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(54) HYDRAULIC VARIABLE CAMSHAFT TIMING WITH A TEMPERATURE BASED HYDRAULIC SWITCH

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(52) **U.S. Cl.**
CPC ... ***F01L 1/3442*** (2013.01); *F01L 2001/34423* (2013.01); *F01L 2001/34426* (2013.01); *F01L 2001/34433* (2013.01); *F01L 2001/34453* (2013.01)

(58) **Field of Classification Search**
CPC ... F01L 2001/34433; F01L 2001/34423; F01L 2800/01; F01L 1/3442; F01L 2001/34426; F01L 2001/3443
See application file for complete search history.

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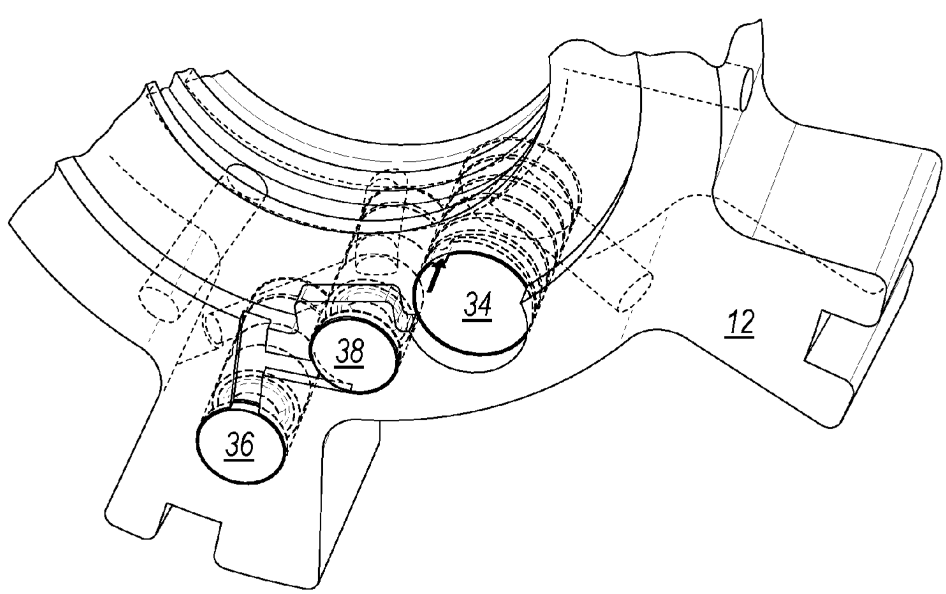
(57) **ABSTRACT**

A hydraulic variable camshaft timing (VCT) assembly including a stator having at least one fluid chamber; and a rotor, received by and angularly displaceable relative to the stator, having at least one vane positioned within the fluid chamber extending radially outwardly from a hub, and a hydraulic switch assembly positioned in the rotor to regulate a flow of fluid between an advancing chamber and a retarding chamber through the vane.

13 Claims, 8 Drawing Sheets



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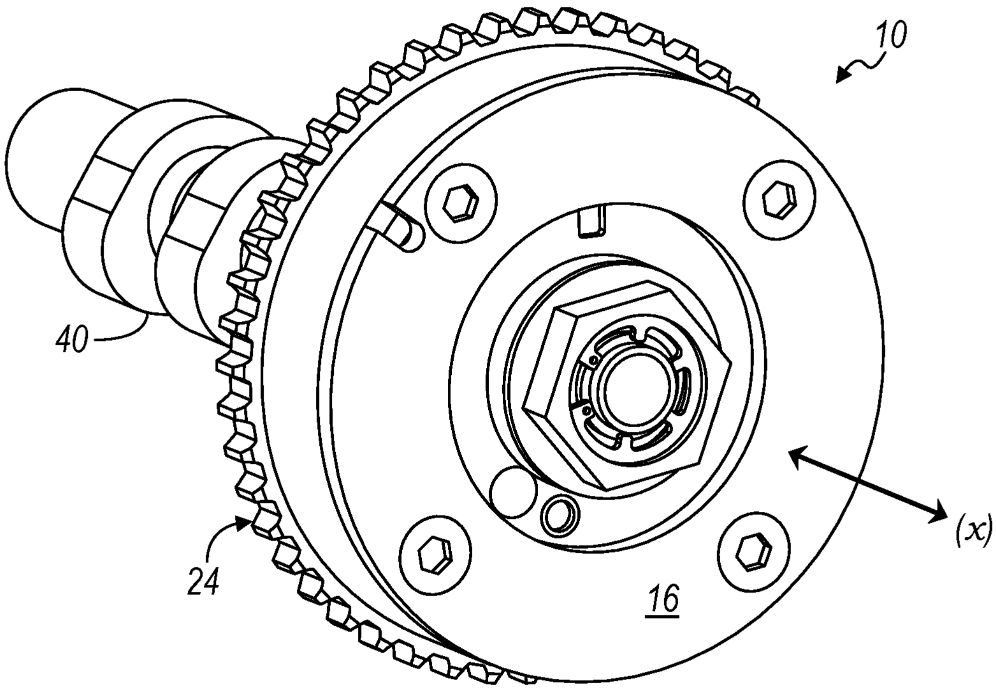
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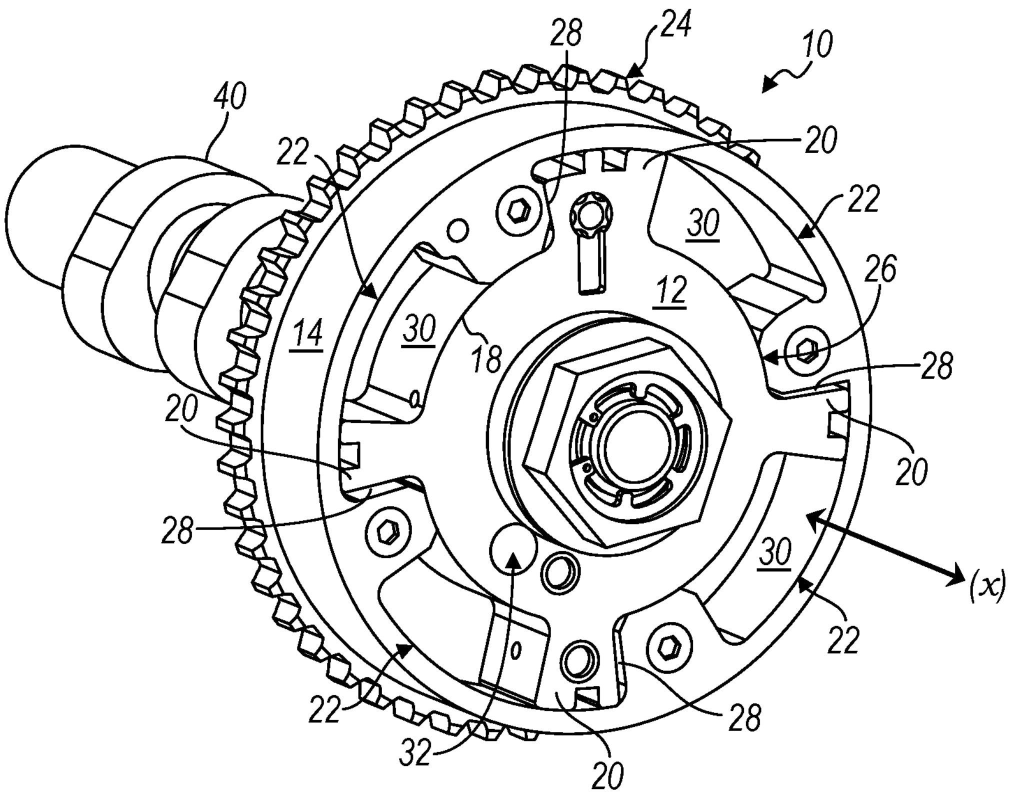
40
24
16
(x)

