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(54) **SYSTEM AND METHOD FOR CONTROLLING A TEMPERATURE OF OIL IN A POWER-PLANT OF A VEHICLE**

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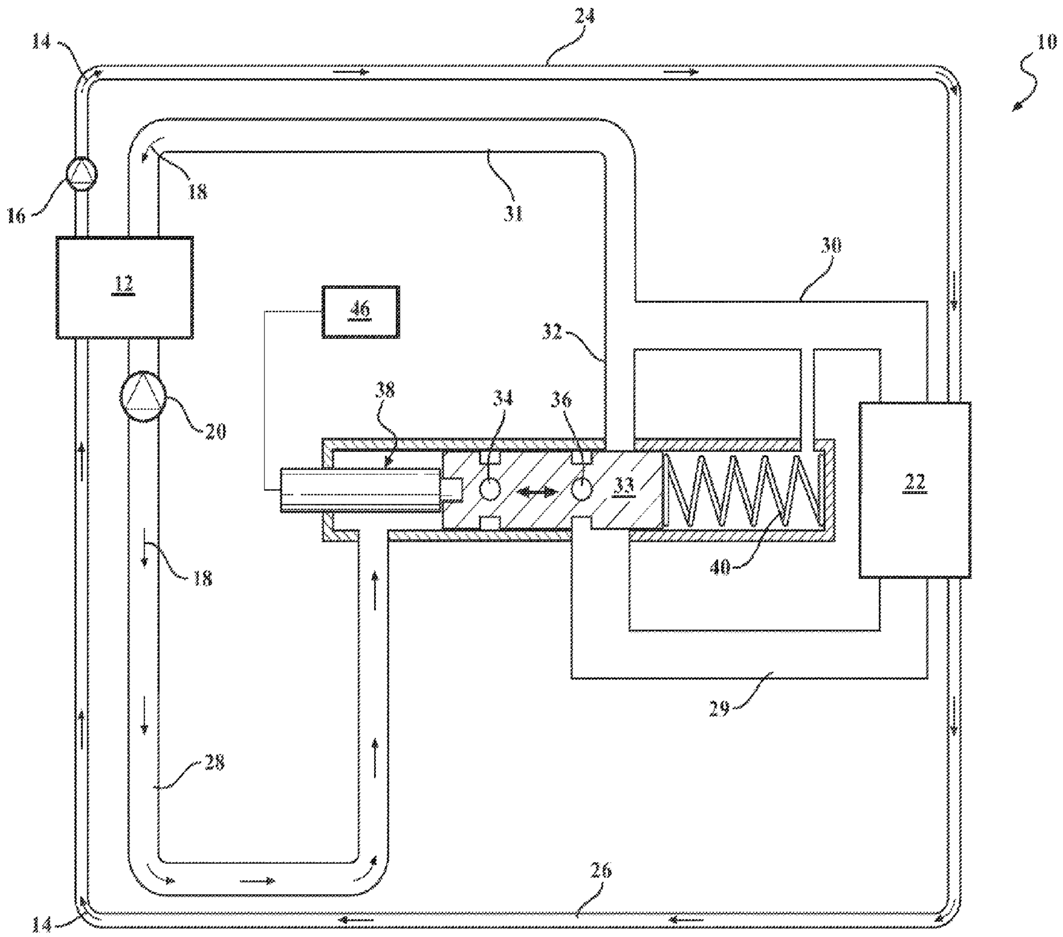
(57) **ABSTRACT**

A system is provided for controlling a temperature of oil in a power-plant operable to propel a vehicle. The system includes a heat-exchanger arranged relative to the power-plant. The heat-exchanger is configured to receive the oil from the power-plant, modify the temperature of the oil, and return the modified temperature oil to the power-plant. The system also includes a valve configured to direct the oil through the heat-exchanger during a warm-up operation of the power-plant such that the temperature of the oil is increased. The valve is also configured to direct the oil to bypass the heat-exchanger during a low load operation of the power-plant such that the temperature of the oil is increased. Additionally, the valve is configured to direct the oil through the heat-exchanger during a high load operation of the power-plant such that the temperature of the oil is decreased.



