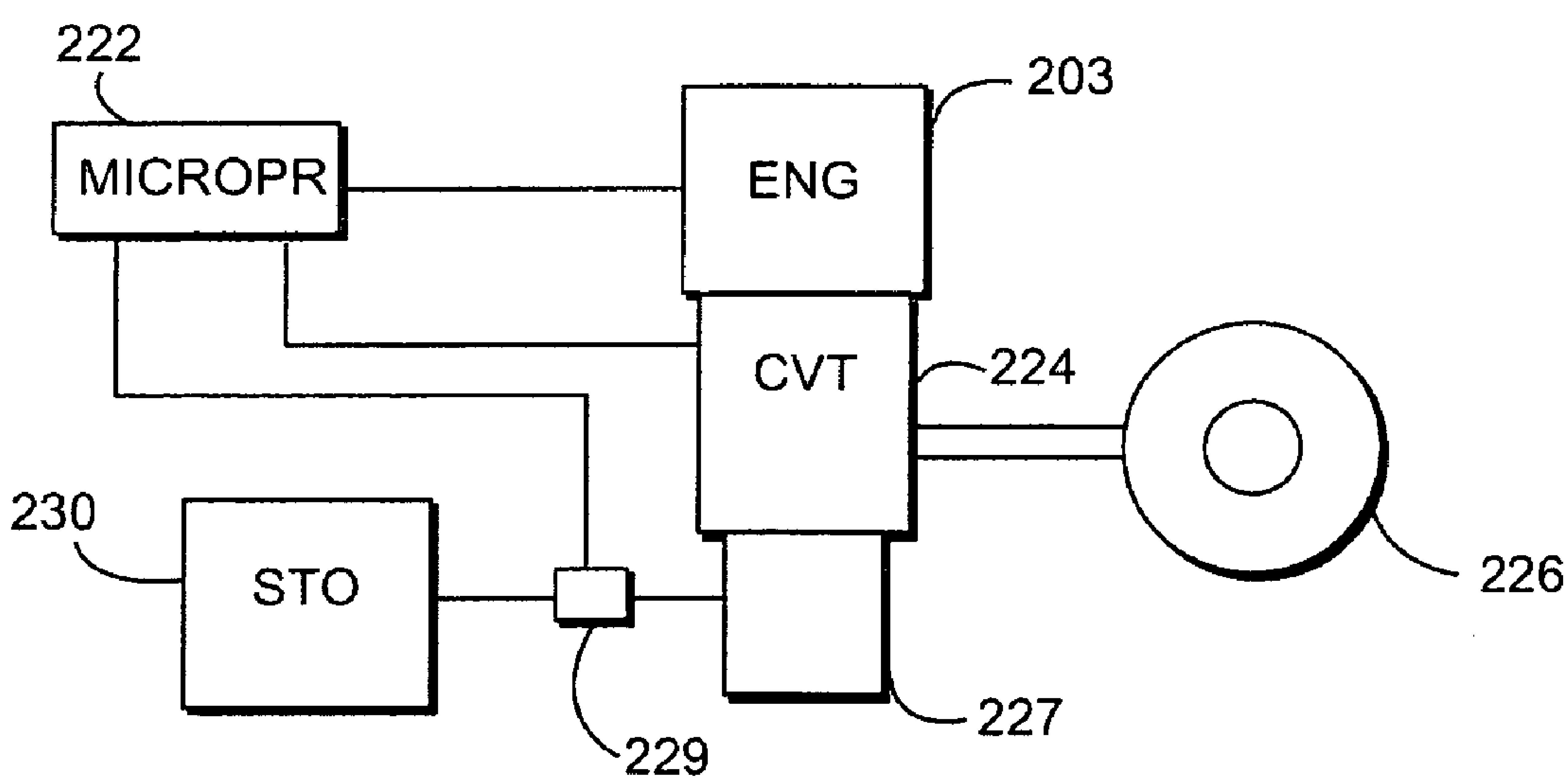
222
MICROPR
ENG
203
CVT
224
230
STO
226
229
227

Fig. 12

RADIAL ENGINE POWER SYSTEM

BACKGROUND OF THE INVENTION

[0001] This application claims the benefit of U.S. Provisional Patent Application Ser. No. ______ filed on May 13, 2004 as Attorney Docket Number D2GRE001.11.

FIELD OF THE INVENTION

[0002] The present invention is directed to a power system including a radial internal combustion engine serving as a prime mover, and an associated energy storage system which cooperates with the radial engine.

DESCRIPTION OF THE PRIOR ART

[0003] Internal combustion engines have long been used to power transport vehicles on land, in and on water, and in the air. Initially, internal combustion engines were directly connected to wheels, propellers, and other elements of a vehicle which acts on an environmental medium to effect propulsion. In some applications, power generated by internal combustion engines has been transformed before bearing on the propulsion effecting elements of the vehicle. For example, diesel electric railway locomotives have diesel engines serving as prime movers which power generators, which generators in turn supply electrical power to drive motors which rotate wheels. In a further development, internal engines have been utilized to store power onboard a vehicle. A well known example is that of electric boats, particularly of the submarine type. Submarine type vehicles have both liquid fuel tanks and also storage batteries. Output of the internal combustion engine can be exploited to rotate a propeller or to charge the batteries.