FIG. 1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32
20

FIG. 2

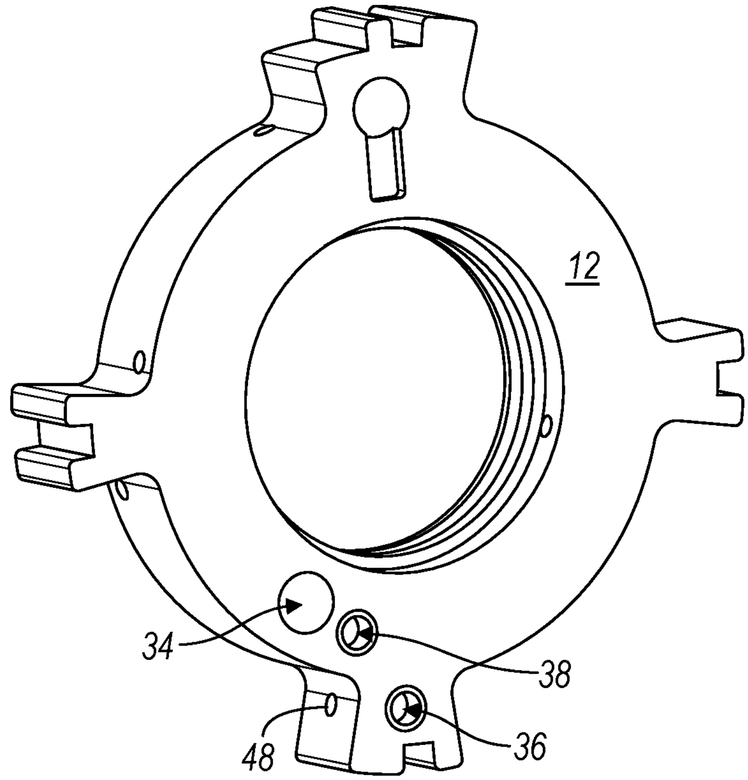


FIG. 3A

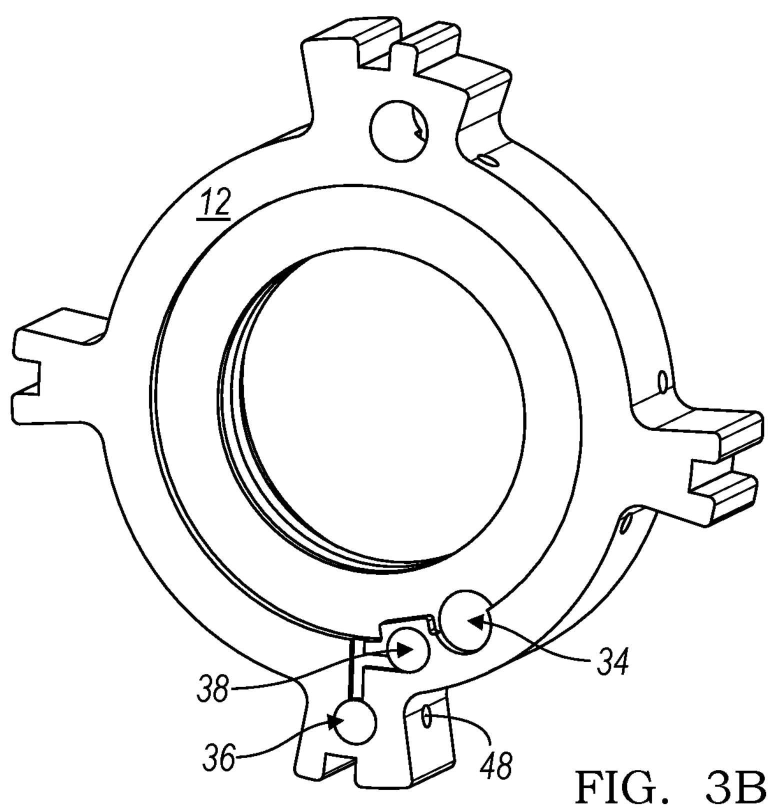


FIG. 3B

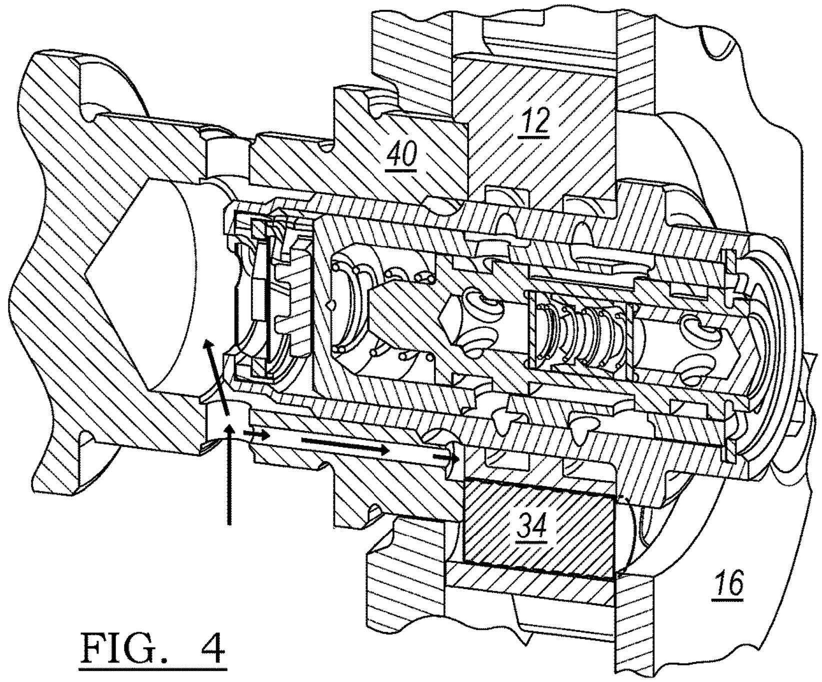


FIG. 4

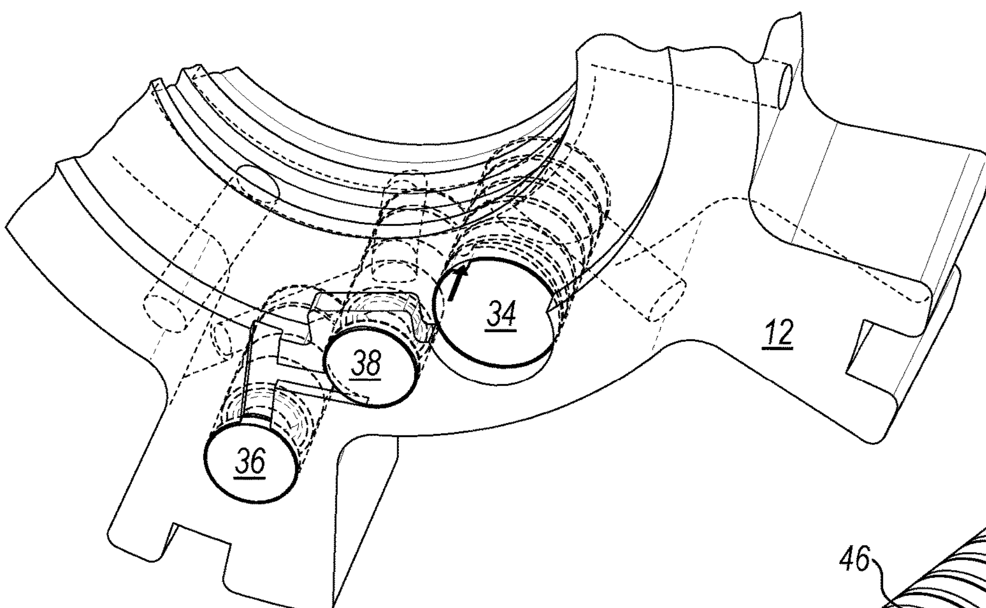


FIG. 5A

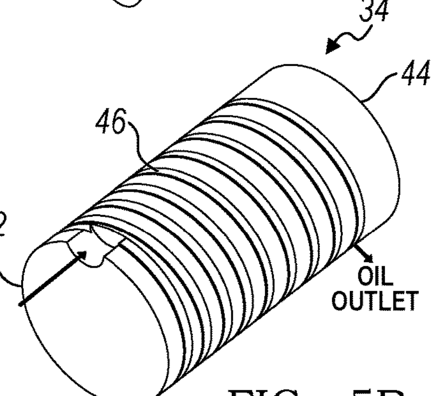
