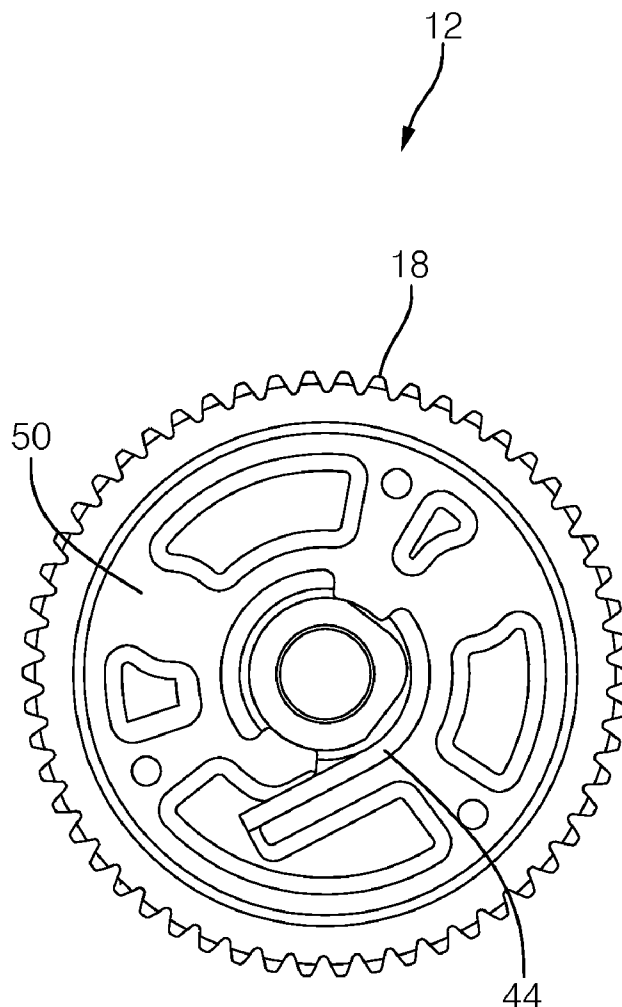




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(19) **United States**(12) **Patent Application Publication****Lichti et al.**(10) **Pub. No.: US 2014/0123920 A1**(43) **Pub. Date: May 8, 2014**(54) **CAMSHAFT PHASER WITH CENTRALLY  
LOCATED LOCK PIN VALVE SPOOL****Publication Classification**(71) Applicant: **DELPHI TECHNOLOGIES, INC.**,  
Troy, MI (US)(51) **Int. Cl.**  
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P. Shum**, Mendon, NY (US)(52) **U.S. Cl.**  
USPC ..... **123/90.15**(73) Assignee: **DELPHI TECHNOLOGIES, INC.**,  
TROY, MI (US)(57) **ABSTRACT**(21) Appl. No.: **13/667,127**

A camshaft phaser includes a stator having lobes and a rotor disposed within the stator having vanes interspersed with the lobes. A lock pin disposed within one of the rotor and the stator selectively engages a seat for preventing relative rotation between the rotor and the stator when the lock pin is engaged with the seat. A bolt extends coaxially through the rotor and the stator to attach the camshaft phaser to a camshaft. A valve spool in the bolt controls the flow of oil to and from the lock pin. The bolt includes a supply drilling extending therethrough to supply pressurized oil to the valve spool.

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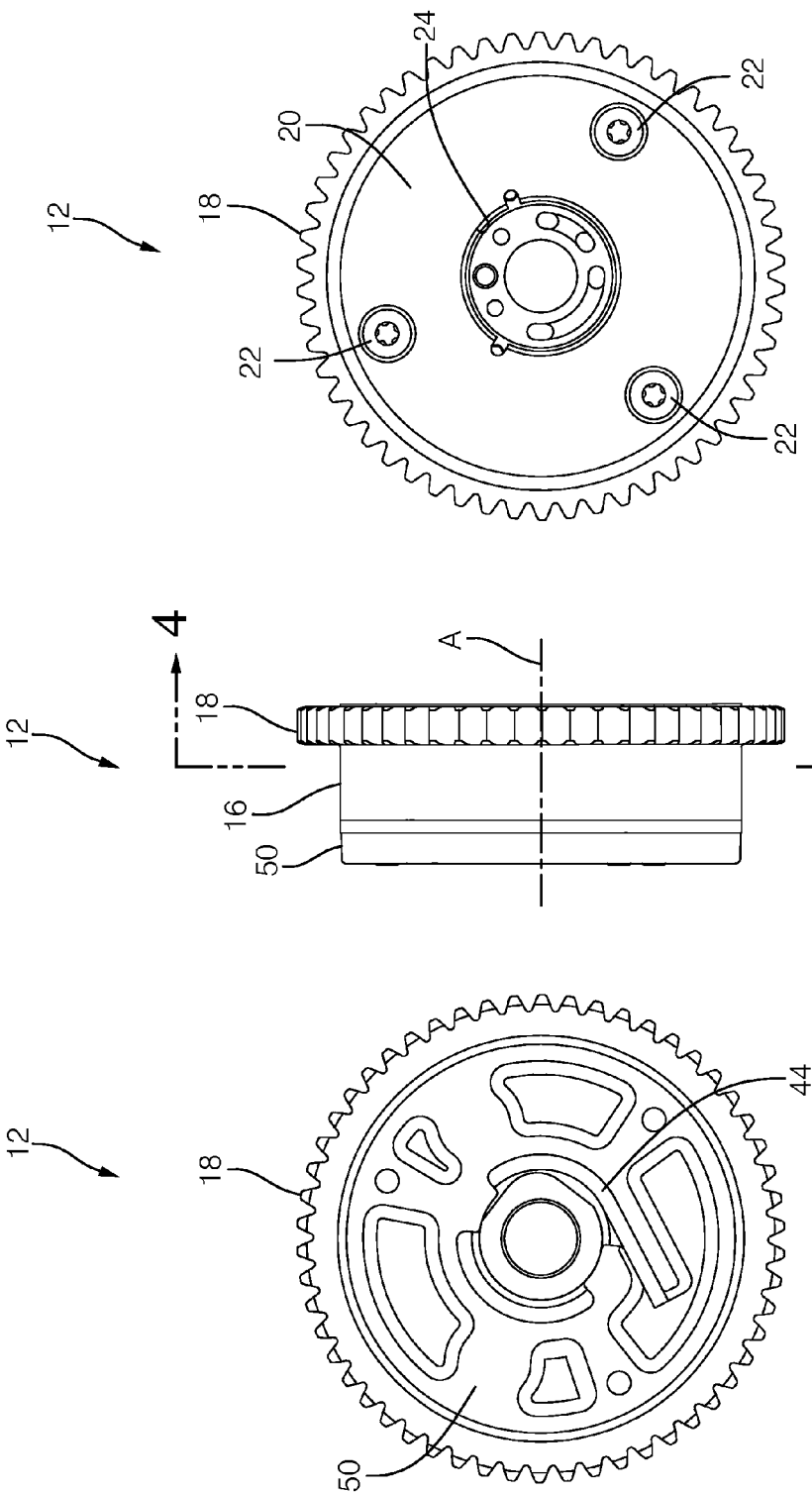