[0004] The recent automotive development of so-called hybrid vehicles has demonstrated that remarkable fuel savings are enabled by combining internal combustion and electric power plants in a transport vehicle. A hybrid vehicle has both an internal combustion engine and also an electric motor which may, depending upon the specific design, may individually and collectively be brought to bear on propulsion of the vehicle. Arrangement of different hybrid schemes vary, but one element all hybrid schemes have in common is that power demanded of an internal combustion engine over time is far more constant than is the case with vehicles wherein an internal combustion engine is not supplemented by electrical power.

[0005] Considering now the internal combustion engine which is selected for use with hybrid vehicles, contemporary practice is limited to those engines wherein at least one and usually a plurality of pistons are reciprocatingly disposed within bores or cylinders formed in a stationary structural engine block. Each piston is operably connected to a rotary crankshaft by a connecting rod. The output of these conventional engines is one or more rotating shafts, which are drivably connected to a suitable transmission, to a generator, or to another element for inducing propulsion. While these engines are entirely operable, they fail to exploit certain characteristics which are available in internal combustion engines. One of these characteristics is use of the flywheel effect, wherein inertia of a relatively large or heavy rotating mass may be exploited to provide power independently of the energy being liberated in the combustion chambers, at least for a temporary period of time. While conventional engines can be fitted with suitably heavy flywheels or other rotatable masses, this comes at a detrimental cost in conventional engines. That is, total weight of the engine is increased. There is a need for an engine which overcomes this situation while still providing the benefits of the flywheel effect.

[0006] A second characteristic is that while apparent reciprocation between piston and engine block occurs, this is not at the full cost in energy of periodically accelerating and decelerating the pistons within the engine block, as occurs in stationary block engines. Because the engine block defining the combustion cylinders rotates about an axis offset from that of the crankshaft to which the pistons are connected, at least a component of the apparent magnitude of reciprocation of the pistons occurs without axially accelerating each piston the full extent of the apparent stroke.

[0007] There exists an engine design which provides a relatively large rotating mass without arbitrarily increasing total engine mass, and which provides piston reciprocation which does not require periodic accelerations of each piston in alternating directions. In the early twentieth century, a radial rotary engine was developed for use with aircraft. This engine, which came to be known as the "Gnome" radial engine, essentially caused the engine block and cylinder heads to rotate about the crankshaft, which remained stationary relative to its associated vehicle. In practice, the crankshaft was secured in fixed relation to the fuselage of the aircraft. The propeller was fixed to the rotating engine block, which propeller and engine block then rotated as a unitary element. This arrangement was responsible for remarkable advances in early aircraft performance as regards aircraft velocity. A drawback of the engine in the environment of small aircraft was the gyroscope effect developed by the rotating mass, which introduced difficulties in steering the aircraft. As these small aircraft were combat aircraft, with maneuverability being a particularly prized characteristic, this early engine fell from favor despite some advantages which remain to this day. It would be desirable to utilize the advantages of a rotary block, reciprocating piston internal combustion engine in stored energy hybridized vehicles today.

SUMMARY OF THE INVENTION

[0008] The present invention combines the advantages of a rotary block, reciprocating piston internal combustion engine with an energy storage system to improve on benefits which accrue from today's hybrid vehicle arrangements. To this end, the present invention uses an improved rotary block radial engine in combination with one or more energy storage systems which can release power independently of power being developed within the engine by combustion of the fuel at any one instant in time. This engine provides a large rotating flywheel mass with no attendant increase in overall mass, minimal reciprocating load of pistons, and frequency in firing of a two stroke cycle engine.

[0009] Engine output is supplemented by stored energy. In one embodiment, this stored energy takes the form of compressed gasses which have been generated by the engine and stored. In another embodiment of the invention, electrical energy rather than compressed gasses may be generated and stored. Advantageously, when power from internal combustion is not required, combustion may be discontinued and the pistons may then be exploited to serve as a compressor.

[0010] When power is not required, a mechanical adjustment to the crankshaft is made. This adjustment permits the engine block and pistons to rotate without imposing a driving force on the crankshaft. Thus that energy originating in the engine and presently taking the form of kinetic energy may be conserved without dissipation which otherwise would be caused by decelerating the engine back to the stationary condition. As a consequence, combustion which would merely waste fuel when idling may be discontinued. The engine block with its relatively great mass would continue to rotate. This permits power to be derived from a flywheel effect and also eliminates the step of rotating the internal combustion engine when restarting it.

[0011] The engine is improved over the early aircraft engine in several preferred yet optional ways. One is that it is preferably although not necessarily operated as a diesel. A second is that an adjustment feature is provided which enables the engine to change its operation from that of an internal combustion engine to that of an air pump. A further improvement is that of making the crankshaft adjustable such that the pistons orbit ineffectually thereabout in tandem with the rotating engine block, so that the engine rotates without idling or active power production. Still another improvement is providing stepped pistons wherein an air suction chamber is provided which is greater in volume than the combustion chamber, thereby achieving a supercharged effect with no additional moving parts. Valves may be of the exposed port type, or alternatively of the poppet type. Where gas compression and storage is selected for energy storage, engine exhaust heat may be used to increase pressure of stored compressed gasses. Gasses may include both atmospheric air and also exhaust gas. A further improvement incorporates a recirculating lubrication system rather than the "one use" system originally provided wherein lubricant was ejected from the engine after a single introduction to a piston and cylinder assembly.