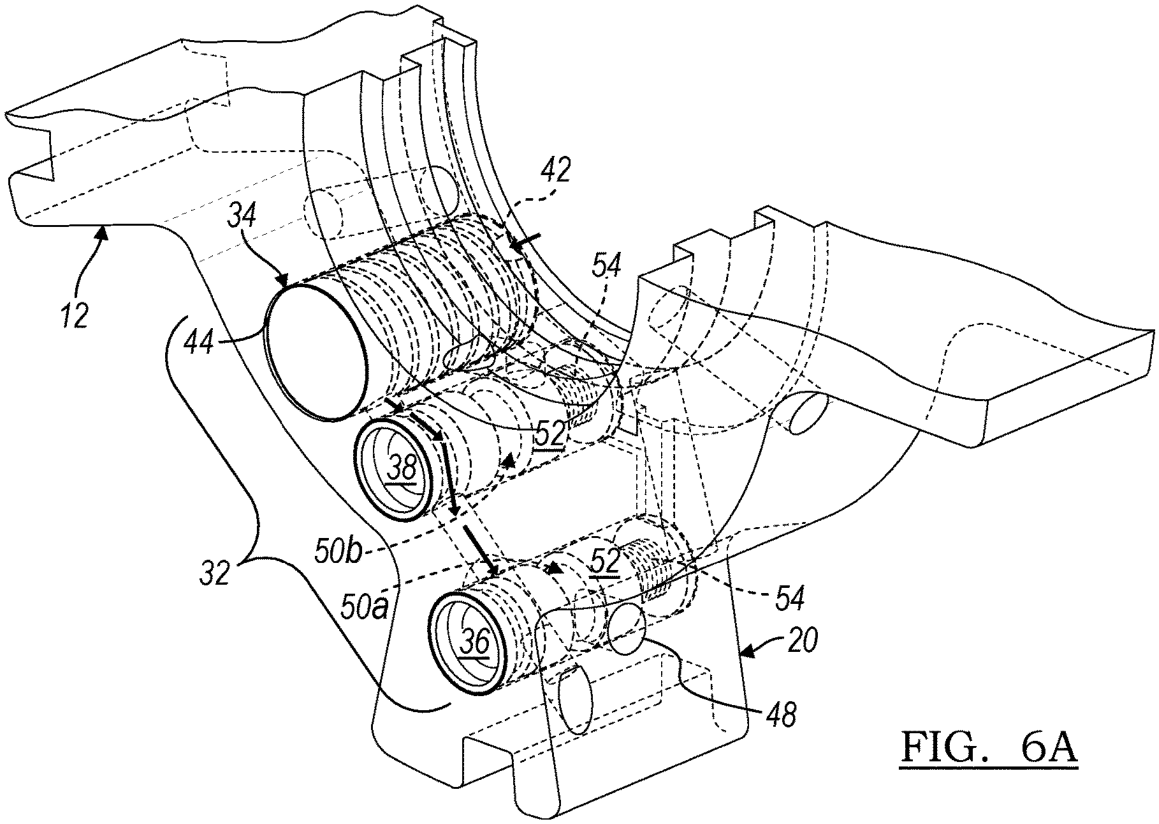


FIG. 5B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34
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12
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50b
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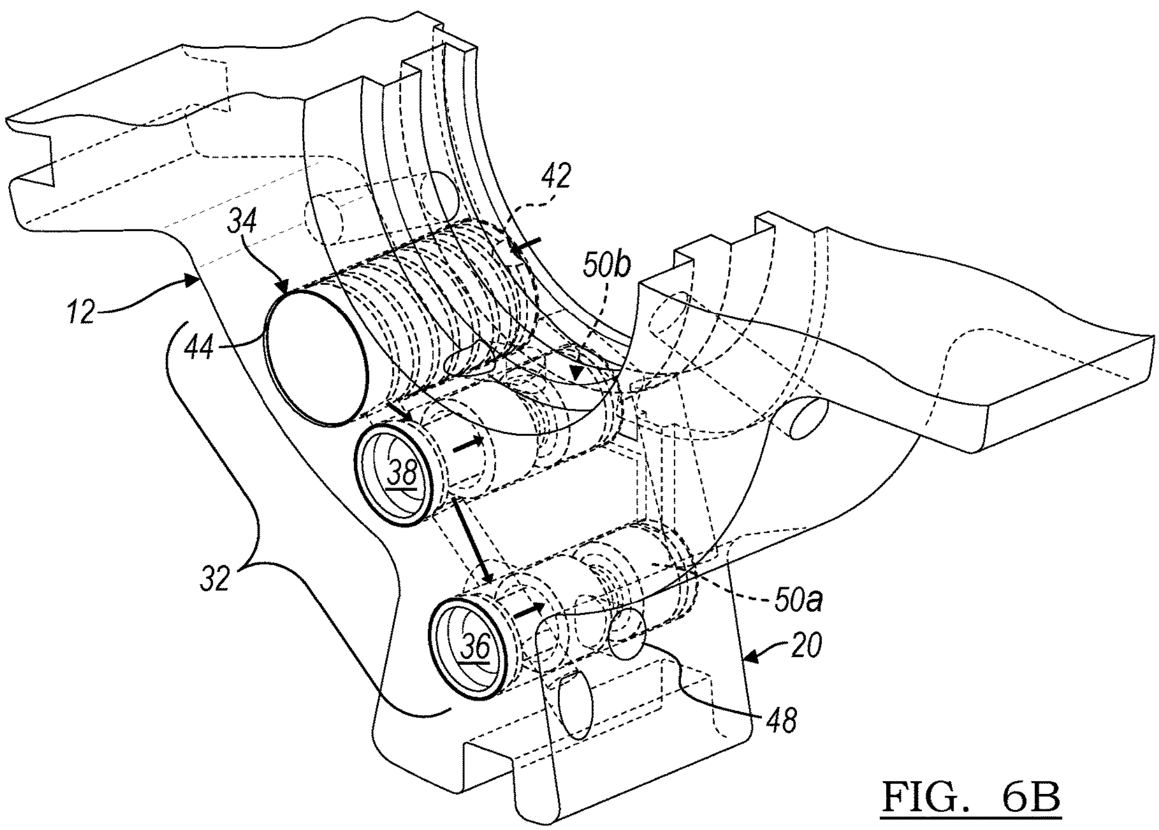
50a
36
20
48