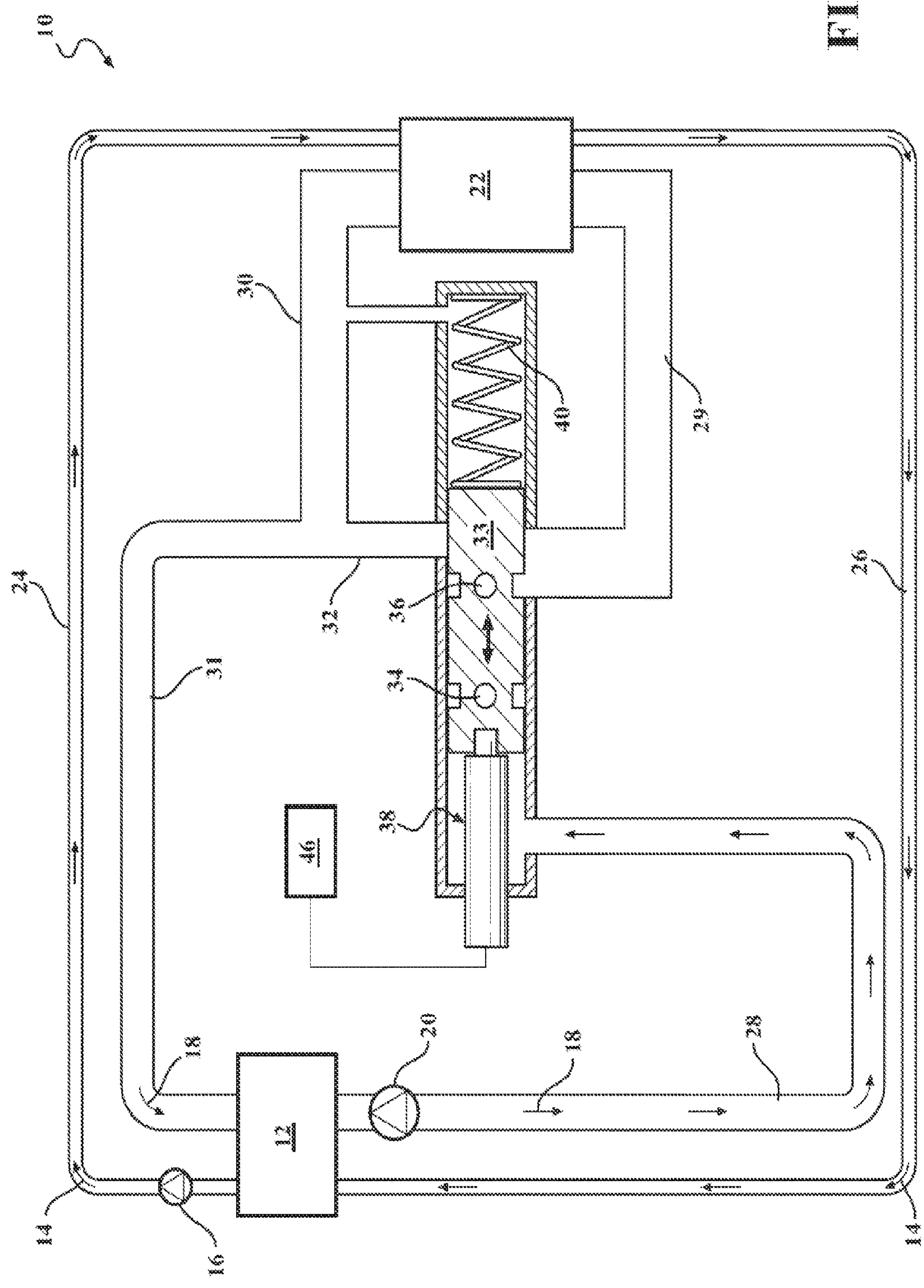


FIG. 1

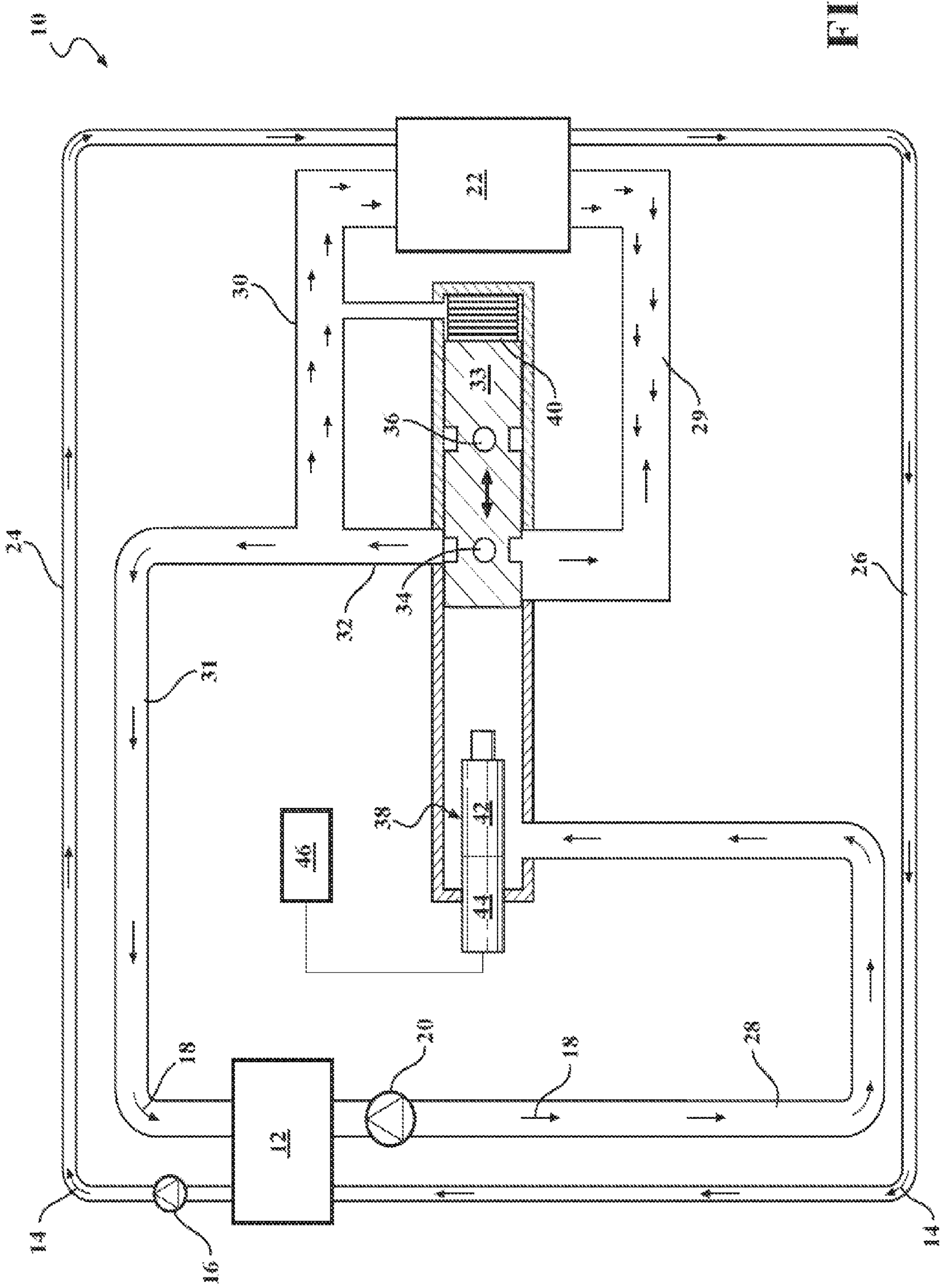


FIG. 2

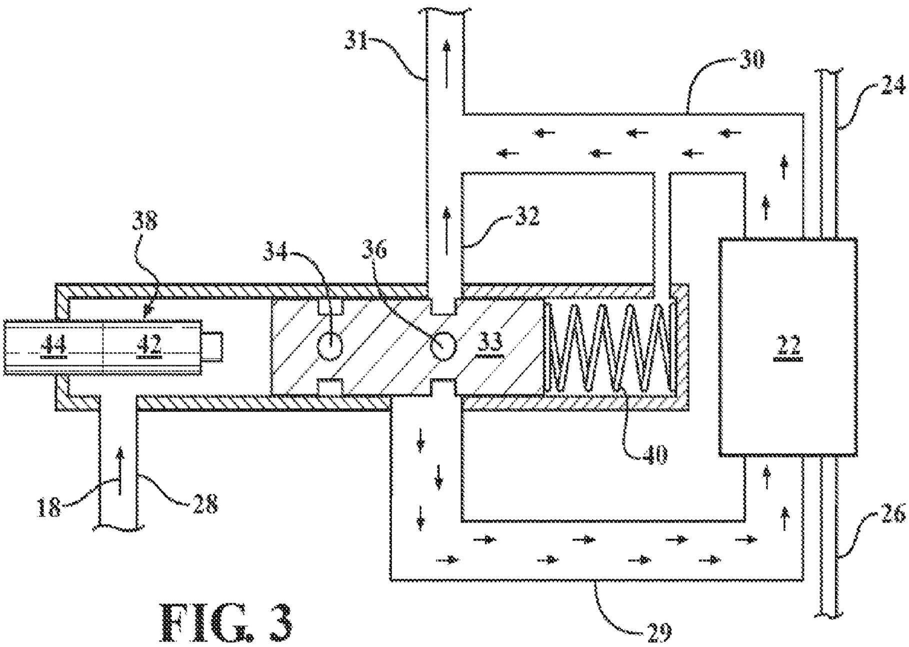