[0012] It is an object of the invention to utilize a rotary radial engine having a stationary crankshaft and minimal parasitic piston reciprocation losses as a prime mover in a hybrid power plant which incorporates selectively releasable energy storage.

[0013] It is another object to modify a rotary radial engine to enable engine block rotation to achieve a flywheel effect without idling.

[0014] It is a further object of the invention to modify a rotary radial engine to incorporate a recirculating lubrication system.

[0015] It is still another object of the invention to provide a supercharging feature with minimal increase in moving parts.

[0016] Still another object of the invention is to supplement stored energy in the form of compressed gasses with heat derived from waste exhaust heat.

[0017] It is an object of the invention to provide improved elements and arrangements thereof by apparatus for the purposes described which is inexpensive, dependable, and fully effective in accomplishing its intended purposes.

[0018] These and other objects of the present invention will become readily apparent upon further review of the following specification and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] Various objects, features, and attendant advantages of the present invention will become more fully appreciated as the same becomes better understood when considered in conjunction with the accompanying drawings, in which like reference characters designate the same or similar parts throughout the several views, and wherein:

[0020] FIG. **1** is a diagrammatic, top plan view of a radial rotary engine of the type utilized in an embodiment of the present invention.

[0021] FIG. **2** is a cross sectional, enlarged detail view of the lower left of FIG. **1**.

[0022] FIG. **3** is a side elevational, enlarged detail view of components which are an alternative embodiment of components seen at the center of FIG. **2**.

[0023] FIG. **4** is a top plan view generally corresponding to FIG. **1**, but drawn to reduced scale and showing the engine with its crankshaft moved to an adjusted position such that its rotational axis is coincident with the rotational axis of the cylinders.

[0024] FIG. **5** is an enlarged side elevational, mostly cross sectional detail view of an alternative embodiment of the invention, with the engine turned such that the crankshaft extends horizontally.

[0025] FIG. **6** is a block diagram of power producing, storing, and utilizing components of a motor vehicle according an embodiment of the invention wherein the novel system generates and stores electrical energy.

[0026] FIG. **7** is a side cross sectional view of a further embodiment of an engine according to the present invention.

[0027] FIG. **8** is a side elevational detail view of an optional auxiliary function of a rocker arm of another alternative embodiment.

[0028] FIG. **9** is a diagrammatic, partially cross sectional, side elevational view of an embodiment of the novel engine.

[0029] FIG. **10** is a cross sectional, top perspective view of a component seen near the top of FIG. **9**.

[0030] FIG. **11** is a top plan view of an embodiment of an engine according to the present invention, with the crankshaft shown in cross section.

[0031] FIG. **12** is a block diagram of power producing, storing, and utilizing components of a motor vehicle according an embodiment of the invention wherein the novel system generates and stores energy in pneumatic form.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0032] The present invention combines the attributes of a radial rotary engine **10** with an energy storage system. Referring first to FIG. **1**, basic operation of a radial rotary engine will be summarized. A plurality of pistons **12**, **14**, **16** are pivotally connected to a multi-armed connecting rod **18** which in turn encircles a journal **20** of a crankshaft **22**. Journal **20** is eccentrically located on crankshaft **22**. Crankshaft **22** is located inside annular cylinder block **24**. Three axes **26**, **28**, **30** are seen in the top plan view of FIG. **1**. Axis **26** indicates the center line of journal **20**. Axis **28** indicates the center line of crankshaft **22**. Axis **30** indicates the rotational axis of cylinder block **24**. In a radial rotary engine, crankshaft **22** is fixed to its associated vehicle (not shown in its entirety). As will be explained, cylinder block **24** rotates about stationary crankshaft **22**. Pistons **12**, **14**, **16** and connecting rod **18** rotate in tandem with cylinder block, but in respective compound motions. Pistons **12**, **14**, **16** undergo apparent oscillation or reciprocation within their respective cylinders **32**, **34**, **36**. This is a consequence of axis of rotation **30** of cylinder block **24** being spaced apart from axis **26** of crankshaft journal **22**. At this point, it is important to note that pistons **12**, **14**, **16** are stepped, and hence have a T-shaped profile when viewed in the side elevation of FIG. **1**. Cylinders **32**, **34**, **36** are correspondingly stepped and also exhibit T-shaped profiles. It is preferred that cylinders **32**, **34**, **36** be slightly canted in the direction of rotation (with the outermost section of the cylinder leading, and the innermost section of the cylinder trailing), rather than projecting in purely radial directions from axis of rotation **30**. Connecting rod **18** both rotates about axis **26** as cylinder block **24** rotates, subject to accommodating piston position.

[0033] It will be appreciated that for visual clarity, certain necessary features of engine **10** are omitted from view in FIG. **1**. Illustratively, gas flow valves and associated mechanisms, fuel supply, an ignition source, a cooling system, a lubricating system, and a supporting electrical system are all omitted from the diagrammatic view of FIG. **1**. The embodiment of FIG. **1** is directed to a rotary equivalent of a two stroke engine having exposed port valves. As will be subsequently described, both the number of strokes of a single cycle of operation and also the types of valves may be varied to suit specific applications. In the embodiment of FIG. **1**, cylinders **32**, **34**, **36** respectively have inlet passages **38**, **40**, **42** and outlet or exhaust passages **46**, **48**, **50**.