FIG. 1

FIG. 2

FIG. 3

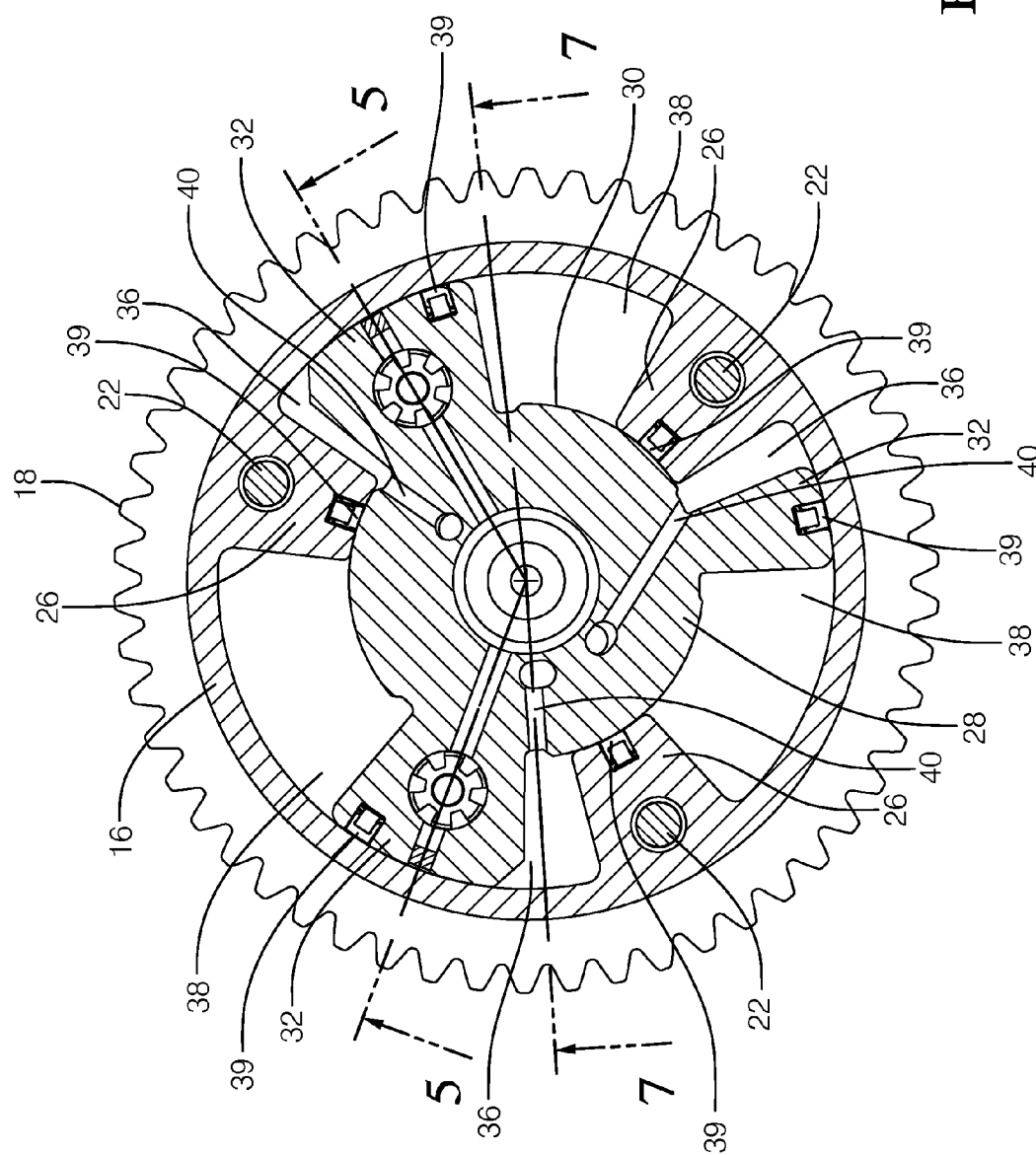


FIG. 4

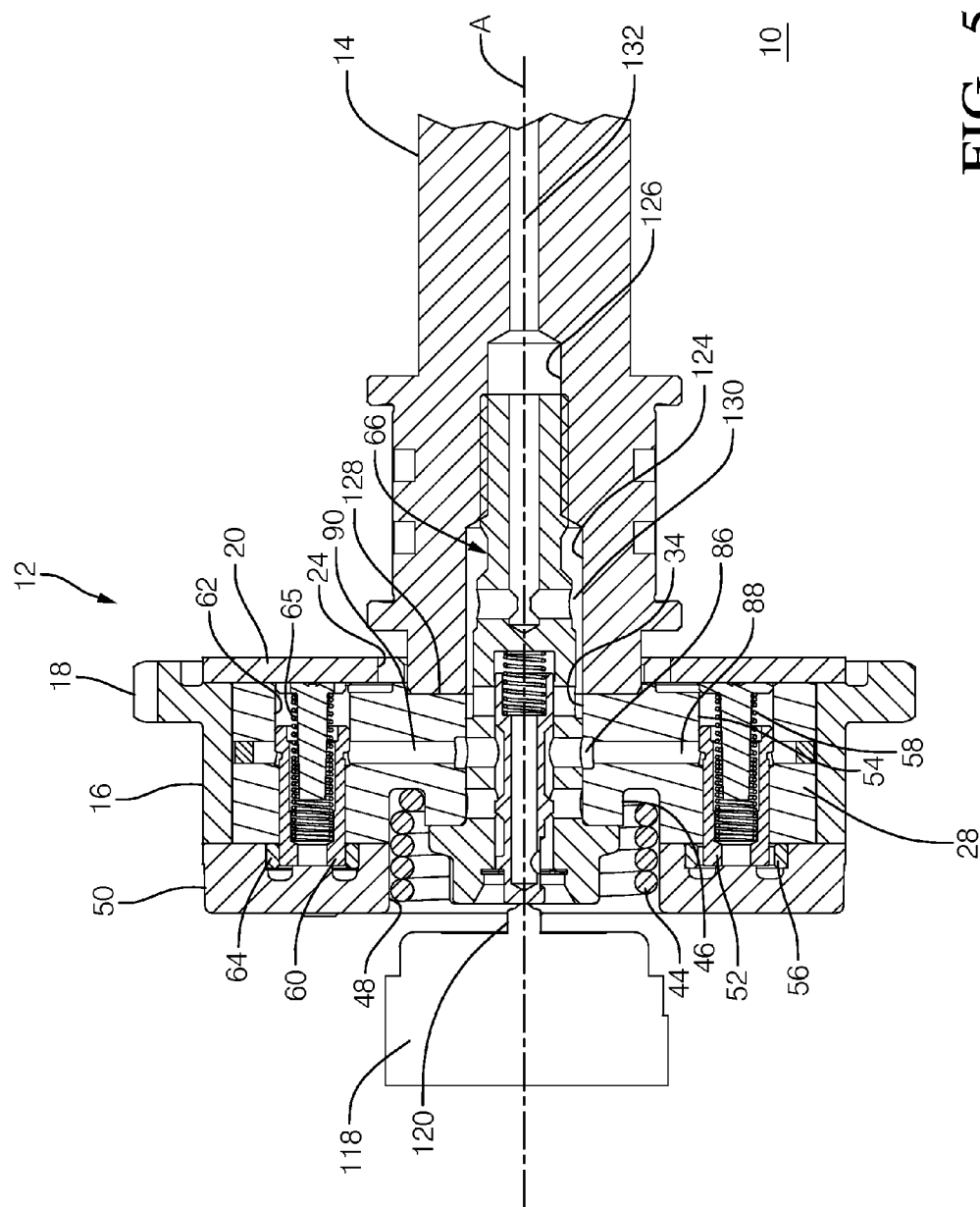


FIG. 5

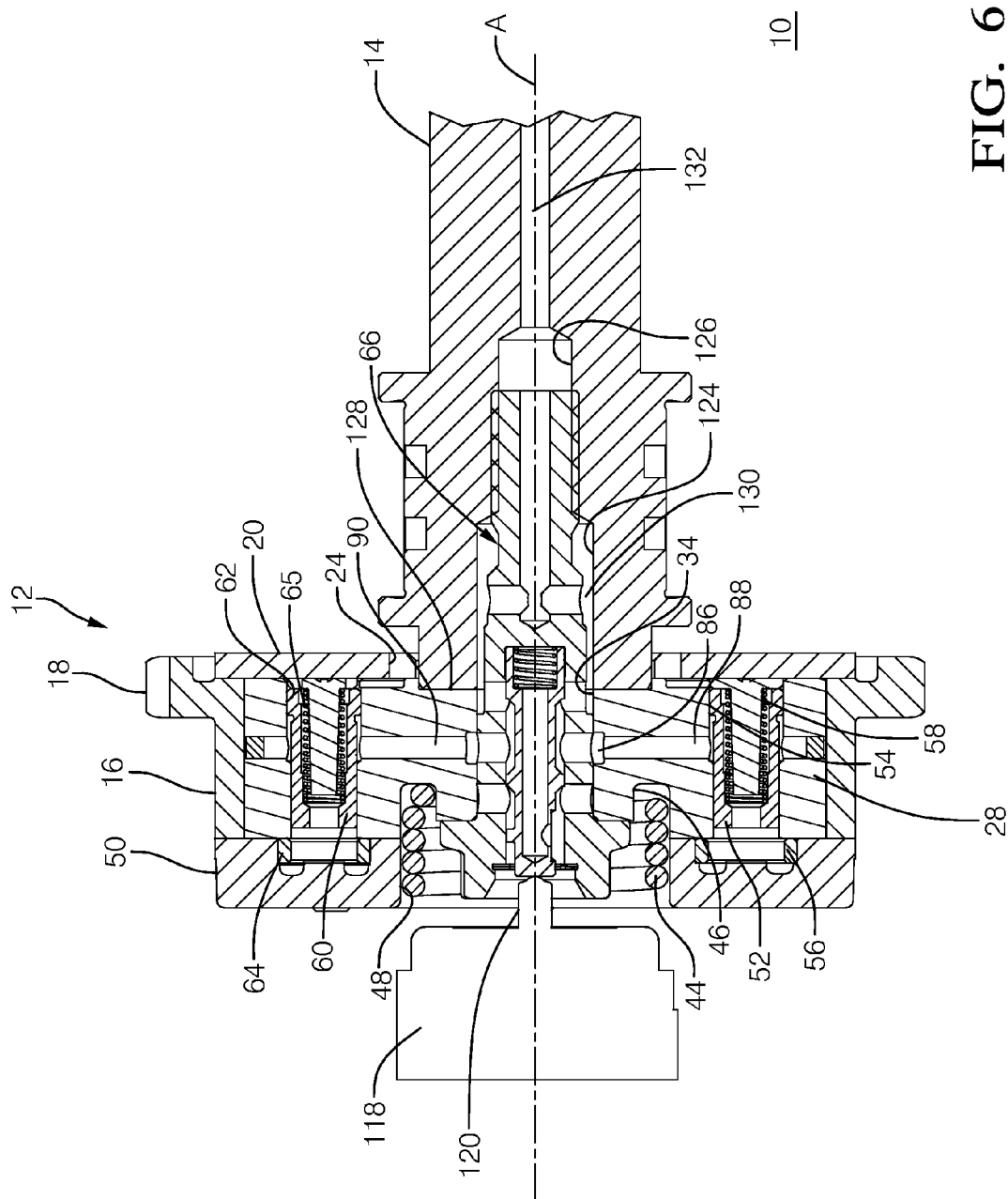


FIG. 6

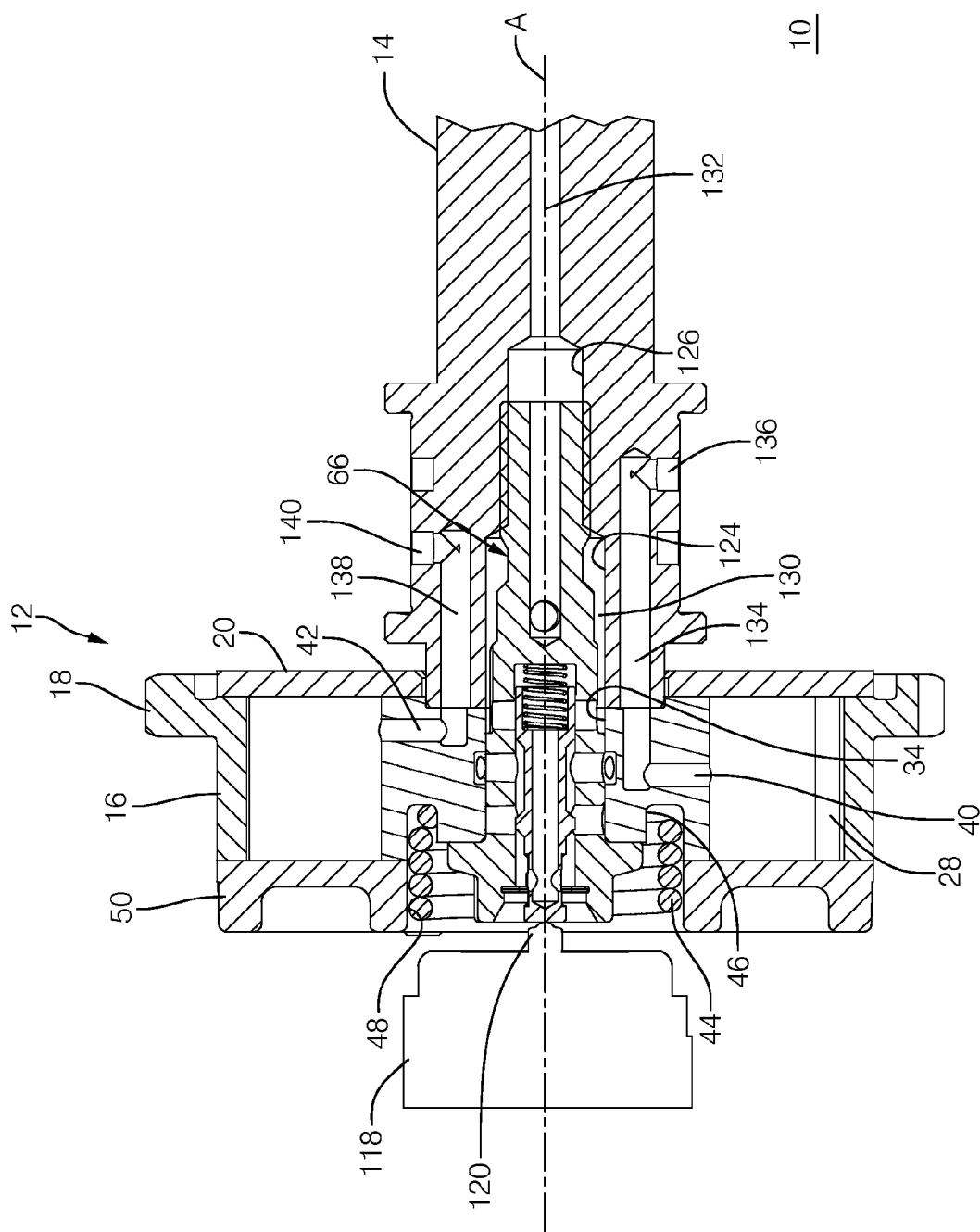


FIG. 7

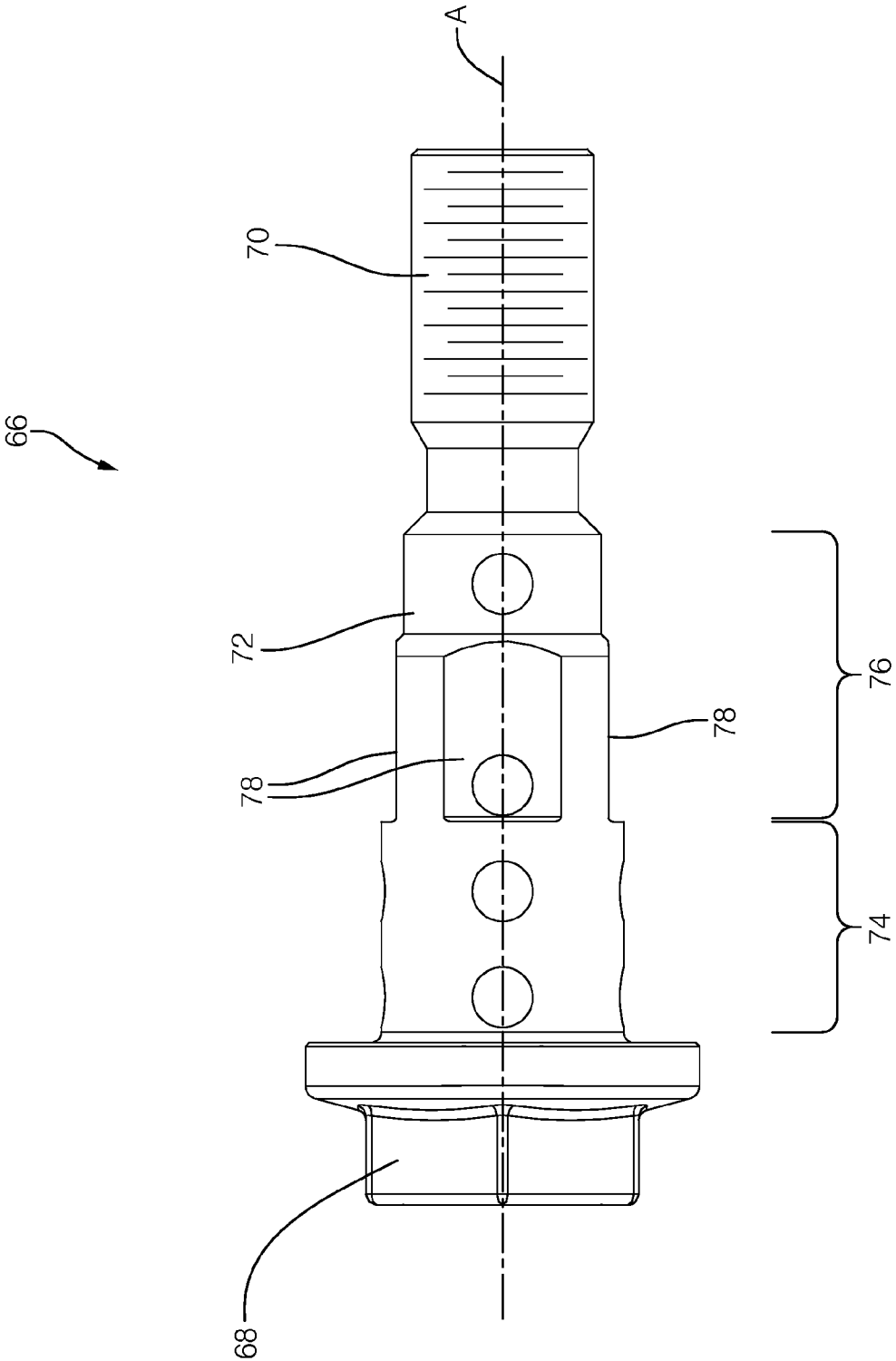


FIG. 8

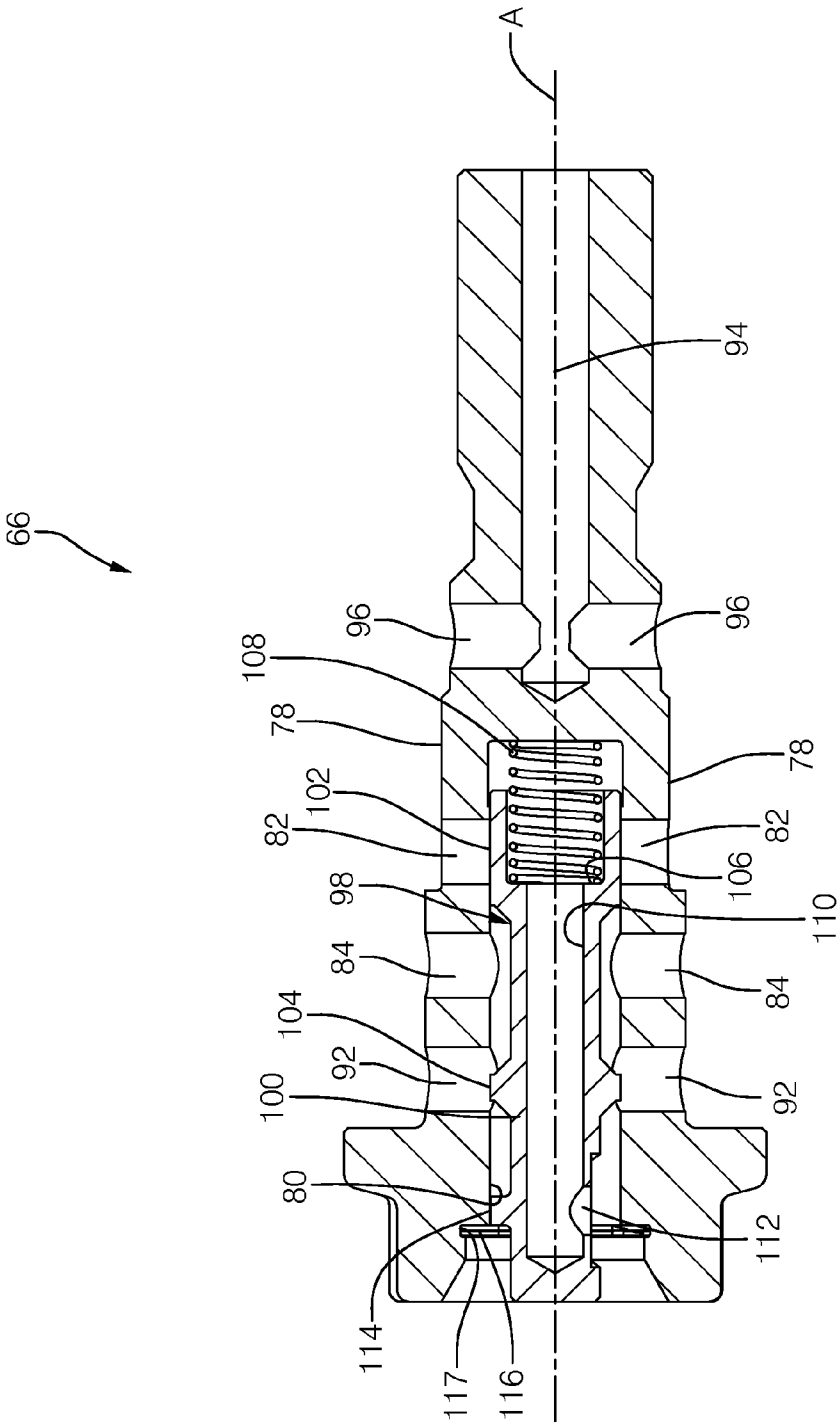


FIG. 9

FIG. 10

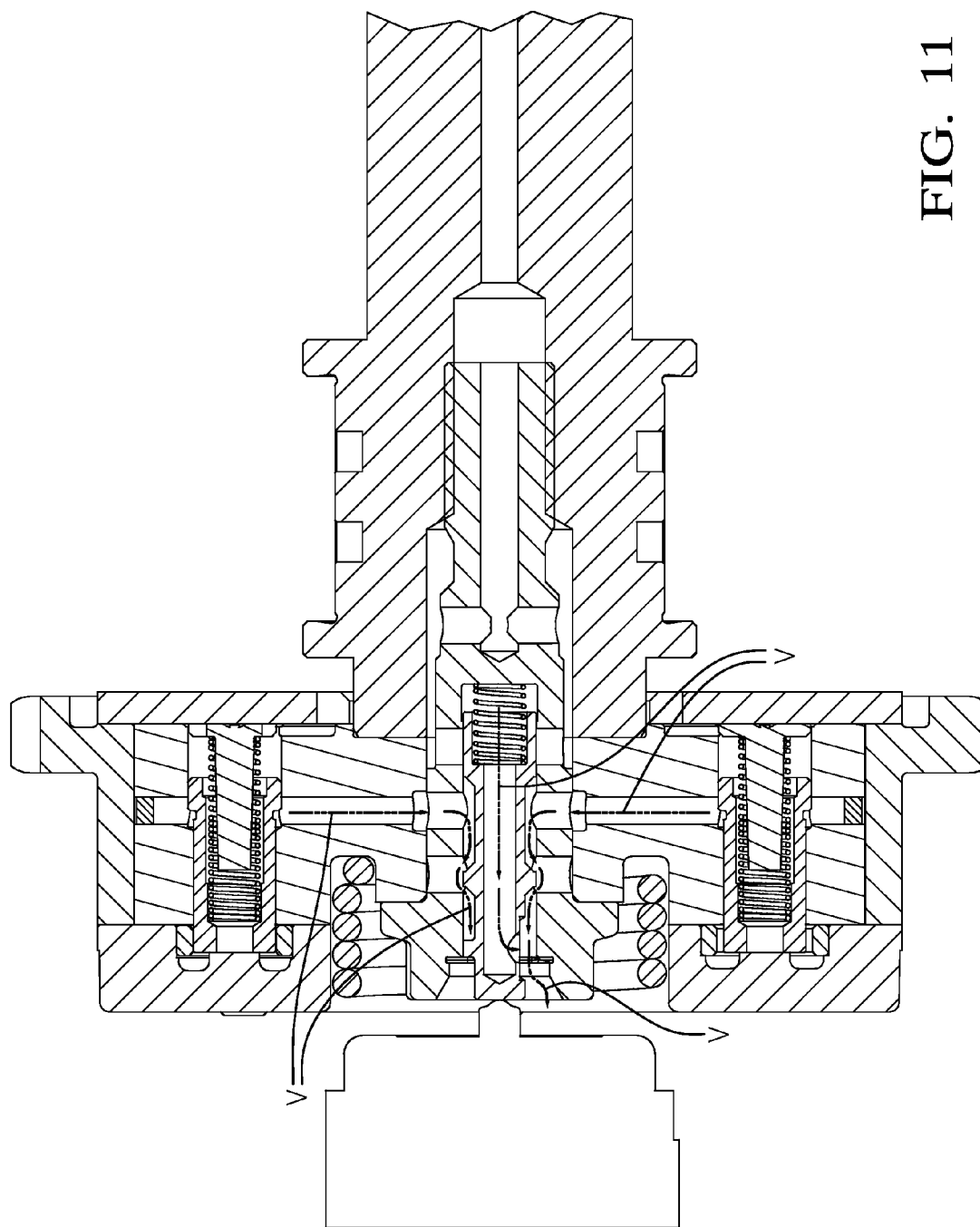


FIG. 11

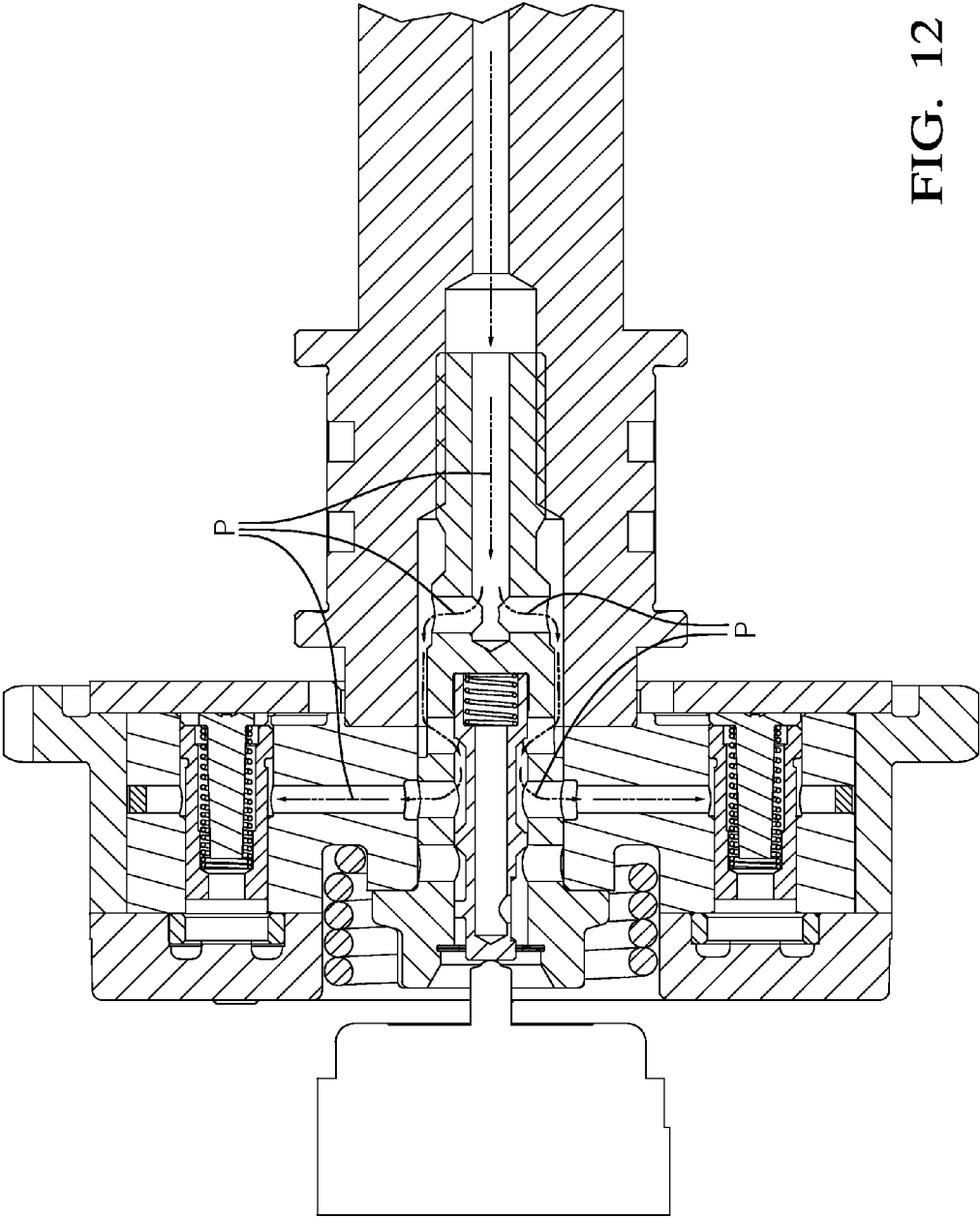


FIG. 12

## CAMSHAFT PHASER WITH CENTRALLY LOCATED LOCK PIN VALVE SPOOL

### TECHNICAL FIELD OF INVENTION

**[0001]** The present invention relates to a hydraulically actuated camshaft phaser for varying the phase relationship between a crankshaft and a camshaft in an internal combustion engine; more particularly to such a camshaft phaser including a lock pin for selectively preventing a change in phase relationship; and even more particularly to such a camshaft phaser which includes a lock pin valve spool for locking and unlocking the lock pin.

### BACKGROUND OF INVENTION

**[0002]** A typical vane-type camshaft phaser generally comprises a plurality of outwardly-extending vanes on a rotor interspersed with a plurality of inwardly-extending lobes on a stator, forming alternating advance and retard chambers between the vanes and lobes. Engine oil is selectively supplied to one of the advance and retard chambers and vacated from the other of the advance and retard chambers in order to