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FIG. 3

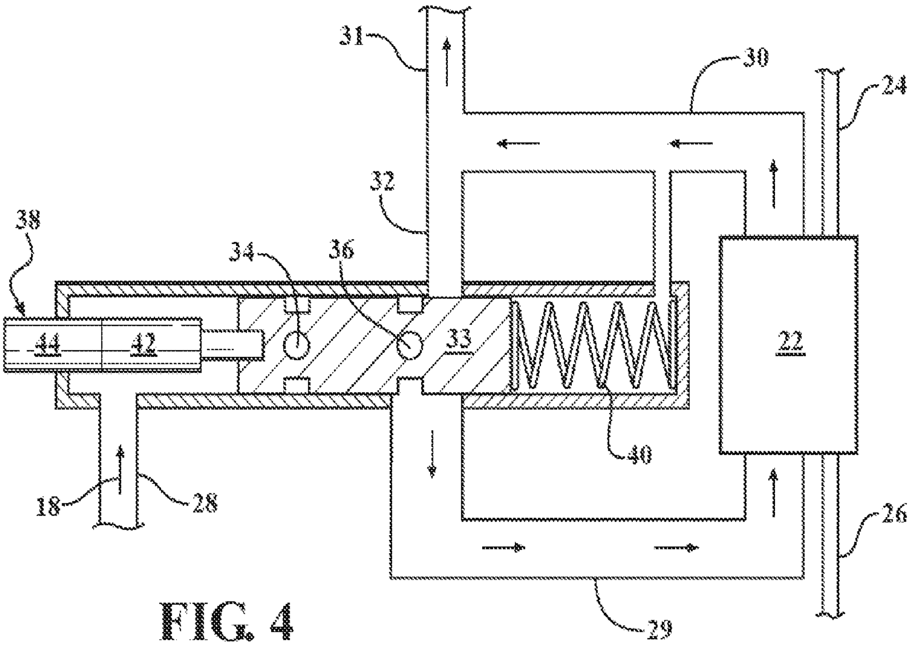
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FIG. 4