[0034] In the embodiment of FIG. **1**, cylinders **32**, **34**, **36** are stepped in order to achieve a supercharging effect. To this end, inlet passages **38**, **40**, **42**, which open to the open interior **52** of annular cylinder block **24** or to any suitable location for drawing in ambient air, communicate with the relatively large portions of cylinders **32**, **34**, **36**. As pistons **12**, **14**, **16** descend (which of course occurs sequentially rather than simultaneously), a vacuum develops in the lower portions **54**, **56**, **58** of cylinders **12**, **14**, **16**. As each piston **12**, **14**, or **16** descends below (in the sense of approaching axis **30**), it uncovers its associated inlet passage **38**, **40**, or **42**. Air then flows into the exposed lower cylinder portion **54**, **56**, or **58**. As each piston **12**, **14**, or **16** ascends (moving oppositely the direction of descent), volume of lower portions **54**, **56**, or **58** of cylinders **32**, **34**, or **36** decreases, thus compressing air contained therein.

[0035] Turning now to FIG. **2**, further operation is described for only piston **12**, it being understood that remaining cylinders **14** and **16** undergo similar motions and functions. Piston **12** carries on board a poppet valve **60** which seats on a shoulder **62** formed in the upper section **64** of piston **12**. Upper section **64** is hollow, having an air passage **66** formed therein. A plurality of ports **68**, **70** are formed in the wall of upper section **64** of piston **12**. As pressure of compressed air contained within lower section **54** of cylinder **32** increases with ascent of piston **12**, air is urged to flow into air passage **66**. Pressure bears against the underside of poppet valve **60**. At a predetermined pressure value, air pressure overcomes the resistance of spring **72**, and flows into the upper portion **74** of cylinder **32**. Spring **72** is urged to expand, and is retained by keeper **75** fixed to the stem of valve **60**. Of course, at this point, projection of piston **12** into upper portion **74** obstructs exhaust passage **46**. Air contained within upper portion **74** of cylinder **32**, highly compressed, is then combusted by injecting fuel from a fuel injector **76**. For diesel operation, a glow plug (not shown) could be supplied if desired.

[0036] When piston **12** descends, exhaust passage **46** is uncovered, as shown in FIG. **2**. Exhaust is expelled by residual pressure, and is conducted to a suitable location for disposal. Again, during the same descent, vacuum develops in lower section **54** of cylinder **32**. A new cycle may then begin.

[0037] FIG. **2** shows details of connection of piston **12** to connecting rod **18**. A yoke **78** formed integrally with piston **12** supports a wrist pin **80**. Wrist pin **80** is in turn rotatably engaged by a yoke **82** of connecting rod **18**.

[0038] FIG. **3** shows an optional yet preferred embodiment of the invention. In the arrangement of FIG. **3**, poppet valve **60**, shown isolated from its supporting piston structure as described prior, is provided with a counterweight feature. Two counterweights **84**, **86** are rotatably supported on pins **88**, **90** fixed to the wall of an upper section of a piston **12**, **14**, or **16**, and may pivot about respective axes **92**, **94**. Each counterweight **84** or **86** has an associated arm **96** or **98** which contacts keeper **75** of poppet valve **60**. Opening of poppet valve **60** acts on arms **96**, **98** in a manner causing counterweights **84**, **86** to rotate on their respective support pins **88**, **94**. A compression coil spring **100** is compressed by this action. Spring **100** urges counterweights **84**, **86** to bear on keeper **75** to close poppet valve **60**. Valve **60** closes after air pressure is equalized on both sides thereof.

[0039] While engine **10** is capable of producing torque as a consequence of internal combustion during rotation, it is desired to exploit an inherent energy storage characteristic of radial rotary engines. That is that because the cylinder block rotates about stationary crankshaft **22**, ordinary engine operation generates a flywheel effect which is much greater than for stationary block, rotary crankshaft engines (not shown). Inertia of this rotating mass can be conserved to a considerable degree without requiring internal combustion to proceed. Turning now to FIG. **4**, engine **10** is shown in a state adjusted to permit cylinder block **24** to rotate in freewheeling fashion. That is, cylinder block **24**, pistons **12**, **14**, **16**, and connecting rod **18** rotate in tandem about rotational axis **30**. This is accomplished by rotating crankshaft **22** until journal axis **26** is coincident with rotational axis **30**. Referring momentarily again to FIG. **1**, this situation is shown in broken line **102**. Line **122** indicates the path taken by journal **20** as crankshaft **22** is rotated counterclockwise in the view of FIG. **1**. Alternatively stated, under active power conditions, when pistons **12**, **14**, **16** undergo displacement within their respective cylinders **32**, **34**, **36**, connecting rod **18** rotates coaxially about first axis of rotation **26**. Under inertial power conditions, connecting rod **18** rotates coaxially about second axis of rotation **30**, and no displacement of pistons **12**, **14**, **16** within respective cylinders **32**, **34**, **36** occurs.