FIG. 6A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50b
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50a
36
20
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FIG. 6B

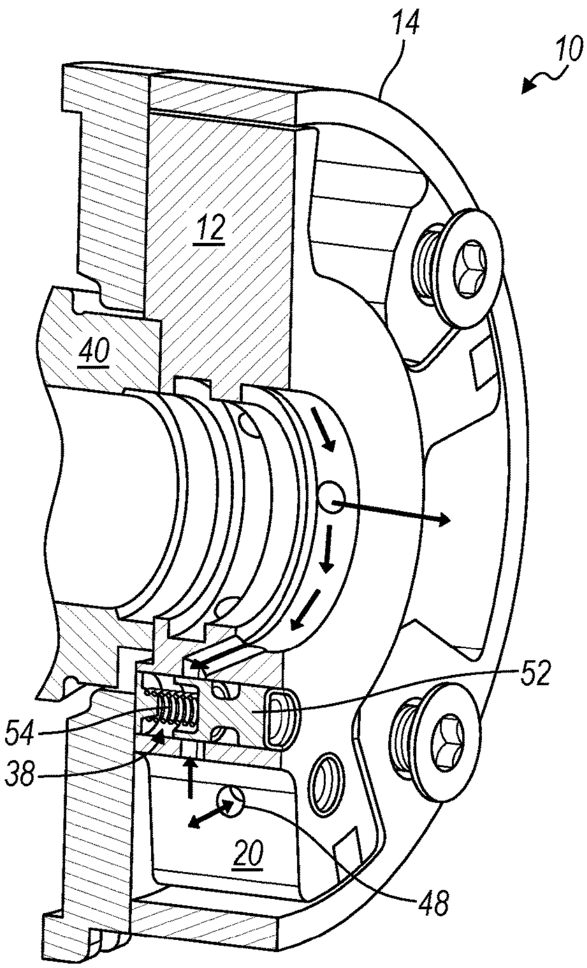

FIG. 7A

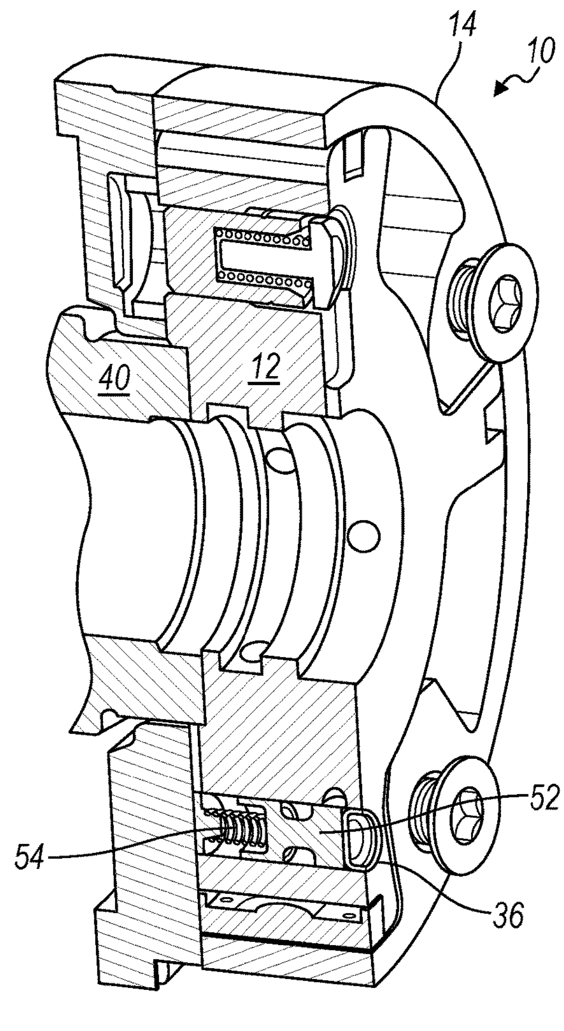

FIG. 7B

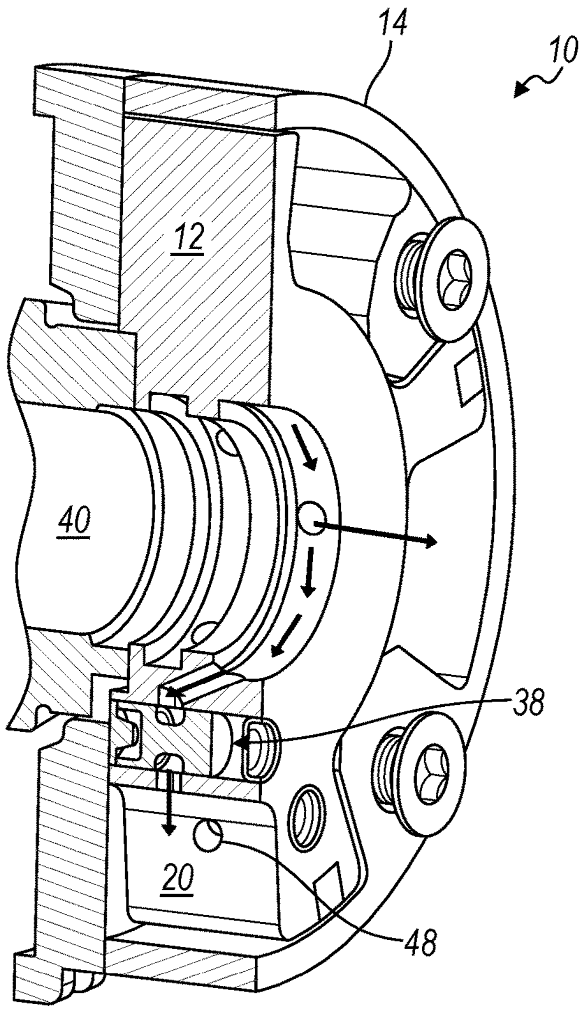

FIG. 8A

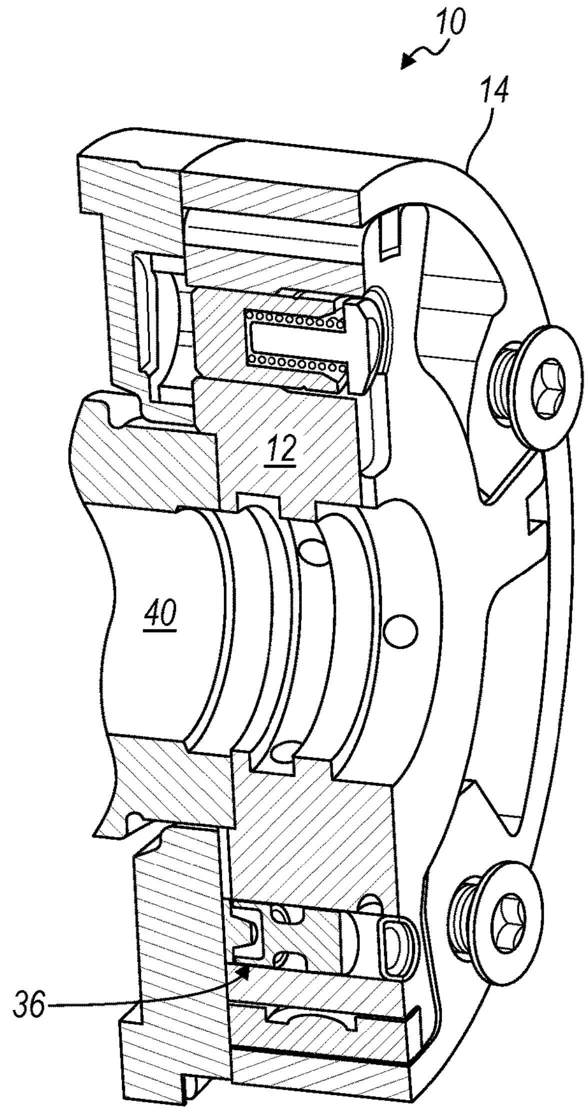

FIG. 8B

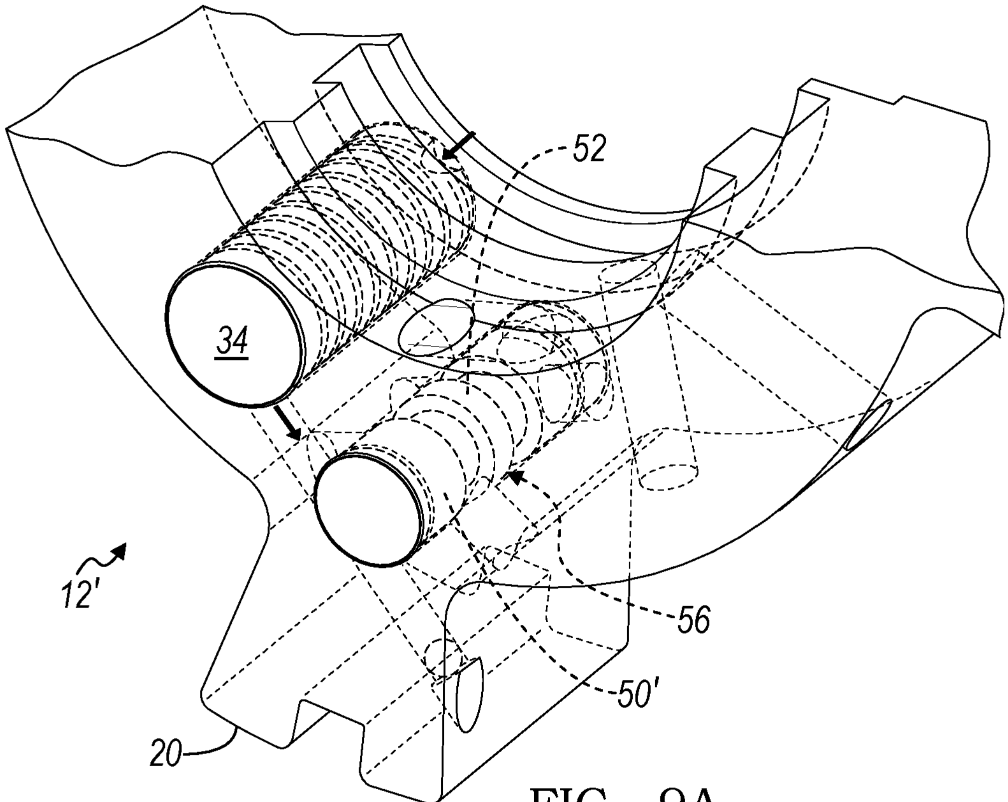

FIG. 9A

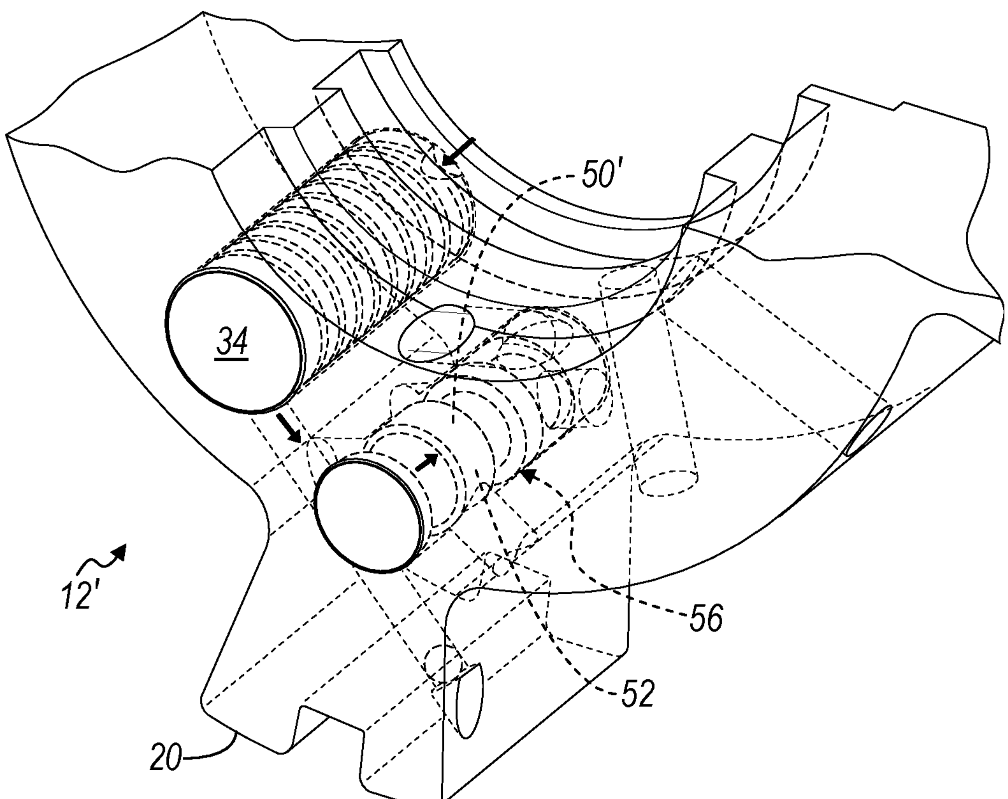

FIG. 9B

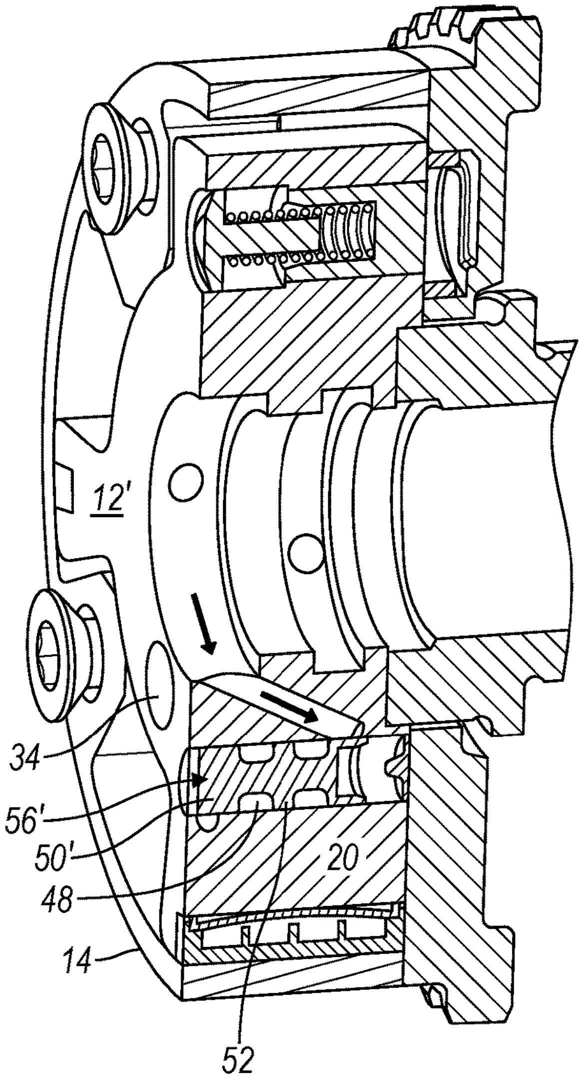

FIG. 10

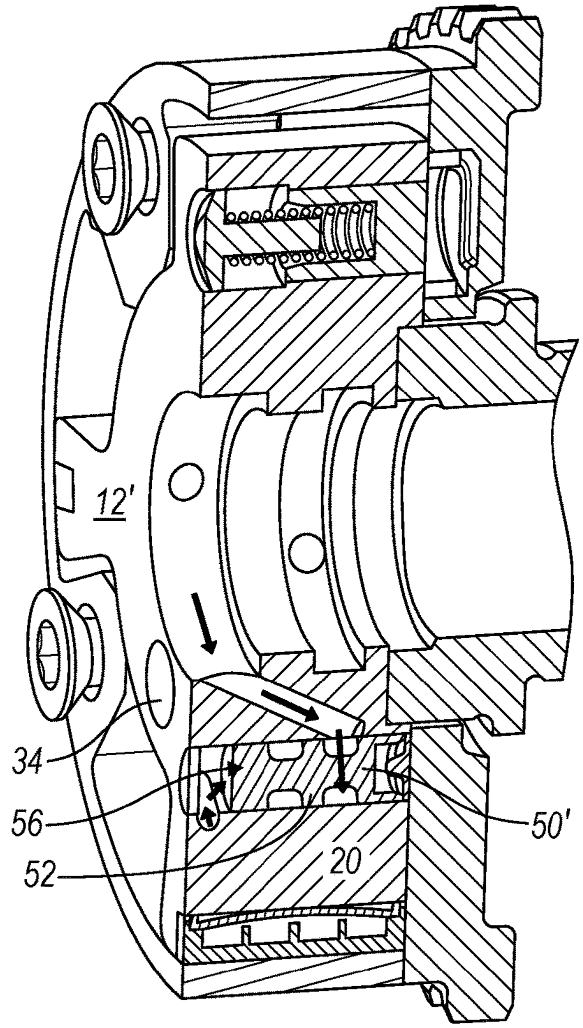

FIG. 11

HYDRAULIC VARIABLE CAMSHAFT TIMING WITH A TEMPERATURE BASED HYDRAULIC SWITCH

TECHNICAL FIELD

The present application relates to internal combustion engines (ICEs) and, more particularly, to variable camshaft timing used with ICEs.

BACKGROUND

Internal combustion engines (ICEs) use one or more camshafts to open and close intake and exhaust valves in response to cam lobes selectively actuating valve stems as the camshaft(s) rotate