rotate the rotor within the stator and thereby change the phase relationship between an engine camshaft and an engine crankshaft. Camshaft phasers also commonly include an intermediate lock pin which selectively prevents relative rotation between the rotor and the stator at an angular position that is intermediate of a full advance position and a full retard position. The intermediate lock pin is engaged and disengaged by venting oil from the intermediate lock pin and supplying pressurized oil to the intermediate lock pin respectively. Supplying and venting of oil to and from the intermediate lock pin is preferably performed by an oil control valve that operates independently of another oil control valve which is used to supply and vent oil from the advance and retard chambers because oil may need to be supplied or vented from the advance and retard chambers in order to align the intermediate lock pin with its corresponding intermediate lock pin seat.

**[0003]** United States Patent Application Publication No. US 2011/0271919 A1 to Kaneko shows such a camshaft phaser. Kaneko teaches a first oil control valve that is external to the camshaft phaser for changing the phase relationship. The first oil control valve requires two annular grooves to be formed in a camshaft bearing in order to supply and vent oil to and from the advance and retard chambers. Kaneko also teaches a second oil control valve that is external to the camshaft phaser for controlling the intermediate lock pins. The second oil control valve requires an additional annular groove to be formed in the camshaft bearing in order to supply and vent oil from the intermediate lock pins. Each annular groove formed in the camshaft bearing must be separated from each adjacent annular groove by a sufficient distance in order to prevent oil leakage between the annular grooves. However, some camshaft bearings may not be sufficiently large to accommodate three annular grooves and there may not be sufficient space available to increase the size of the camshaft bearing to accommodate three annular grooves.

**[0004]** What is needed is a camshaft phaser which minimizes or eliminates one or more of the shortcomings as set forth above.

### SUMMARY OF THE INVENTION

**[0005]** Briefly described, a camshaft phaser is provided for controllably varying the phase relationship between a crank-

shaft and a camshaft in an internal combustion engine. The camshaft phaser includes a stator rotatable about an axis and having a plurality of lobes, the stator being connectable to the crankshaft of the internal combustion engine to provide a fixed ratio of rotation between the stator and the crankshaft. The camshaft phaser also includes a rotor coaxially disposed within the stator and having a plurality of vanes interspersed with the stator lobes defining alternating advance chambers and retard chambers. The advance chambers receive pressurized oil in order to change the phase relationship between the crankshaft and the camshaft in the advance direction and the retard chambers receive pressurized oil in order to change the phase relationship between the camshaft and the crankshaft in the retard direction. The rotor is attachable to the camshaft of the internal combustion engine to prevent relative rotation between the rotor and the camshaft. The camshaft phaser also includes a lock pin disposed within one of the rotor and the stator for selective engagement with a lock pin seat for substantially preventing relative rotation between the rotor and stator when the lock pin is engaged with the lock pin seat. Pressurized oil is selectively supplied to the lock pin in order to disengage the lock pin from the lock pin seat and oil is selectively vented from the lock pin in order to engage the lock pin with the lock pin seat. A camshaft phaser attachment bolt extends coaxially through the rotor and the stator and is threadably engageable into the camshaft to attach the camshaft phaser to the camshaft. A lock pin valve spool controls the flow of oil to and from the lock pin and is located within the camshaft phaser attachment bolt. The camshaft phaser attachment bolt includes a supply drilling through the camshaft phaser attachment bolt to supply pressurized oil to the lock pin control valve spool.