[0040] Any suitable mechanism or rotation adjuster, some being known, may be employed to make this adjustment. Illustratively, a pivotal lever which may be moved manually or under power, such as by electrical power, may swing crankshaft **22** in an arcuate path established by guides. A purely illustrative example is shown in FIG. **11**, wherein crankshaft **22** is slidably supported in a guide track **23** formed at the structure of engine **10** supporting cylinder block **24** (see FIG. **1**). Crankshaft **22** engages guide track **23** in any suitable way, such as by having a cooperating T-slot configuration (not shown). Crankshaft **22** is engaged by a movable yoke **25** which moves arcuately together with crankshaft **22**. Yoke **25** encloses an electric motor **27** having a double ended projecting output shaft **29**, each end bearing a respective gear **31** or **33**. Gears **31**, **33** engage respective toothed racks **35**, **37**. When motor **27** operates, crankshaft **22** is moved along the path established by guide track **23**. Motor **27** is reversible to enable selective shifting of crankshaft **22** between the active power and inertial conditions.

[**0041**] FIG. **5** shows an illustrative way of adjusting rotational orientation of crankshaft **104**. In the embodiment of FIG. **5**, there is shown an engine **103** which is generally similar to engine **10** of FIG. **1**, except that engine **103** includes a crankshaft adjustment feature. Crankshaft **104** is supported at each end by a stout shaft **106** or **108** fixed to the vehicle. Crankshaft **104** has an offset journal **110** which is the structural and functional equivalent of journal **22** of FIG. **1**. A connecting rod **112** which generally corresponds in structure and function to connecting rod **18** of FIG. **1** engages journal **110**. At one end, crankshaft **104** has a ring gear **114** fixed thereto. A motor **116** having a geared shaft **118** engages ring gear **114**. When an electrical power signal is received on a communication or power cable **120**, motor **116** rotates ring gear **114** to a suitable degree to effect crankshaft adjustment described above and shown in FIG. **1**.

[**0042**] The major rotating parts of engine **110** can function as a flywheel, without consuming fuel by idling, and with minimal frictional losses when crankshaft **104** is appropriately adjusted. This may be exploited to add to power available when conducting internal combustion, on its own should engine **110** be modified to include a mechanical connection (not shown) thereto in the idle mode, by incorporating electrical generating apparatus into the cylinder block (not shown) of engine **103**, or in any other known way of exploiting inertia of a rotating mass.

[**0043**] FIG. **6** shows a diagram of a preferred application of engine **103**. Engine **103** is controlled by an engine management computer or microprocessor **122**. A continuously variable transmission **124** receives the rotary output of engine **103** and by suitable shafting or the like, transmits power to road wheels (shown symbolically as wheel **126**) of a land going motor vehicle (not shown in its entirety). Use of a continuously variable transmission, in addition to the usual versatility provided thereby, enables vehicle speed to be maintained even as the engine rotating mass decreases, with or without combustion occurring. This effect is more pronounced in a radial rotary engine **10** or **103**, more so than in a rotary crankshaft engine (not shown). Engine **103** incorporates a power output element (not separately shown), such as an onboard electrical generator, air compressor, or other power output element.

[**0044**] Power generated by engine **103** above that required for vehicle propulsion and associated support functions such as power for external signalling, exterior illumination, general interior lighting, heating, cooling, ventilation, onboard audio and video equipment, communications equipment, and the like, may be apportioned to the auxiliary power output element by microprocessor **122**. Conveniently, energy can be stored even while the vehicle is moving, without increasing or modifying engine rotational speed whenever available power at a selected engine speed exceeds demands for propulsive and support power. In the illustrative example of FIG. **6**, engine **103** incorporates an electrical generator. Microprocessor **122** compares power required for propulsion, for example, by considering foot throttle control position, vehicle velocity, and the effective gear ratio of transmission **124**, and imposes appropriate field excitation on the generator. A power control device such as switch **128** is then operated by a signal from microprocessor **122** to connect generator output to a suitable storage device such as a battery **130**. Preferably, battery **130** is different from a storage battery (not shown) conventionally used by a motor vehicle to serve the engine and auxiliary functions.

[**0045**] It is presently contemplated that an advantageous energy storage system could, either in place of or in addition to a generator, be provided by an air compressor. Referring now to FIG. **12**, an engine **203** and continuously variable transmission **224**, which are generally similar to their counterparts shown in FIG. **6**, are arranged to drive a vehicle road wheel **226**, and also to drive an air pump **227**. When engine **203** drives pump **227** through transmission **224**, a valve **229** is open, enabling compressed air to flow to a storage tank **230**. At other times, valve **229** is closed. When it is desired to draw power in the form of compressed air from tank **230**, valve **229** is opened. Compressed air may then act on pump **227**, reversing operation of pump **227** from that of a pump to that of a pneumatic motor. These functions are preferably managed by a microprocessor **222** in a "drive-by-wire" arrangement, or an arrangement wherein the operator of the vehicle operates switches which provide input signals to microprocessor **222** rather than providing mechanical inputs which directly actuate the desired functions.

[**0046**] It would be possible to modify engine **203** by suitable changes to air exhaust valves (not separately shown) and their associated passages and by discontinuing combustion and operating engine **203** as a pump. A conventional exhaust conduit may be routed in close proximity to the compressed air receptacle. This increases effective pressure of stored compressed air, using only otherwise waste heat of the exhaust.