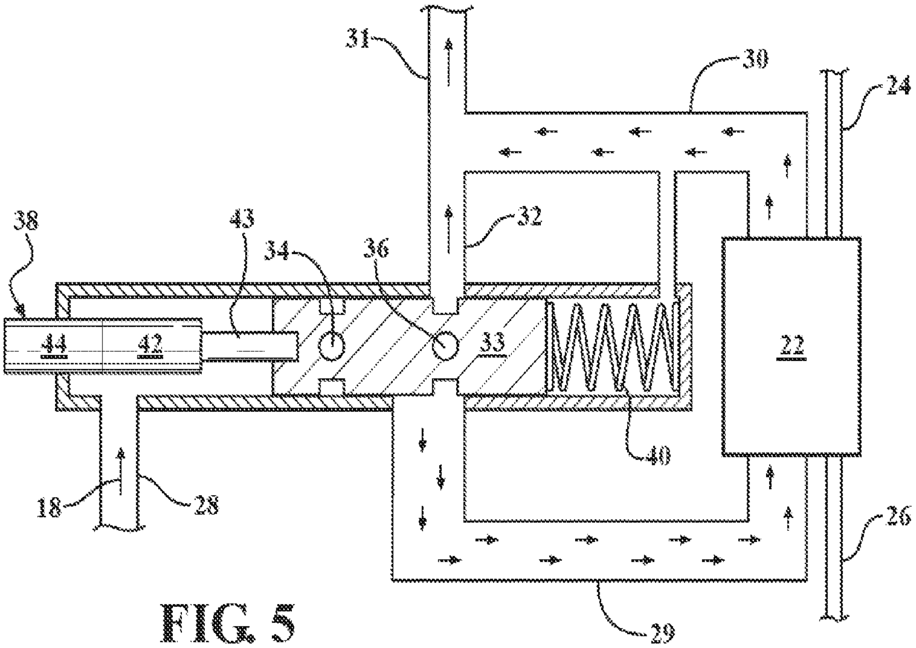
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FIG. 5

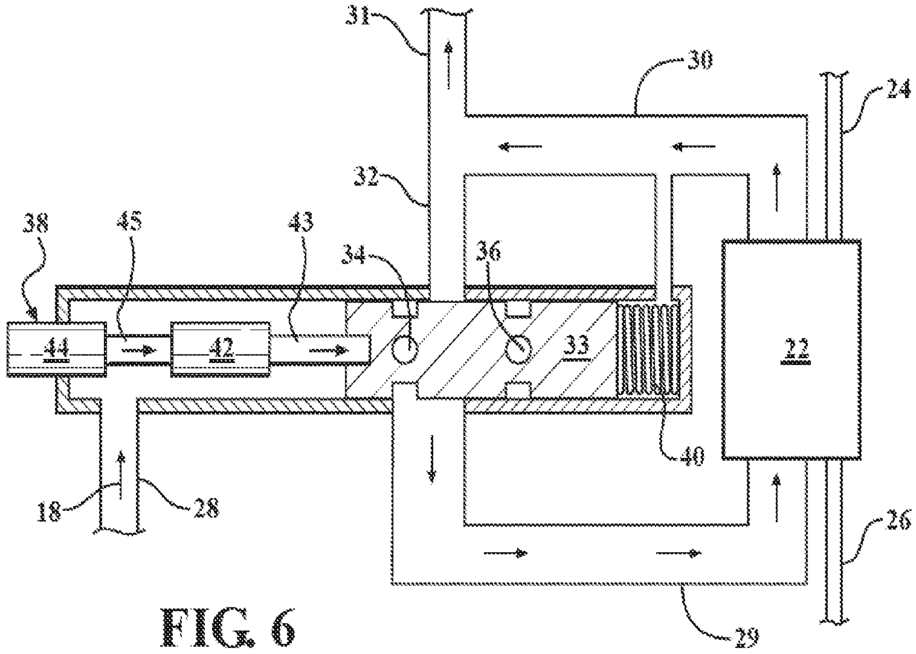
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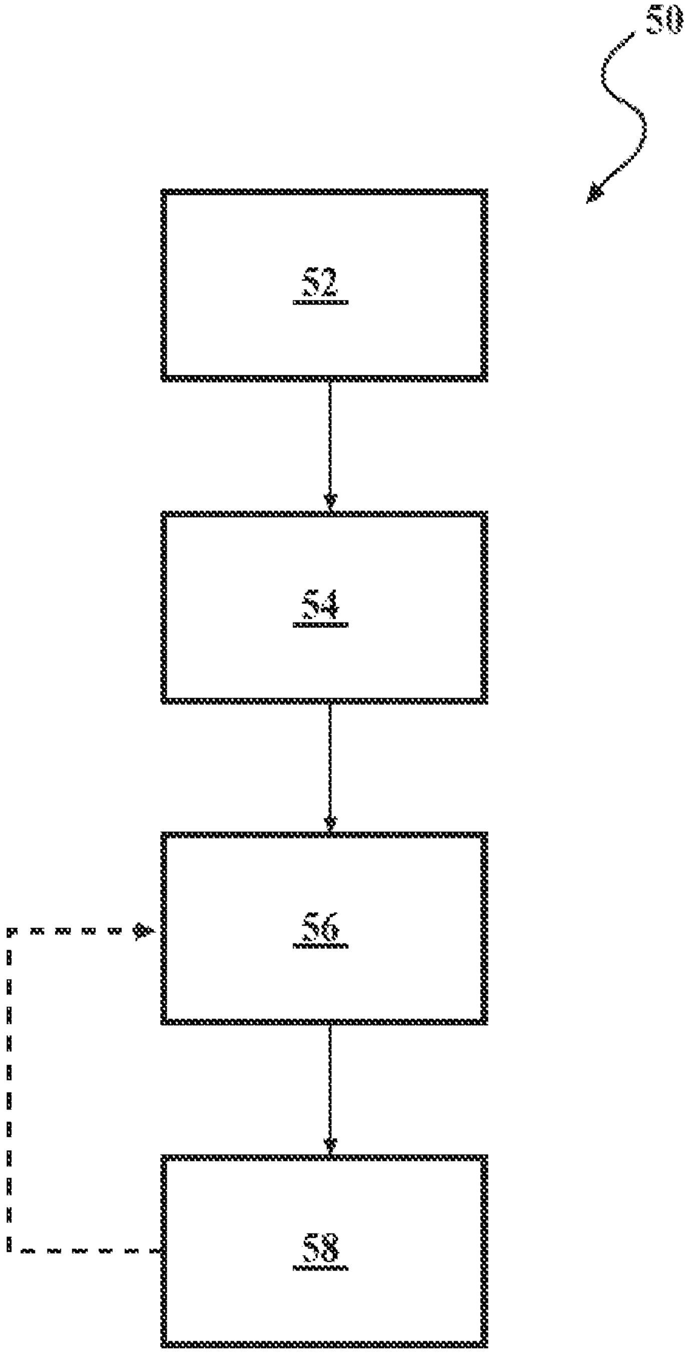
FIG. 6