### BRIEF DESCRIPTION OF DRAWINGS

**[0006]** This invention will be further described with reference to the accompanying drawings in which:

**[0007]** FIG. 1 a front elevation view of a camshaft phaser in accordance with the present invention;

**[0008]** FIG. 2 is a side elevation view of the camshaft phaser of FIG. 1;

**[0009]** FIG. 3 is a back elevation view of the camshaft phaser of FIGS. 1 and 2;

**[0010]** FIG. 4 is a radial cross section of the camshaft phaser of FIGS. 1-3 taken through section line 4-4 of FIG. 2;

**[0011]** FIG. 5 is an axial cross section of the camshaft phaser of FIGS. 1-4 taken through section line 5-5 of FIG. 4 and showing a lock pin spool positioned to vent oil from lock pins of the camshaft phaser and also showing the camshaft phaser attached to a camshaft of an internal combustion engine and an actuator attached to the camshaft phaser;

**[0012]** FIG. 6 is the axial cross section of FIG. 5 now showing the lock pin spool positioned to supply pressurized oil to the lock pins of the camshaft phaser;

**[0013]** FIG. 7 is an axial cross section of the camshaft phaser of FIGS. 1-4 taken through section line 7-7 of FIG. 4 and showing the camshaft phaser attached to a camshaft of an internal combustion engine and an actuator attached to the camshaft phaser;

**[0014]** FIG. 8 is a side elevation view of a camshaft phaser attachment bolt of the camshaft phaser of FIGS. 1-7;

**[0015]** FIG. 9 is an enlarged view of a camshaft phaser attachment bolt and the lock pin spool of FIG. 5;

**[0016]** FIG. 10 is an enlarged view of a camshaft phaser attachment bolt and the lock pin spool of FIG. 6;

[0017] FIG. 11 is the axial cross section of FIG. 5 showing the path taken by vented oil; and

[0018] FIG. 12 is the axial cross section of FIG. 6 showing the path taken by pressurized oil.

#### DETAILED DESCRIPTION OF INVENTION

[0019] In accordance with a preferred embodiment of this invention and referring to FIGS. 1-12 wherein like reference numerals are used to identify identical components in the various views, an internal combustion engine 10 is shown which includes a camshaft phaser 12 extending along an axis A. Internal combustion engine 10 also includes a camshaft 14 which is rotatable about axis A based on rotational input from a crankshaft and chain (not shown) driven by a plurality of reciprocating pistons (also not shown). As camshaft 14 is rotated, it imparts valve lifting and closing motion to intake and/or exhaust valves (not shown) as is well known in the internal combustion engine art. Camshaft phaser 12 allows the timing between the crankshaft and camshaft 14 to be varied. In this way, opening and closing of the intake and/or exhaust valves can be advanced or retarded in order to achieve desired engine performance.

[0020] Camshaft phaser 12 includes a stator 16 having a sprocket 18 which is driven by a chain or gear (not shown) driven by the crankshaft of internal combustion engine 10. Alternatively, sprocket 18 may be a pulley driven by a belt. A back cover 20 is placed over one end of stator 16 and is sealingly secured to stator 16 with sprocket bolts 22 in a way that will be described in more detail later. Back cover 20 includes a back cover central bore 24 for receiving camshaft 14 coaxially therethrough which is allowed to rotate relative to sprocket 18.

[0021] A stator 16 is generally cylindrical and includes a plurality of radial chambers defined by a plurality of lobes 26 extending radially inward. In the embodiment shown, there are three lobes 26 defining three radial chambers, however, it is to be understood that a different number of lobes may be provided to define radial chambers equal in quantity to the number of lobes.

[0022] A rotor 28 includes central hub 30 with a plurality of vanes 32 extending radially outward therefrom and central through bore 34 which extends axially therethrough centered about axis A. The number of vanes 32 is equal to the number of radial chambers provided in stator 16. Rotor 28 is coaxially disposed within stator 16 such that each vane 32 divides each radial chamber into advance chambers 36 and retard chambers 38. The radial tips of lobes 26 are mateable with central hub 30 in order to separate the radial chambers from each other. Each of the radial tips of vanes 32 and lobes 26 may include one of a plurality of wiper seals 39 to substantially seal adjacent advance and retard chambers 36, 38 from each other.

[0023] Central hub 30 includes a plurality advance oil passages 40 and retard oil passages 42 formed therein (only one advance oil passage 40 and one retard oil passage 42 is visible in FIG. 7). Each one of the plurality of advance oil passages 40 is in fluid communication with one of the advance chambers 36 for supplying oil thereto and therefrom while each one of the plurality of retard oil passages 42 is in fluid communication with one of the retard chambers 38 for supplying oil thereto and therefrom.

[0024] A bias spring 44 is disposed within an annular pocket 46 formed in rotor 28 and within a central bore 48 of a camshaft phaser cover 50. Bias spring 44 is grounded at one

end thereof to camshaft phaser cover 50 and is attached at the other end thereof to rotor 28. When internal combustion engine 10 is shut down, bias spring 44 may urge rotor 28 toward the full advance position within stator 16.

[0025] Camshaft phaser 12 includes a staged dual lock pin system for selectively preventing relative rotation between rotor 28 and stator 16 at a predetermined angular position which is between the extreme advance and extreme retard positions. A primary lock pin 52 is slidably disposed within primary lock pin bore 54 formed in one of the plurality of vanes 32 of rotor 28. A primary lock pin seat 56 is an insert fitted into camshaft phaser cover 50 for selectively receiving primary lock pin 52 therewithin. Primary lock pin seat 56 is larger than primary lock pin 52 to allow rotor 28 to rotate relative to stator 16, for example only, about 5° on each side of the predetermined angular position when primary lock pin 52 is seated within primary lock pin seat 56. The enlarged nature of primary lock pin seat 56 allows primary lock pin 52 to be easily received therewithin. When primary lock pin 52 is not desired to be seated within primary lock pin seat 56 as shown in FIG. 6, pressurized oil is supplied to primary lock pin 52, thereby urging primary lock pin 52 out of primary lock pin seat 56 and compressing a primary lock pin spring 58. Conversely, when primary lock pin 52 is desired to be seated within primary lock pin seat 56 as shown in FIG. 5, the pressurized oil is vented from primary lock pin 52, thereby allowing primary lock pin spring 58 to urge primary lock pin 52 toward camshaft phaser cover 50. In this way, primary lock pin 52 is seated within primary lock pin seat 56 by primary lock pin spring 58 when rotor 28 is positioned within stator 16 to allow alignment of primary lock pin 52 with primary lock pin seat 56.

[0026] A secondary lock pin 60 is slidably disposed within secondary lock pin bore 62 formed in one of the plurality of vanes 32 of rotor 28. A secondary lock pin seat 64 is an insert fitted into camshaft phaser cover 50 for selectively receiving secondary lock pin 60 therewithin. Secondary lock pin 60 fits within secondary lock pin seat 64 in a close sliding relationship, thereby substantially preventing relative rotation between rotor 28 and stator 16 when secondary lock pin 60 is received within secondary lock pin seat 64. A small amount of relative rotation between rotor 28 and stator 16 may be permitted, for example only, about 0.5° in each direction of rotation of rotor 28 while still considering relative rotation between rotor 28 and stator 16 to be substantially prevented. When secondary lock pin 60 is not desired to be seated within secondary lock pin seat 64 as shown in FIG. 6, pressurized oil is supplied to secondary lock pin 60, thereby urging secondary lock pin 60 out of secondary lock pin seat 64 and compressing a secondary lock pin spring 65. Conversely, when secondary lock pin 60 is desired to be seated within secondary lock pin seat 64 as shown in FIG. 5, the pressurized oil is vented from the secondary lock pin 60, thereby allowing secondary lock pin spring 65 to urge secondary lock pin 60 toward camshaft phaser cover 50. In this way, secondary lock pin 60 is seated within secondary lock pin seat 64 by secondary lock pin spring 65 when rotor 28 is positioned within stator 16 to allow alignment of secondary lock pin 60 with secondary lock pin seat 64.

[0027] When it is desired to prevent relative rotation between rotor 28 and stator 16 at the predetermined angular position, the pressurized oil is vented from both primary lock pin 52 and secondary lock pin 60, thereby allowing primary lock pin spring 58 and secondary lock pin spring 65 to urge

primary and secondary lock pins 52, 60 toward camshaft phaser cover 50 respectively. In order to align primary and secondary lock pins 52, 60 with primary and secondary lock pin seats 56, 64 respectively, rotor 28 may be rotated with respect to stator 16 by one or more of supplying pressurized oil to advance chambers 36, supplying pressurized oil to retard chambers 38, urging from bias spring 44, and torque from camshaft 14. Since primary lock pin seat 56 is enlarged, primary lock pin 52 will be seated within primary lock pin seat 56 before secondary lock pin 60 is seated within secondary lock pin seat 64. With primary lock pin 52 seated within primary lock pin seat 56, rotor 28 is allowed to rotate with respect to stator 16 by, for example only, about 10°. Rotor 28 may be further rotated with respect to stator 16 by one or more of supplying pressurized oil to advance chambers 36, supplying pressurized oil to retard chambers 38, urging from bias spring 44, and torque from camshaft 14 in order to align secondary lock pin 60 with secondary lock pin seat 64, thereby allowing secondary lock pin 60 to be seated within secondary lock pin seat 64. Supply and venting of oil to and from advance chambers 36, retard chambers 38, and primary and secondary lock pins 52, 60 will be described in more detail later.