[**0047**] In an advantageous use of the invention, a motor vehicle (not shown in its entirety) is driven in a "coast down" mode wherein once a predetermined vehicle speed is attained, engine operation is changed from active power generation through internal combustion to rotation only. In the "rotation only" mode, pistons undergo no displacement and merely rotate together with the cylinder block. Stored inertial energy may then be applied for vehicle propulsion. Speed may be maintained relatively constant where a continuously variable transmission is employed. Alternatively, in the absence of a continuously variable transmission, a constant ratio transmission may connect the rotating mass to the vehicle drive wheels. When a predetermined minimum vehicle speed is reached, the crankshaft may be adjusted to reestablish internal combustion operation. The speed of the vehicle may be progressively increased to the predetermined high speed, at which point a new coast down cycle may be put into play. Prior experiments have shown that this is an effective strategy in increasing average fuel mileage. It is currently believed that one source of efficiency is that of utilizing the engine only at full volumetric efficiency when internal combustion occurs. The flywheel effect tends to oppose rapid speed loss and thus reduces frequency of switching between active power operation and coast down operation.

[0048] The exact nature of engine **10** or **103** may be varied to suit. The selected form of the engine may encompass either two stroke cycle operation or four stroke cycle operation, depending upon the valve system provided. It is also optional to switch operation between two stroke and four stroke cycles by appropriate manipulation of valving. Combustion may be either of the compression ignition type or of the spark ignition type, with appropriate fuel and ignition systems being fitted to the engine.

[0049] In some engine operation regimens, it may be necessary to have poppet valves in place of the inlet ports and exhaust ports shown for the previously described embodiments. FIG. **7** shows an arrangement for providing a poppet valve carried in the cylinder block or cylinder head. In the embodiment of FIG. **7**, engine **132** has an external protective housing **134**, a crankshaft **136**, and a cylinder block **138**. Crankshaft **136** and cylinder block **138** function in the manner of the previously described embodiments as to power production, but vary in valve arrangements and in ignition type. Cylinder block **138** has an upwardly projecting member **140** which includes a receptacle for slidably receiving a lifter or tappet **142**. A pushrod **144** is supported at one end by interference with tappet **142** and at the other end by a rocker arm **146**. Rocker arm **146** reciprocatingly drives a poppet valve **148**. Location of valve **148** is shown in purely symbolic fashion. In practice, its location and orientation may be varied as appropriate to replace or supplement the exposed port valves of the prior embodiments.

[0050] Tappet **142** rotates in tandem with cylinder block **138**, and is operated by a cam lobe **150**. Cam lobe **150** is fixedly mounted on a an enlarged portion of crankshaft **136**, or cam carrier **152**. It will be appreciated that although cam lobe **150** is a fixed or stationary component of engine **132**, rotation of cylinder block **138** causes mutual motion with cam lobe **150**. Cam lobe **150** therefore operates in conventional fashion despite its unconventional location.

[0051] FIG. **7** also shows how a mechanical fuel injection system may be fitted to engine **132**. A projecting member **154** essentially similar to projecting member **140** houses a fuel injection plunger **156** housed in a bore formed in member **154**. Plunger **156** is displaced by a cam lobe **157** in a manner similar to operation of tappet **142**. Plunger **156** imposes pressure on fuel, which is then conducted to an injector such as injector **76** of FIG. **2**. Supporting elements of a fuel injection system, such as a return line, will be understood to be provided where required.

[0052] Both the valve elements including tappet **142**, pushrod **144**, and rocker arm **146**, and also fuel injection plunger **156** may be returned to their initial positions in known fashion by respective return springs (not shown). It will be appreciated that where necessary to achieve different timing and duration characteristics, different tiers of cam lobes may be provided for the fuel injection and valve systems. Also, where it is desirable to vary timing of one set of cam lobes independently from the other, separately controlled concentric sleeves (not shown) may be provided in encircling relation about crankshaft **136**. These sleeves may each be operated by a motor such as motor **116** of FIG. **5** to effect the desired control.

[0053] FIG. **8** shows a modification to valve rocker arms to enable an auxiliary function to be driven therefrom. Illustratively, rocker arm **158** has a fulcrum generally indicated at **160**, an arm portion **162** extending to engage a valve stem **164** and valve spring **166**, an arm portion **168** extending to engage a pushrod **170**, and an auxiliary arm **172**. A push rod **174** is yoked to a pin **176** or otherwise pivotally connected to auxiliary arm **172**. Push rod **174** operates a plunger **178** slidably disposed within a chamber **180** of a housing **182**. In those embodiments wherein push rod **174** not yoked, then a return spring (not shown) is preferably provided to return plunger **178** to its initial position after displacement by push rod **174**. Reciprocation of plunger **178** pressurizes lubricant (not shown) or other fluid contained in chamber **180**. Pressurized fluid exits through a conduit **184**. Loss through entry opening **186** is prevented by a ball type check valve **188**. One function that may be satisfied in this manner is that of fuel injectors, particularly for diesel operation. It may be desirable to inject a cylinder other than that associated with rocker arm **158** to assure appropriate timing of injection with respect to the combustion cycle.