and overcome the force of valve springs that keep the valves seated. The shape and angular position of the cam lobes can impact the operation of the ICE. In the past, the angular position of the camshaft relative to the angular position of the crankshaft was fixed. But performance can be improved by varying the angular position of the camshaft relative to the crankshaft using variable camshaft timing (VCT) technologies. VCT technologies can be implemented using VCT devices (sometimes referred to as camshaft phasers) that change the angular position of the camshaft relative to the crankshaft. These camshaft phasers can be hydraulically-actuated. With respect to hydraulically-actuated camshaft phasers, the speed at which the angular position of the camshaft changes relative to the crankshaft can also affect ICE performance. It would be helpful to implement a camshaft phaser that changes the angular position of the camshaft relative to the crankshaft more quickly, especially at lower temperatures.

SUMMARY

In one implementation, a hydraulic variable camshaft timing (VCT) assembly includes a stator having at least one fluid chamber; and a rotor, received by and angularly displaceable relative to the stator, having at least one vane positioned within the fluid chamber extending radially outwardly from a hub, and a hydraulic switch assembly positioned in the rotor to regulate a flow of fluid between an advancing chamber and a retarding chamber through the vane.

In one implementation, a hydraulic VCT assembly includes a stator having at least one fluid chamber; a rotor, received by and angularly displaceable relative to the stator, having at least one vane positioned within the fluid chamber extending radially outwardly from a hub, and a hydraulic switch assembly positioned in the rotor to prevent a flow of fluid between an advancing chamber and a retarding chamber at or below a predetermined temperature and permit the flow of fluid between the advancing chamber and the retarding chamber above the predetermined temperature.