[0028] Camshaft phaser cover 50 is sealingly attached to stator 16 by sprocket bolts 22 that extend through sprocket 18 and stator 16 and threadably engage camshaft phaser cover 50. In this way, stator 16 is securely clamped between sprocket 18 and camshaft phaser cover 50 in order to axially and radially secure sprocket 18, stator 16, and camshaft phaser cover 50 to each other.

[0029] Camshaft phaser 12 is attached to camshaft 14 with a camshaft phaser attachment bolt 66. Camshaft phaser attachment bolt 66 includes a bolt head 68 at the end of camshaft phaser attachment bolt 66 that is distal from camshaft 14, a bolt threaded end 70 that is proximal to camshaft 14, and a bolt shank 72 connecting bolt head 68 to bolt threaded end 70. A shank sealing portion 74 of bolt shank 72 that is cylindrical and proximal to bolt head 68 extends coaxially through central hub 30 of rotor 28 in a close fitting relationship. A shank supply portion 76 of bolt shank 72 extends away from shank sealing portion 74 and connects shank sealing portion 74 to bolt threaded end 70. Shank supply portion 76 includes recessed features, illustrated as flats 78, on an outside surface thereof. The function of flats 78 will be more apparent when the operation of camshaft phaser 12 is described.

[0030] A blind bore 80 extends coaxially into camshaft phaser attachment bolt 66 beginning at the end of camshaft phaser attachment bolt 66 that is defined by bolt head 68. Camshaft phaser attachment bolt 66 includes supply drillings 82 which extend radially through camshaft phaser attachment bolt 66 from blind bore 80 to flats 78, thereby providing fluid communication between flats 78 and blind bore 80. Camshaft phaser attachment bolt 66 also includes lock pin drillings 84 which extend radially through camshaft phaser attachment bolt 66 from blind bore 80 to shank sealing portion 74, thereby providing fluid communication between shank sealing portion 74 and blind bore 80. Lock pin drillings 84 are aligned with an annular lock pin groove 86 formed on the inside surface of central through bore 34 of rotor 28. Lock pin groove 86 is in fluid communication with lock pin oil passages 88, 90 which are in fluid communication with primary lock pin 52 and secondary lock pin 60 respectively. Camshaft phaser attachment bolt 66 also includes vent drillings 92

which extend radially through camshaft phaser attachment bolt 66 from blind bore 80 to shank sealing portion 74, however, as will be understood more clearly later, the function of vent drillings 92 does not required fluid communication be provided between blind bore 80 and shank sealing portion 74. Accordingly, vent drillings 92 may be substituted with an annular groove (not shown) extending radially outward from blind bore 80. It should be understood that the term “drillings” as applied to supply drillings 82, lock pin drillings 84, and vent drillings 92 does not imply a process for forming the features.

[0031] A bolt supply bore 94 extends coaxially into camshaft phaser attachment bolt 66 from bolt threaded end 70. Bolt supply bore 94 extends into shank supply portion 76 but does not intersect with blind bore 80. Bolt supply passages 96 extend radially outward from bolt supply bore 94 through shank supply portion 76.

[0032] A lock pin valve spool 98 is slideably disposed within blind bore 80 of camshaft phaser attachment bolt 66 for selectively allowing pressurized oil from supply drillings 82 to be communicated to primary lock pin 52 and secondary lock pin 60 when lock pin valve spool 98 is slid to an unlocking position. Lock pin valve spool 98 also selectively prevents pressurized oil from being communicated from supply drillings 82 to primary lock pin 52 and secondary lock pin 60 and vents oil from primary lock pin 52 and secondary lock pin 60 when lock pin valve spool 98 is slid to a locking position.

[0033] Lock pin valve spool 98 includes a valve spool body 100 which is sized to provide radial clearance with blind bore 80. An annular supply land 102 extends radially outward from valve spool body 100 at the end of valve spool body 100 proximal to supply drillings 82. Supply land 102 is sized to ride closely within blind bore 80 and substantially prevents fluid communication between supply drillings 82 and lock pin drillings 84 when lock pin valve spool 98 is in the locking position.

[0034] Lock pin valve spool 98 also includes an annular vent land 104 which extends radially outward from valve spool body 100 and is positioned axially away from supply land 102 toward bolt head 68. Vent land 104 is sized to ride closely within blind bore 80 and substantially prevents fluid communication between lock pin drillings 84 and vent drillings 92 when lock pin valve spool 98 is in the unlocking position.

[0035] Lock pin valve spool 98 also includes a spool spring seat 106 defined by a bore extending axially into the end of lock pin valve spool 98 that is proximal to the bottom of blind bore 80. Spool spring seat 106 receives one end of a spool spring 108 while the other end of spool spring 108 is grounded to the bottom of blind bore 80. Spool spring 108 applies a biasing force on lock pin valve spool 98 away from the bottom of blind bore 80.

[0036] Lock pin valve spool 98 also includes a spool vent bore 110 extending coaxially into lock pin valve spool 98 from spool spring seat 106 and axially past vent land 104. A spool vent connecting passage 112 extends radially through lock pin valve spool 98 to provide fluid communication between spool vent bore 110 and blind bore 80.

[0037] Lock pin valve spool 98 also includes a retention wing 114 extending radially outward from valve spool body 100, however, retention wing 114 does not extend around the entire perimeter of valve spool body 100 and may be sized to not ride closely within blind bore 80. When lock pin valve spool 98 is in the locking position, retention wing 114 abuts a

retention clip **116** which is fixed within a retention clip groove **117** formed in blind bore **80** of camshaft phaser attachment bolt **66**, thereby limiting the travel of lock pin valve spool **98** and retaining lock pin valve spool **98** within blind bore **80**. Retention clip **116** provides radial clearance with valve spool body **100** as will be described in more detail later.

**[0038]** An actuator **118** is provided to displace lock pin valve spool **98** from the locking position to the unlocking position. Actuator **118** may be, for example, a solenoid actuator with an actuator shaft **120**. When an electric current is applied to actuator **118**, actuator shaft **120** moves lock pin valve spool **98** toward the bottom of blind bore **80** to the unlocking position, thereby compressing spool spring **108**. When the application of the electric current to actuator **118** is stopped, spool spring **108** urges lock pin valve spool **98** back to the locking position. Solenoid actuators are well known and will not be described further herein. While actuator **118** has been described as a solenoid actuator, it should be understood that any type of actuator may be used which would provide the necessary axial movement to lock pin valve spool **98**.

**[0039]** Camshaft **14** is provided with a stepped camshaft bore which includes a clearance bore **124** and a threaded bore **126** which is smaller in diameter than clearance bore **124**. Clearance bore **124** extends coaxially into camshaft **14** from the end of camshaft **14** that abuts rotor **28**. Rotor **28** may include a rotor pocket **128** which fits closely with the outer circumference of camshaft **14** in order to ensure that rotor **28** is coaxial with camshaft **14**. Clearance bore **124** is sized to provide an annular chamber **130** radially between shank supply portion **76** of camshaft phaser attachment bolt **66** and clearance bore **124**. Threaded bore **126** includes internal threads which threadably engage bolt threaded end **70** of camshaft phaser attachment bolt **66**. Accordingly, when camshaft phaser attachment bolt **66** is tightened to a predetermined torque, bolt head **68** acts axially on rotor **28** such that rotor **28** is clamped securely between bolt head **68** and camshaft **14**. In this way, camshaft phaser **12** is secured to camshaft **14**. A camshaft oil supply passage **132** may be in fluid communication with threaded bore **126** for supplying pressurized oil to threaded bore **126** as will be described in more detail later.

**[0040]** Camshaft **14** includes camshaft advance passages **134** (only one is visible in FIG. 7) in order to supply and vent oil from advance chambers **36**. Camshaft advance passages **134** are in fluid communication with advance oil passages **40** of rotor **28** and are in fluid communication with an annular camshaft advance groove **136** formed in the outside bearing surface of camshaft **14**. Similarly, camshaft **14** includes camshaft retard passages **138** (only one is visible in FIG. 7) in order to supply and vent oil from retard chambers **38**. Camshaft retard passages **138** are in fluid communication with retard oil passages **42** of rotor **28** and are in fluid communication with annular camshaft retard groove **140** formed in the outside bearing surface of camshaft **14**. Supplying and venting of oil to and from camshaft advance groove **136** and camshaft retard groove **140** is controlled by a phase control valve (not shown) in order to position rotor **28** relative to stator **16** to achieve desired operating characteristics of internal combustion engine **10**.