[0054] FIG. **9** shows details of induction and exhaust gas flow and also how certain support functions, such as lubricant and circulation and electrical connections are provided to engine **210**. FIG. **9** also clearly differentiates between moving and stationary parts. Engine **210** is generally similar in function and construction to its counterparts of FIGS. **1** and **7**. Engine **210** comprises a rotatable cylinder block **238** which contains cylinder and piston assemblies, a connecting rod, and a crankshaft positioning adjuster (not separately shown) which may be similar to those described prior. Cylinder block **238** is generally circular if viewed in top plan, and rotates as indicated by arrow A. Stationary parts are shown in cross hatching. Cross hatching is employed only to indicate stationary parts and to assist in discerning walls separating passages, and should not be construed to indicated continuous, solid constituency of illustrated components.

[0055] Cylinder block **238** has a shaft **240** which is supported on radial bearings **242** and thrust bearing **244** (shown representatively rather than literally). Bearings **242**, **244** are mounted in a suitably sturdy frame or support member **246**. Preferably, bearings **242** and **244** are of the self-sealed type used to support wheels on stub axles in conventional wheeled road going vehicles, and are independent of the forced lubrication system. Mounted to shaft **240** are a toothed wheel or gear **248**, a coolant pump **250**, and an oil pump **252**. An electric starter motor **254** is operably connectable to gear **248**. Pumps **250** and **252** may be, for example, of the eccentric lobe type, where an eccentric lobe (not separately shown) is driven by shaft **240**. Outputs of pumps may be conducted by suitable conduits to the points of use or to intermediate conduits as necessary.

[0056] Fluids necessary for supporting functions are introduced into cylinder block **238** through an intake conduit **256**. The nature of intake conduit **256** is better understood by examining FIG. **10**. Intake conduit **256** has a central passageway **258** for inducting combustion air into cylinder block **238** from air filter **260**, with flow indicated by arrows (see FIG. **9**). Passageways internal to cylinder block **238** (not shown, but functionally similar to intake passages **38**, **40**, **42** of FIG. **1**) are provided in cylinder block **238** to conduct combustion air to individual cylinders (not shown in FIG. **9**).

[0057] A second passageway **262** is arranged concentrically about yet isolated from passageway **258**. Unlike passageway **258**, which is open at both top and bottom, passageway **262** has an upper wall **264** to constrain fluids to communicate at the top only with a tube **266**. A third passageway **268** is concentrically disposed about passageway **262**, again isolated therefrom. Passageway **268** has an upper wall **270** and is in communication with a tube **272**. The outer wall of each passageway **258**, **262**, or **268** has an associated seal, such as a compressible O-ring **274**, **276**, or **278**.

[0058] Again referring to FIG. **9**, intake conduit **256** is held in fixed position abutting cylinder block **238** such that O-rings **274**, **276**, **278** make contact with cylinder block **238**. Cylinder block **238** has internal passages or conduits which correspond to passageways **258**, **262**, and **268**. Each internal passage is configured annularly and in direct registry beneath its associated passageway **258**, **262**, **268**. Thus fluids pass from stationary intake conduit **256** into cylinder block **238** even when the latter is rotating relative to the former.

[0059] Illustratively, coolant may be pumped from pump **250** to a liquid-to-air heat exchanger such as a conventional radiator, then to inlet tube **266** (see FIG. **10**) of intake conduit **256**. Coolant will then pass to an appropriate internal passage of cylinder block **238** and recirculated. Coolant may be discharged in any suitable way from cylinder block **238**, such as by an arrangement similar to that of intake conduit **256**. This may be accomplished by increasing the number of passageways from those shown in intake conduit **256** to establish a conduit having both intake and discharge functions, by providing a generally similar conduit at shaft **240**, or in any other suitable way.

[0060] A suitable lubricant such as engine oil may be pumped from pump **252** to a suitable oil filter (not shown), through an oil cooler if desired, and then to tube of intake conduit **256**. Oil then passes through passageway **268** (see FIG. **10**) and into an appropriate passage formed in cylinder block **238**. Oil is recovered by a dry sump method and eventually recirculated to pump **252**. It is preferred to employ a dry sump lubrication scheme, wherein lubricant is pumped back to the supply pump. In this capacity, it is preferred to provide piston rings which constrain lubricant to accumulate within the breathing chamber (such as lower section or portion **54** of the cylinder depicted in FIG. **2**). Oil collection galleries (not shown) may then conduct oil under the influence of centrifugal force arising from engine rotation to a return pump. This pump may be of the plunger type shown in and described with reference to FIG. **8**. It should be stated that the plunger arrangement shown in FIG. **8** may be modified to include more than one plunger and more than one purpose being served. Illustratively, rocker arm driven plunger pumps may serve both oil return and fuel injection systems. Alternatively, a plunger and spring cam driven from the crank shaft may be employed (this embodiment is not shown). Inertia and centrifugal force may be employed to propel lubricant through a spiral return path (this embodiment is not shown).