In one implementation, a hydraulic VCT assembly includes a stator having at least one fluid chamber; a rotor, received by and angularly displaceable relative to the stator, having at least one vane positioned within the fluid chamber extending radially outwardly from a hub, and a hydraulic switch assembly positioned in the rotor to regulate a flow of fluid between an advancing chamber and a retarding chamber through the vane; and a contorted fluid path, in fluid communication with the hydraulic switch assembly, sized and shaped so that fluid flow from a fluid source maintains a fluid valve in a position that permits fluid flow between the advancing chamber and the retarding chamber at or below a predetermined temperature and prevents fluid flow between the advancing chamber and the retarding chamber above the predetermined temperature.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view depicting an implementation of a hydraulic variable camshaft timing (VCT) phaser assembly with a hydraulic switch assembly;

FIG. **2** is another perspective view depicting an implementation of a hydraulic VCT phaser assembly with a hydraulic switch assembly;

FIG. **3***a* is a perspective view depicting an implementation of a rotor used with a hydraulic VCT phaser assembly and a hydraulic switch assembly;

FIG. **3***b* is another perspective view depicting an implementation of a rotor used with a hydraulic VCT phaser assembly and a hydraulic switch assembly;

FIG. **4** is a cross-sectional view depicting an implementation of a hydraulic VCT phaser assembly and a hydraulic switch assembly;

FIG. **5***a* is another perspective view depicting an implementation of a rotor used with a hydraulic VCT phaser assembly and a hydraulic switch assembly;

FIG. **5***b* is a perspective view depicting a portion of an implementation of a hydraulic VCT phaser assembly and a hydraulic switch assembly;

FIG. **6***a* is a cross-sectional view depicting an implementation of a rotor used with a hydraulic VCT phaser assembly and a hydraulic switch assembly;

FIG. **6***b* is another cross-sectional view depicting a portion of an implementation of a hydraulic VCT phaser assembly and a hydraulic switch assembly;

FIG. **7***a* is a cross-sectional view depicting an implementation of a hydraulic VCT phaser assembly and a hydraulic switch assembly;

FIG. **7***b* is another cross-sectional view depicting an implementation of a hydraulic VCT phaser assembly with a hydraulic switch assembly;

FIG. **8***a* is another cross-sectional view depicting an implementation of a hydraulic VCT phaser assembly and a hydraulic switch assembly;

FIG. **8***b* is another cross-sectional view depicting an implementation of a hydraulic VCT phaser assembly and a hydraulic switch assembly;

FIG. **9***a* is another cross-sectional view depicting an implementation of a rotor used with a hydraulic VCT phaser assembly and a hydraulic switch assembly;

FIG. **9***b* is another cross-sectional view depicting an implementation of a rotor used with a hydraulic VCT phaser assembly and a hydraulic switch assembly;

FIG. **10** is another cross-sectional view depicting an implementation of a hydraulic VCT phaser assembly with a hydraulic switch assembly; and

FIG. **11** is another cross-sectional view depicting an implementation of a hydraulic VCT phaser assembly with a hydraulic switch assembly.

DETAILED DESCRIPTION

A hydraulic variable camshaft timing (VCT) phaser assembly includes a hydraulic switch assembly that permits the flow of fluid between two or more chambers in the phaser when the fluid exists at or below a predetermined temperature but prevents the flow of fluid once the fluid exceeds that temperature. In previous VCT phasers, the speed at which the phaser angularly displaced a camshaft relative to a crankshaft may be limited by fluid in a chamber. For example, if the VCT phaser is advancing, restricted fluid flow exiting a retarding chamber may limit the speed at which fluid can enter an advancing chamber, and vice-versa. Phasing speed can be particularly limited at lower fluid temperatures. But as fluid temperature rises with internal combustion engine temperature, the fluid, such as engine oil, becomes less viscous and fluid flow increases. However, too much flow can result in unwanted oscillations of a rotor.

The hydraulic VCT phaser assembly having the hydraulic switch assembly disclosed here includes a contorted fluid path in fluid communication with one or more fluid switches. The contorted fluid path is sized and shaped such that fluid flow from a fluid source maintains a fluid valve in a position that permits flow of fluid between an advancing chamber and a retarding chamber at or below a predetermined temperature and prevents the flow of fluid between the advancing chamber and the retarding chamber above that temperature. Implementations disclosed here depict the hydraulic valve assembly to include two fluid logic valves, however, other implementations are possible that use only one.

An implementation of a VCT phaser assembly in the form of a hydraulically-controlled camshaft phaser **10** is shown in FIGS. **1-2**. An example of a hydraulically-controlled camshaft phaser is described in U.S. Pat. No. 8,356,583, the contents of which are hereby incorporated by reference. The phaser includes a rotor **12**, a stator **14**, and an end plate **16**. The rotor **12** has a hub **18** with vanes **20** that extend radially outwardly away from the hub **18** and an axis of rotation (x). Apart from the vanes **20**, the rotor **12** can include one or more fluid chambers **22** for selectively communicating fluid toward between fluid chambers **22** as well as with a fluid supply and a fluid tank (not shown). The hub **18** can be rigidly coupled to a distal end of a camshaft in a way that the rotor **12** and the camshaft are not angularly displaced relative to each other.

The stator **14** can include a camshaft sprocket **24** on a radially-outer surface of the stator **14**. The camshaft sprocket **24** can engage an endless loop, such as a chain, that also engages a crankshaft sprocket that transmits rotational force from the crankshaft to the stator **14**. The rotor **12** can be positioned within the stator **14** to rotate relative to the stator **14** and angularly displace the rotor **12** relative to the stator **14** and change the phase of the camshaft relative to the crankshaft. The rotor **12** can be received within a stator cavity **26** formed within the stator **14** such that the vanes **20** extend into fluid chambers **22** formed within the stator cavity **26**. The fluid chambers **22** are located radially-outwardly from the hub **18** such that each vane **20** can divide the fluid chamber **22** into an advancing chamber portion **28** and a retarding chamber portion **30**. The rotor **12** can rotate about the axis of rotation (x) within the stator cavity **26** in response to fluid supplied to or exiting from the advancing or retarding chamber portions **28**, thereby changing the angular position of the camshaft relative to the angular position of the stator **14**.

The rotor **12** is shown with a hydraulic switch assembly **32** in more detail in FIGS. **3-8**. The hydraulic switch assembly **32** includes a contorted fluid path **34**, a short logic valve **36**, and a chamber logic valve **38**. Fluid can be supplied from a fluid source (not shown) through a camshaft **40** to the contorted fluid path **34**. The contorted fluid path **34** can be a non-linear fluid path from an inlet **42** to an outlet **44** that at least somewhat impedes fluid flow at lower temperatures when fluid, such as engine oil, is more viscous than at higher temperatures. The contorted fluid path **34** in one implementation can be a circular cross-sectioned rod or plug having fluid channels formed on an outer radial surface. However, it should be appreciated that the contorted fluid path **34** can be implemented in a variety of different ways. For example, the contorted fluid path can be defined by the threads of a center bolt used to house a spool valve that controls phasing of the camshaft phaser. Or in another example, the contorted fluid path can be etched into a rotor or an end plate face. The fluid channels **46** can extend from the inlet **42** to the outlet **44**. As fluid enters the inlet **42**, the rate at which the fluid flows can be reduced at lower engine temperatures. As the fluid temperature rises, so too can the rate at which the fluid flows through the contorted fluid path **34**.