FIG. 7



SYSTEM AND METHOD FOR CONTROLLING A TEMPERATURE OF OIL IN A POWER-PLANT OF A VEHICLE

TECHNICAL FIELD

[0001] The present invention relates to a system and a method for controlling a temperature of oil in a power-plant of a vehicle.

BACKGROUND

[0002] As a by-product of generating power for propelling a motor vehicle, the vehicle's power-plant, such as an internal combustion engine, typically generates heat energy. Accordingly, after the power-plant is activated, it proceeds through a "warm-up" period during which the temperature of the power-plant is increased from an ambient temperature. Generally, following the warm-up period, the power-plant is cooled in order to maintain its operating temperature in a particular range and ensure the power-plant's efficient and reliable performance.

[0003] In a majority of motor vehicles, power-plants are cooled by a circulating fluid, such as a specially formulated chemical compound mixed with water. Additionally, vehicle power-plants are lubricated and cooled by oils that are generally derived from petroleum-based and non-petroleum synthesized chemical compounds. Such oils mainly use base oils composed of hydrocarbons that are blended with chemical additives to minimize a power-plant's internal friction and wear.

SUMMARY

[0004] A system is provided for controlling a temperature of oil in a power-plant operable to propel a vehicle. The system includes a heat-exchanger arranged relative to the power-plant. The heat-exchanger is configured to receive the oil from the power-plant, modify the temperature of the oil, and return the modified temperature oil to the power-plant. The system also includes a valve configured to direct the oil through the heat-exchanger during a warm-up operation of the power-plant such that the temperature of the oil is increased. The valve is also configured to direct the oil to bypass the heat-exchanger during a low load operation of the power-plant such that the temperature of the oil is increased. Additionally, the valve is configured to direct the oil through the heat-exchanger during a high load operation of the power-plant such that the temperature of the oil is decreased.

[0005] The valve may be additionally configured to direct the oil to bypass the heat-exchanger during a low ambient temperature start of the power-plant such that the temperature of the oil is not modified by the heat-exchanger.

[0006] The system may also include an actuator configured to operate the valve. The system may additionally include a spring configured to bias or load the valve against the actuator. The actuator may be one of a wax motor and a solenoid. The wax motor may be configured as a two-stage wax motor. Furthermore, the system may include a controller in electrical communication with the actuator. In such a case, the controller is configured to regulate the actuator according to one of the warm-up, low load, and high load operation of the power-plant.

[0007] Moreover, the system may additionally include a fluid pump configured to circulate a coolant through the heat-exchanger for modifying the temperature of the oil.

[0008] The power-plant may be an internal combustion engine.

[0009] A method of controlling a temperature of oil in a vehicle power-plant is also provided.

[0010] The above features and advantages and other features and advantages of the present invention are readily apparent from the following detailed description of the best modes for carrying out the invention when taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. **1** is a schematic diagrammatic view of a vehicle system employing one type of an actuator and configured to control temperature of oil in a power-plant;

[0012] FIG. **2** is a schematic diagrammatic view of the vehicle system employing an alternate type of an actuator, illustrating a power-plant during a cold start operation;

[0013] FIG. **3** is a schematic diagrammatic view of the vehicle system shown in FIG. **2**, illustrating the power-plant during a subsequent warm-up operation;

[0014] FIG. **4** is a schematic diagrammatic view of the vehicle system shown in FIG. **2**, illustrating the power-plant during continued warm-up operation;

[0015] FIG. **5** is a schematic diagrammatic view of the vehicle system shown in FIG. **2**, illustrating the power-plant during a low load operation;

[0016] FIG. **6** is a schematic diagrammatic view of the vehicle system shown in FIG. **2**, illustrating the power-plant during a high load operation; and

[0017] FIG. **7** schematically illustrates, in flow chart format, a method of controlling a temperature of oil of the power-plant shown in FIGS. **1-6**.

DETAILED DESCRIPTION

[0018] Referring to the drawings, wherein like reference numbers refer to like components, FIGS. **1-6** show a system **10** adapted for controlling a temperature of oil in a power-plant **12** of a motor vehicle. The power-plant **12** may be an internal combustion (IC) engine, such as a spark ignition or a compression ignition engine, a fuel cell, or an electric motor operable to propel the vehicle. As such, the subject vehicle may be a conventional, a hybrid, or an electric type.

[0019] The power-plant **12** produces heat energy as a by-product of generating power used to propel the vehicle. Such heat energy is removed by a circulating heat transfer fluid or coolant **14**, continuously cycling through multiple coolant conduits of the system **10** via a fluid or coolant pump **16**. The contemplated coolant is typically a solution of a suitable organic chemical (most often ethylene glycol, diethylene glycol, or propylene glycol) in water. The power-plant **12** is additionally cooled and lubricated by a body of oil **18**. The oil **18** is continuously circulated through multiple oil conduits of the system **10** and through specifically configured channels and lubrication ports (not shown) arranged inside the power-plant **12** via an oil pump **20**. The contemplated oil is generally derived from a petroleum or a non-petroleum based chemical compound synthesized to minimize the power-plant's internal friction and wear.