**[0041]** A description of the operation of camshaft phaser **12** relative to locking and unlocking of primary lock pin **52** and secondary lock pin **60** will now be given. When it is desired to unlock primary lock pin **52** and secondary lock pin **60**,

thereby allowing rotor **28** to rotate relative to stator **16**, actuator **118** is energized with an electric current. When actuator **118** is energized with an electric current, actuator shaft **120** is moved axially toward lock pin valve spool **98** which causes lock pin valve spool **98** to move axially in blind bore **80** toward the bottom end of blind bore **80** and compressing spool spring **108**. This allows pressurized oil from camshaft oil supply passage **132** to be supplied to bolt supply bore **94**, bolt supply passages **96**, and annular chamber **130**. From annular chamber **130**, the oil passes to supply drillings **82** of camshaft phaser attachment bolt **66** by way of the space formed radially between flats **78** of camshaft phaser attachment bolt **66** and central through bore **34** and clearance bore **124**. Since supply land **102** is not blocking supply drillings **82**, the oil is allowed to continue to blind bore **80** where it passes to lock pin drillings **84** of camshaft phaser attachment bolt **66**, lock pin groove **86** of rotor **28**, and lock pin oil passages **88**, **90** where the oil is allowed to unseat or unlock primary lock pin **52** from primary lock pin seat **56** and secondary lock pin **60** from secondary lock pin seat **64**. It should be noted that vent land **104** blocks fluid communication between lock pin drillings **84** and vent drillings **92** when lock pin valve spool **98** is in this position. For clarity, FIG. **12** includes arrows P to show the path taken by the pressurized oil which unlocks primary lock pin **52** from primary lock pin seat **56** and secondary lock pin **60** from secondary lock pin seat **64**.

**[0042]** Conversely, when it is desired to lock primary lock pin **52** and secondary lock pin **60**, thereby preventing rotor **28** from rotating relative to stator **16**, actuator **118** is not energized with an electric current. When actuator **118** is not energized with an electric current, actuator shaft **120** is moved axially in a direction away from lock pin valve spool **98**, thereby causing lock pin valve spool **98** to move axially in blind bore **80** away from the bottom end of blind bore **80** under the force of spool spring **108** until lock pin valve spool **98** abuts retention clip **116**. When this occurs, supply land **102** is positioned to block supply drillings **82**, thereby preventing pressurized oil from being communicated from camshaft oil supply passage **132** to lock pin drillings **84**. At the same time, vent land **104** is aligned with vent drillings **92**; however, vent land **104** has an axial length sufficiently small as to not block vent drillings **92**. This allows oil from primary lock pin **52** and secondary lock pin **60** to vent through the end of camshaft phaser attachment bolt **66** that is proximal to actuator **118** by passing through lock pin oil passages **88**, **90**, lock pin groove **86**, lock pin drillings **84**, vent drillings **92**, and blind bore **80**. It should be noted that any oil that may leak past supply land **102** toward the bottom of blind bore **80** is vented through the end of camshaft phaser attachment bolt **66** by passing through spool vent bore **110**, spool vent connecting passage **112**, and blind bore **80**. For clarity, FIG. **11** includes arrows V to show the path taken by the vented oil which locks primary lock pin **52** with primary lock pin seat **56** and secondary lock pin **60** with secondary lock pin seat **64** when rotor **28** is positioned appropriately with stator **16**.

**[0043]** While the recessed features of shank supply portion **76** that allow pressurized oil to reach supply drillings **82** have been illustrated as flats **78**, it should now be understood that the recessed features could take other forms. For example only, flats **78** may be substituted with grooves, channels, flutes, or a reduced diameter section of shank supply portion **76**.

[0044] While this invention has been described in terms of preferred embodiments thereof, it is not intended to be so limited, but rather only to the extent set forth in the claims that follow.

We claim:

1. A camshaft phaser for controllably varying the phase relationship between a crankshaft and a camshaft in an internal combustion engine, said camshaft phaser comprising:

a stator rotatable about an axis and having a plurality of lobes, said stator being connectable to said crankshaft of said internal combustion engine to provide a fixed ratio of rotation between said stator and said crankshaft;

a rotor coaxially disposed within said stator and having a plurality of vanes interspersed with said stator lobes defining alternating advance chambers and retard chambers, wherein said advance chambers receive pressurized oil in order to change the phase relationship between said crankshaft and said camshaft in the advance direction and said retard chambers receive pressurized oil in order to change the phase relationship between said camshaft and said crankshaft in the retard direction, said rotor being attachable to said camshaft of said internal combustion engine to prevent relative rotation between said rotor and said camshaft;

a lock pin disposed within one of said rotor and said stator for selective engagement with a lock pin seat for substantially preventing relative rotation between said rotor and said stator when said lock pin is engaged with said lock pin seat, wherein pressurized oil is selectively supplied to said lock pin in order to disengage said lock pin from said lock pin seat, and wherein oil is selectively vented from said lock pin in order to engage said lock pin with said lock pin seat;

a camshaft phaser attachment bolt extending coaxially through said rotor and said stator and threadably engageable into said camshaft to attach said camshaft phaser to said camshaft; and

a lock pin valve spool for controlling the flow of oil to and from said lock pin, wherein said lock pin valve spool is located within said camshaft phaser attachment bolt; wherein said camshaft phaser attachment bolt includes a supply drilling extending through said camshaft phaser attachment bolt to supply pressurized oil to said lock pin valve spool.

2. A camshaft phaser as in claim 1 wherein said lock pin valve spool is located within a blind bore of said camshaft phaser attachment bolt.

3. A camshaft phaser as in claim 2 wherein said supply drilling extends radially from said blind bore through said camshaft phaser.

4. A camshaft phaser as in claim 3 wherein said camshaft phaser attachment bolt includes a recessed feature on an outside surface thereof, thereby forming a passage radially between said camshaft phaser attachment bolt and at least one of said rotor and said camshaft for supplying pressurized oil to said supply drilling.

5. A camshaft phaser as in claim 4 wherein said recessed feature is a flat.

6. A camshaft phaser as in claim 6 wherein said camshaft phaser attachment bolt includes a lock pin

drilling extending radially from said blind bore through said camshaft phaser attachment bolt to provide fluid communication from said blind bore to said lock pin.

7. A camshaft phaser as in claim 6 wherein said lock pin drilling is spaced axially from said supply drilling such that said supply drilling is proximal to said camshaft and said lock pin drilling is distal from said camshaft.

8. A camshaft phaser as in claim 7 wherein said camshaft phaser attachment bolt includes a vent drilling extending radially outward from said blind bore and spaced axially away from said lock pin drilling such that said lock pin drilling is proximal to said camshaft and said vent drilling is distal from said camshaft.

9. A camshaft phaser as in claim 8 wherein said lock pin valve spool is slideable within said blind bore between a locked position to engage said lock pin with said lock pin seat and an unlocked position to disengage said lock pin from said lock pin seat.

10. A camshaft phaser as in claim 9 wherein said lock pin valve spool includes a supply land that prevents fluid communication between said supply drilling and said lock pin drilling when said lock pin valve spool is in said locked position.

11. A camshaft phaser as in claim 10 wherein said supply land blocks said supply drilling when said lock pin valve spool is in said locked position.

12. A camshaft phaser as in claim 10 wherein said supply land permits fluid communication between said supply drilling and said lock pin drilling when said lock pin valve spool is in said unlocked position.

13. A camshaft phaser as in claim 10 wherein said lock pin valve spool includes a vent land that prevents fluid communication between said lock pin drilling and said vent drilling when said lock pin valve spool is in said unlocked position.

14. A camshaft phaser as in claim 13 wherein said vent land permits fluid communication between said lock pin drilling and said vent drilling when said lock pin valve spool is in said locked position.

15. A camshaft phaser as in claim 14 wherein said vent land provides a path for oil to vent from said lock pin to outside of said camshaft phaser.

16. A camshaft phaser as in claim 4 wherein said camshaft phaser attachment bolt includes a bolt supply bore extending axially into and end of said camshaft phaser that is proximal to said camshaft, said bolt supply bore being in fluid communication with said supply drilling.

17. A camshaft phaser as in claim 16 wherein said camshaft phaser attachment bolt includes a bolt supply passage extending radially outward from said bolt supply bore and through said camshaft phaser attachment bolt.

18. A camshaft phaser as in claim 17 wherein said bolt supply passage is in fluid communication with said passage formed radially between said recessed feature and at least one of said rotor and said camshaft.

19. A camshaft phaser as in claim 1 wherein movement of said lock pin valve spool does not change the phase relationship between said crankshaft and said camshaft.

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