The fluid exiting the outlet **44** can then be communicated to the short logic valve **36** and the chamber logic valve **38**. The chamber logic valve **38** selectively permits the flow of fluid to the advancing chamber portion **28** or the retarding chamber portion **30** based on the rate of fluid flow through the contorted fluid path **34**. The short logic valve **36** selectively permits the flow of fluid between advancing and retarding chamber portions **28**, **30** based on the rate of fluid flow through the contorted fluid path **34**. The short logic valve **36** can control the flow of fluid through the vane **20** via a shorting fluid path **48**. The short logic valve **36** and the chamber logic valve **38** can be linearly movable spool valves extending parallel with an axis of camshaft rotation, having spools **50** with one or more lands **52**, that are biased into a default position by a spring **54** or another biasing member. The default position of the short logic valve **36** can permit the flow of fluid through the shorting fluid path **48** between the advancing chamber portion **28** and the retarding chamber portion **30** while the default position of the chamber logic valve **38** can prevent the flow of fluid from a control valve to either the advancing or retarding chamber portions **28**, **30**. As fluid flow through the contorted fluid path **34** increases along with engine temperature, the flow can exert sufficient linear force on the spool **50** to overcome the bias of the spring **54** and move the spool **50** linearly. The short logic valve **36** can then have a spool **50***a* with lands **52** that move to prevent the flow of fluid through the shorting fluid path **48**. And the increased fluid flow can move the spool **50***b* of the chamber logic valve **38** so that the lands **52** no longer prevent the flow of fluid from the contorted fluid path **34** to the advancing or retarding chamber portions **28**, **30**.

After the engine is turned off, the springs **54** included in the short logic valve **36** and the chamber logic valve **38** can move the spools **50** back to their default positions and fluid flow can reverse moving fluid toward the contorted fluid path **34** and the fluid source. The reversed flow of fluid can move the fluid from the fluid outlet **44** and towards the inlet **42**. This can help if the engine were to stall as the logic valves **36**, **38** would resist losing fluid pressure thereby facilitating a restart. The hydraulic switch assembly **32**, including the fluid paths and the logic valves, can be tuned to desired performance attributes based on variable such as fluid channel size and size/shape of logic valves.

Another implementation of a hydraulic switch assembly including no more than one fluid logic valve is shown. The assembly may be included with a rotor **12'** having a somewhat longer axial length measured along an axis of camshaft rotation relative to embodiments of the assembly including two or more fluid logic valves. The rotor **12'** can include a dual logic valve **56** extending along an axial length of the rotor **12'** that can control the flow of fluid through the shorting fluid path **48** between the advancing and retarding chamber portions **28**, based on the rate of fluid flow through the contorted fluid path **34** as well as the flow of fluid from a control valve to either the advancing or retarding chamber portions **28**, **30**. The dual logic valve **56** can include a spool **50'** having lands **52** that move linearly to permit or restrict the flow of fluid through shorting fluid path **48** and fluid to the advancing and retarding chamber portions **28**, **30**. FIGS. **9***a* and **10** depict the spool **50'** biased into a default position by a spring when fluid temperature is relatively low. The spool **50'** permits the flow of fluid through the shorting fluid path **48**. As the internal combustion engine warms and the fluid becomes less viscous, the rate of fluid flow through the contorted fluid path **34** can increase thereby overcoming the spring bias and linearly move the spool **50'** so that the flow of fluid through the shorting fluid path is prevented while fluid flow to the advancing and retarding chamber portions **28**, **30** is permitted, as shown in FIGS. **9***b* and **11**.

It is to be understood that the foregoing is a description of one or more embodiments of the invention. The invention is not limited to the particular embodiment(s) disclosed herein, but rather is defined solely by the claims below. Furthermore, the statements contained in the foregoing description relate to particular embodiments and are not to be construed as limitations on the scope of the invention or on the definition of terms used in the claims, except where a term or phrase is expressly defined above. Various other embodiments and various changes and modifications to the disclosed embodiment(s) will become apparent to those skilled in the art. All such other embodiments, changes, and modifications are intended to come within the scope of the appended claims.

As used in this specification and claims, the terms "e.g.," "for example," "for instance," "such as," and "like," and the verbs "comprising," "having," "including," and their other verb forms, when used in conjunction with a listing of one or more components or other items, are each to be construed as open-ended, meaning that the listing is not to be considered as excluding other, additional components or items. Other terms are to be construed using their broadest reasonable meaning unless they are used in a context that requires a different interpretation.

What is claimed is:

1. A hydraulic variable camshaft timing (VCT) assembly, comprising:

a stator having at least one fluid chamber; and

a rotor, received by and angularly displaceable relative to the stator, having at least one vane positioned within the at least one fluid chamber extending radially outwardly from a hub, and a contorted fluid path positioned in the rotor to regulate a flow of fluid between an advancing chamber and a retarding chamber, further comprising a chamber logic valve that controls a flow of fluid to the advancing chamber or the retarding chamber based on a rate of fluid flow through the contorted fluid path and a short logic valve that controls a flow of fluid through a shorting fluid path, wherein the contorted fluid path selectively impedes the flow of fluid through the contorted fluid path depending on temperature.

2. The hydraulic VCT assembly recited in claim **1**, wherein the contorted fluid path impedes the flow of fluid within the at least one fluid chamber at lower temperatures.

3. The hydraulic VCT assembly recited in claim **2**, wherein the contorted fluid path comprises a rod or plug having fluid channels formed on an outer radial surface.

4. The hydraulic VCT assembly recited in claim **1**, wherein the short logic valve and the chamber logic valve comprise spool valves.

5. The hydraulic VCT assembly recited in claim **4**, wherein the spool valves are biased by springs in a position that permits fluid flow.

6. The hydraulic VCT assembly recited in claim **4**, wherein the short logic valve and the chamber logic valve move linearly parallel with an axis of camshaft rotation.

7. The hydraulic VCT assembly recited in claim **1**, further comprising no more than one fluid logic valve.

8. A hydraulic variable camshaft timing (VCT) assembly, comprising:

a stator having at least one fluid chamber;

a rotor, received by and angularly displaceable relative to the stator, having at least one vane positioned within the at least one fluid chamber extending radially outwardly from a hub, and a contorted fluid path positioned in the rotor further comprising a dual logic valve that controls a flow of fluid through a shorting fluid path between advancing and retarding chambers based on a rate of fluid flow through the contorted fluid path as well as a flow of fluid from a control valve to either the advancing chamber or retarding chamber to prevent a flow of fluid between the advancing chamber and the retarding chamber at or below a predetermined temperature and permit the flow of fluid between the advancing chamber and the retarding chamber above the predetermined temperature.

9. The hydraulic VCT assembly recited in claim **8**, wherein the contorted fluid path comprises a rod or plug having fluid channels formed on an outer radial surface.

10. The hydraulic VCT assembly recited in claim **8**, further comprising a short logic valve and a chamber logic valve.

11. The hydraulic VCT assembly recited in claim **10**, wherein the short logic valve and the chamber logic valve comprise spool valves.

12. The hydraulic VCT assembly recited in claim **11**, wherein the spool valves are biased by springs in a position that permits fluid flow.

13. The hydraulic VCT assembly recited in claim **8**, further comprising no more than one fluid logic valve.

* * * * *