[0061] Exhaust is conducted from individual cylinders in a manner similar to that of the embodiment of FIG. **1**. Exhaust passages lead from individual cylinders or combustion chambers (not shown in FIG. **9**) to individual catalytic converters **280**. Exhaust is then discharged into an open chamber **282** formed between cylinder block **238** and a surrounding housing **284**. Housing **284** both confines exhaust gasses and also forms a structural member for supporting intake conduit **256** and other engine ancillaries such as motor mounts, fluid and electrical connections, and the like (none individually shown). Housing **284** is preferably sufficiently stout as to serve as a scatter shield for retaining cylinder block **238** in the event of disintegration, failure of bearings **242**, and the like. Exhaust gasses are preferably discharged tangentially from catalytic converters **280** in a direction opposite to the usual rotational direction of cylinder block **238**, to provide a jet assist effect in propelling cylinder block **238**. Muffling materials may be attached to the interior of housing **284**. Alternatively, a muffler **286** may be provided to silence gasses being discharged from chamber **282**.

[0062] In a currently preferred embodiment of the invention, engine **210** is a compression ignition or diesel engine. Glow plugs (not shown) are provided in their customary relationship to the combustion chambers. Glow plugs may be connected to power for engine starting in the following way. A solenoid plunger operated switch **288** is provided for each cylinder. Each switch **288** is connected to power from a battery (not shown). Each switch **288** includes a contact which projects such that it contacts a corresponding contact formed on cylinder block **238**. The corresponding contacts may be rings disposed continuously about and concentrically to the rotational axis of cylinder block **238**. Alternatively, they may be of relatively small size and in a predetermined location. Coordination of alignment between the stationary and mobile contacts may be achieved by manually adjusting cylinder block **238** to a predetermined location. Alternatively, cylinder block **238** may be arranged to come to a stop at a predictable angular position by utilizing resistance of compression, especially where a relatively small number of cylinders, such as two or three, is utilized.

[0063] Similar switches (not shown) may be provided to provide a ground path. Alternatively, switches **288** may be provided with additional contacts for this purpose. Electrical power supplied through switches **288** is appropriately insulated from ineffective contact to ground, and is conducted to the glow plugs. Solenoid switches **288** are de-energized to retract by spring force after sufficient time to warm the glow plugs adequately. Engine **210** may then be started by rotating cylinder block **238** by starter motor **254**. Preferably, the starting system includes a temperature sensor (not shown), so that when the engine is sufficiently warm to effect combustion spontaneously from the fuel injection system, glow plug operation will not be activated.

[0064] Although not shown, fuel may be supplied to fuel injectors (not separately shown) mounted in the cylinder block assembly in a manner similar to that shown for coolant and lubricant. Preferably a relatively low pressure fuel supply pump is provided, with final high pressure being supplied by plungers such as that described with reference to FIG. **8**.

[**0065**] It should be understood that certain modifications may be made to the embodiments described herein. For example, the number of engine cylinders may be at least two, and any number as desired. As a practical matter, the maximum number of cylinders is held to be about nine, since beyond that number, interference problems occur and the magnitude of the stroke becomes excessive compared to magnitude of the bore for each cylinder.

[**0066**] Arrangements for aspirating the engine other than those shown herein may be utilized, with appropriate modification to valving, porting, and the like. Poppet valves and exposed port valves may be changed to other types where desired. The stepped piston design described herein may be modified to eliminate that construction, may be modified to achieve supercharging in another way, or to eliminate supercharging.

[**0067**] Brushes (not shown) may be employed to conduct electrical signals into the rotating cylinder block where desired.

[**0068**] The descriptions of the preferred embodiments are not to be construed in a limiting sense but rather in illustrative capacity. The scope of the invention should be interpreted according to the appended claims.

I claim:

1. A power system including a radial rotary internal combustion engine as a prime mover, and a power transmission element capable of outputting power selectively from both active internal combustion power production and also inertia of engine rotating mass, wherein said engine includes

a rotatable cylinder block disposed to rotate about an axis of rotation and having formed therein a plurality of cylinders generally oriented to radiate from said axis of rotation, a piston reciprocatingly disposed within each one of said plurality of cylinders, a stationary crankshaft, and a unitary connecting rod encirclingly engaging said crankshaft and pivotally connected to each said piston, wherein said crankshaft has a longitudinal center line offset from said axis of rotation of said cylinder block such that rotation of said cylinder block and pistons about said crankshaft produces apparent reciprocation of each one of said pistons relative to each one of said plurality of cylinders, and

a rotation adjuster disposed to move said crankshaft to a second axis of rotation displaced from said first axis of rotation such that said rotatable cylinder block rotates about said second axis of rotation and each one of said cylinders is located such that said piston of each one of said cylinders avoids causing displacement within its respective said cylinder.

2. The power system according to claim 1, wherein said power transmission element includes a continuously variable transmission disposed to transmit and vary torque and rotational output speed from said engine.

3. The power system according to claim 1, further including an energy storage system for storing energy other than in the form of inertia of engine rotating mass.

4. The power system according to claim 2, wherein said energy storage system includes an air pump driven by said engine, a storage receptacle disposed to receive and store air compressed by said pistons, and a valve enabling compressed air to operate said air pump as a pneumatic motor.

5. The power system according to claim 1, wherein each said cylinder is canted in the direction of rotation wherein the outermost section of each said cylinder being in a leading position, and the innermost section of each said cylinder being in a trailing position relative to said leading position.

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