[0020] The system **10** also includes a heat-exchanger **22** in fluid communication with the power-plant **12**. The heat-exchanger **22** is arranged relative to the power-plant **12**, and is configured to receive the oil **18** from the power-plant, modify the temperature of the oil, and return the modified temperature oil to the power-plant. As shown in FIG. **1**, the heat-exchanger **22** is contemplated as a coolant-to-oil radiator. The heat-exchanger **22** transfers heat energy between the coolant **14** and the oil **18**, depending on the relative temperatures of the bodies of coolant and oil. Accordingly, when the oil temperature is greater than that of the coolant, the heat-exchanger **22** employs the coolant **14** for absorbing heat energy from the oil **18** to thus cool the oil. Additionally, when the coolant temperature is greater than that of the oil, the heat-exchanger **22** employs the coolant **14** for transferring the heat energy to the oil **18** to thus heat the oil. The fluid pump **16** is, therefore, configured to circulate the coolant **14** through the heat-exchanger **22** in order to modify the temperature of the oil **18**.

[0021] The coolant **14** is delivered to the heat-exchanger **22** via a conduit **24** and exits the heat-exchanger via conduit **26**. The oil **18** is delivered to the heat-exchanger **22** via a conduit **29**. After the temperature of the oil **18** has been modified inside the heat-exchanger **22**, the oil exits the heat-exchanger via conduit **30** and proceeds via a conduit **31** back to the power-plant **12**. A conduit **32** is arranged between the conduit **28** and the conduit **31** to permit the oil to bypass the heat-exchanger **22** on demand. The system **10** also includes a spool valve **33**. The valve **33** includes an inner hollow (not shown) that is in fluid communication with the oil **18** and is also connected to the exterior surface of the valve via cross-drill or the like passages represented by apertures **34** and **36**. The valve **33** is shuttled back and forth inside the conduit **28** for selectively controlling the flow of oil **18** through the heat-exchanger **22**. The valve **33** is configured to direct the oil **18** through the heat-exchanger **22** during warm-up and during high load operation of the power-plant **12**. The valve **33** is also configured to block off access of the oil **18** to the conduit **29** to thereby bypass the heat-exchanger **22** during low load operation of the power-plant **12**.

[0022] The system **10** is configured such that directing the oil **18** through the heat-exchanger **22** during the warm-up operation of the power-plant **12** via the valve **33** acts to increase the temperature of the oil when the temperature of the coolant **14** is relatively higher than that of the oil. Additionally, directing the oil through the heat-exchanger **22** during the high load operation of the power-plant **12** via the valve **33** acts to reduce the temperature of the oil when the temperature of the coolant **14** is relatively lower than that of the oil. Furthermore, directing the oil **18** to bypass the heat-exchanger **22** during the low load operation of the power-plant **12** acts to increase the temperature of the oil above that of the coolant **14**.

[0023] The system **10** also includes an actuator **38** and a spring **40**. The spring **40** is configured in a spring set position to bias the valve **33** against the actuator **38**. The spring **40** is sized to overcome a set or predetermined difference in pressure of the oil **18** between the conduits **28** and **32**. The actuator **38** is configured to operate the valve **33** by displacing the valve in the direction of compressing the spring **40** during cold start conditions and subsequent warm-up operation of the power-plant **12**. The actuator **38** may be configured as an externally regulated magnetic solenoid (as shown in FIG. **1**) or as a wax motor (as shown in FIGS. **2-6**). As shown in each of FIGS. **1-6**, the controller **46** is in electrical communication with the actuator **38**. The controller **46** is configured, i.e., programmed, to regulate the actuator according to one of the warm-up, low load, and high load operation of the power-plant **12**. The defining temperature and pressure parameters of the coolant **14** and the oil **18** for each of the warm-up, low load, and high load operation of the power-plant **12** may be established empirically during testing and development of the power-plant and the subject vehicle.

[0024] In the case that the actuator **38** is a wax motor, as illustrated by FIGS. **2-6**, the wax motor functions as a linear actuator that is capable of providing an appropriately short range of linear motion via a plunger. Generally, the wax motor has three principal components, a block of wax, a plunger that bears on the wax, and an electric heater that heats the wax (not shown). The electric heater may be a positive temperature coefficient (PTC) thermistor, which, as known by those skilled in the art, is a type of an electronic component that is characterized by resistance that varies significantly with temperature. The wax motor operates when the electric heater is energized through the application of an electric current to heat the wax block. When the wax block is thus heated, the wax block will expand to drive the plunger to thereby displace the valve **33**. When the electric current is removed, the wax block will cool down and contract to thereby cause the plunger to be pushed in or withdrawn with the assist from the force of the spring **40**. The wax motor may additionally employ an internal spring (not shown) incorporated directly into the wax motor configured to assist the spring **40** in withdrawing the plunger.

[0025] As shown in FIGS. **2-6**, the actuator **38** may also be configured as a two-stage wax motor where essentially two wax motors, each having a plunger, are arranged in series. In the case of the two-stage wax motor, a first wax motor **42** may be configured to be activated by the controller **46** at a first predetermined temperature of the oil **18** to displace the valve **33** via a plunger **43**, thereby exposing the aperture **36** to the conduit **32** and permitting the oil to bypass the heat-exchanger **22** (as shown in FIG. **5**). A second wax motor **44** may be activated by the controller **46** at a second predetermined temperature of the oil **18** to displace both the first wax motor and the valve **33** via a plunger **45** further toward the spring **40**, thereby exposing the aperture **34** to the conduit **29** and permitting the oil to flow to the heat-exchanger **22** (as shown in FIG. **6**). The first and the second predetermined temperatures at which the respective first and second wax motors **42**, **44** are configured to be activated may be established empirically during testing and development of the power-plant **12** and the subject vehicle. Although FIGS. **2-6** illustrate the controller **46** being employed to control the wax motors **42**, **44**, the wax motors may also be configured to react directly to the temperature of the fluid flowing through the conduit **28** without any other external regulation.

[0026] Following is a detailed description of operation of the system **10** in connection with various operating modes of the power-plant **12** shown in FIGS. **2-6**. A cold start of the power-plant **12** is shown in FIG. **2**, where the temperatures of both the coolant **14** and the oil **18** are at an ambient temperature that is significantly below zero Celsius. During such a cold start of the power-plant **12** the pressure of the oil **18** in the conduit **28** is significantly higher than the pressure in conduit **31**. As a result, the pressure of the oil **18** is sufficient to displace the valve **33** away from the actuator **38** to fully compress the spring **40** and expose the aperture **34** to the conduit **32**. Additionally, an internal restriction through the heat-exchanger **22** is sufficient to generate a significant difference in oil pressure between the conduit **29** and the conduit **32** and force the majority of the oil **18** to bypass the heat-exchanger. Accordingly, during the low ambient temperature start of the power-plant **12** the valve **33** directs the oil **18** to bypass the heat-exchanger **22**, such that the temperature of the oil is not modified by the heat-exchanger, and is therefore permitted to increase independently of the temperature of the coolant **14**.

[0027] FIG. **3** illustrates continued operation of the power-plant **12** and the gradual warming up of the oil **18**. As the oil **18** warms up, the pressure of the oil **18** in the conduit **28** decreases, as does the internal restriction through the heat-exchanger **22**, which causes the valve **33** to be displaced back toward the actuator **38** in response to the force of the spring **40**. As the valve **33** is displaced by the spring **40** during the gradual warm up of the power-plant **12**, the aperture **36** becomes exposed to the conduit **32**. Such a change in the difference between oil pressure in the conduits **28** and **31** permits a gradually increasing portion of the oil **18** to go through the heat-exchanger **22** to be heated by the coolant **14**, while the remaining portion of the oil will still flow through the conduit **32**. Thus, during the gradual warming up of the oil **18**, as shown in FIG. **3**, the heat-exchanger **22** performs as an oil heater.

[0028] As shown in FIG. **4**, when the oil **18** continues to warm up, the difference in pressure between the conduits **28** and **31** will decrease below a threshold value, thus permitting the spring **40** to overcome the pressure difference and displace the valve **33** fully toward the actuator **38**. The threshold value of the difference in pressure of the oil **18** may be established empirically during testing and development of the power-plant **12** and the subject vehicle. For example, the threshold value of the difference in pressure of the oil **18** between the conduits **28** and **31** at which the valve **33** can be fully displaced may be set at 150 KPa, which typically occurs around zero degrees Celsius. At such a point, the valve **33** will be fully closed, thereby directing substantially all the flow of the oil **18** through the heat-exchanger **22** to be heated by the coolant **14** and permitting the heat-exchanger to continue performing as an oil heater.

[0029] As substantially all the oil **18** begins to flow through the heat-exchanger **22**, and the power-plant **12** continues to warm up, the temperature of the oil **18** will increase further. As the power-plant **12** continues to warm-up, each of the temperatures of the coolant **14** and the oil **18** will eventually reach the first predetermined temperature. The first predetermined temperature may be set at an equilibrium point where the temperatures of the coolant **14** and the oil **18** are substantially at par. Such an equilibrium point has been established to occur around 80 degrees Celsius for some applications of an IC engine operating at road load in a motor vehicle.

[0030] FIG. **5** illustrates the power-plant **12** in a substantially warm or steady-state operating state where the temperatures of the coolant **14** and of the oil **18** have reached the first predetermined temperature, for example 80 degrees Celsius. Such a steady-state operating state of the power-plant **12** will typically occur when the host vehicle is subjected to a relatively low road load, such as cruising at highway speeds. As shown in FIG. **5**, after the temperature of the oil **18** reaches the first predetermined temperature, the first wax motor **42** of the actuator **38** will be activated by the controller **46** to displace the valve **33** via the plunger **43**. Such displacement of the valve **33** will expose the aperture **36** to the conduit **32** and permit the oil **18** to bypass the heat-exchanger **22**, thus permitting the temperature of the oil to increase above the temperature of the coolant **14**.

[0031] FIG. **6** illustrates the power-plant **12** operating as an increased load. During high load operation of the power-plant **12**, such as at higher vehicle speeds, when the vehicle is traveling up a grade, or is towing a load, the temperature of the oil **18** will increase to above that of the coolant **14**, for example up to 110 degrees Celsius. The temperature of the oil **18** has a particular tendency to exceed the temperature of the coolant **14** in IC engines employing piston squirters. A piston squirter is a device used to spray oil at the underside of a piston that reciprocates inside a cylinder to generate a cooling effect during high load operation of some IC engines. When the temperature of the oil **18** has thus exceeded the temperature of the coolant **14**, the second wax motor **44** of the actuator **38** will be activated by the controller **46**. The activation of the second wax motor **44** will displace the valve **33** via the plunger **45**. Such displacement of the valve **33** will expose the aperture **34** to the conduit **29** and permit the oil **18** to flow through the heat-exchanger **22** to be cooled to the temperature of the coolant **14**, thus allowing the heat-exchanger to perform as an oil cooler.

[0032] FIG. **7** depicts a method **50** of controlling the temperature of oil **18** in the power-plant **12** shown in FIGS. **1-5**. The method **50** is described with reference to FIGS. **1-5**, and the above description of the system **10**. The method commences at block **52**, and then proceeds to frame **54**. In frame **54**, the method includes directing the oil **18** through a heat-exchanger **22** during the warm-up operation of the power-plant **12** such that the temperature of the oil is increased. The method then advances to frame **56**. In frame **56**, the method includes directing the oil **18** to bypass the heat-exchanger **22** during the low load operation of the power-plant **12** such that the temperature of the oil is increased. From frame **56** the method proceeds to frame **58**, where it includes directing the oil **18** through the heat-exchanger **22** during the high load operation of the power-plant **12** such that the temperature of the oil is reduced. According to the method **50**, following frame **58**, the method may loop back to frame **56** and permit the oil to again bypass the heat-exchanger **22** when the power-plant **12** reverts to the low load operation.

[0033] While the best modes for carrying out the invention have been described in detail, those familiar with the art to which this invention relates will recognize various alternative designs and embodiments for practicing the invention within the scope of the appended claims.

1. A system for controlling a temperature of oil in a power-plant operable to propel a vehicle, the system comprising:

a heat-exchanger arranged relative to the power-plant, wherein the heat-exchanger is configured to receive the oil from the power-plant, modify the temperature of the oil, and return the modified temperature oil to the power-plant; and

a valve configured to:

direct the oil through the heat-exchanger during a warm-up operation of the power-plant such that the temperature of the oil is increased;

direct the oil to bypass the heat-exchanger during a low load operation of the power-plant such that the temperature of the oil is increased; and

direct the oil through the heat-exchanger during a high load operation of the power-plant such that the temperature of the oil is decreased.

2. The system of claim **1**, wherein the valve is additionally configured to direct the oil to bypass the heat-exchanger during a low ambient temperature start of the power-plant such that the temperature of the oil is not modified by the heat-exchanger.

3. The system of claim **1**, further comprising an actuator configured to operate the valve.

4. The system of claim **3**, further comprising a spring configured to bias the valve against the actuator.

5. The system of claim **4**, wherein the actuator is one of a wax motor and a solenoid.

6. The system of claim **5**, wherein the wax motor is configured as a two-stage wax motor.

7. The system of claim **5**, further comprising a controller in electrical communication with the actuator, wherein the controller is configured to regulate the actuator according to one of the warm-up, low load, and high load operation of the power-plant.

8. The system of claim **1**, further comprising a fluid pump configured to circulate a coolant through the heat-exchanger to modify the temperature of the oil.

9. The system of claim **1**, wherein the power-plant is an internal combustion engine.

10. A method of controlling a temperature of oil in a power-plant operable to propel a vehicle, the method comprising:

directing the oil during a warm-up operation of the power-plant through a heat-exchanger arranged relative to the power-plant such that the temperature of the oil is increased, wherein the heat-exchanger is configured to receive the oil from the power-plant, modify the temperature of the oil, and return the modified temperature oil to the power-plant;

directing the oil to bypass the heat-exchanger during a low load operation of the power-plant such that the temperature of the oil is increased; and

directing the oil through the heat-exchanger during a high load operation of the power-plant such that the temperature of the oil is decreased.

11. The system of claim **10**, wherein the valve is additionally configured to direct the oil to bypass the heat-exchanger during a low ambient temperature start of the power-plant such that the temperature of the oil is not modified by the heat-exchanger.

12. The method of claim **10**, wherein said directing the oil during each of the warm-up operation, the low load operation, and the high load operation of the power-plant is accomplished via a valve.

13. The method of claim **10**, further comprising operating the valve via an actuator.

14. The method of claim **13**, further comprising biasing the valve against the actuator via a spring.

15. The method of claim **14**, wherein the actuator is one of a wax motor and a solenoid.

16. The method of claim **15**, wherein the wax motor is configured as a two-stage wax motor.

17. The method of claim **15**, further comprising regulating the actuator via a controller, wherein the controller is configured to regulate the actuator according to one of the warm-up, low load, and high load operation of the power-plant.

18. The method of claim **10**, further comprising circulating a coolant through the heat-exchanger via a fluid pump to modify the temperature of the oil.

19. The method of claim **10**, wherein the power-plant is an internal combustion engine.

20. A system for controlling a temperature of oil in a power-plant operable to propel a vehicle, the system comprising:

a heat-exchanger arranged relative to the power-plant, wherein the heat-exchanger is configured to receive the oil from the power-plant, modify the temperature of the oil, and return the modified temperature oil to the power-plant;

a valve configured to:

direct the oil through the heat-exchanger during a warm-up operation of the power-plant such that the temperature of the oil is increased;

direct the oil to bypass the heat-exchanger during a low load operation of the power-plant such that the temperature of the oil is increased;

direct the oil through the heat-exchanger during a high load operation of the power-plant such that the temperature of the oil is decreased; and

direct the oil to bypass the heat-exchanger during a low ambient temperature start of the power-plant such that the temperature of the oil is not modified by the heat-exchanger;

a two-stage wax motor configured to operate the valve; and

a spring configured to bias the valve against the two-stage wax motor.

* * * * *