



(11)

EP 2 161 417 A1

(12)

## EUROPEAN PATENT APPLICATION

(43) Date of publication:  
**10.03.2010 Bulletin 2010/10**

(51) Int Cl.:  
**F01K 25/06** (2006.01)  
**F01K 21/00** (2006.01)

F01K 25/04 (2006.01)

(21) Application number: 09166581.0

(22) Date of filing: 28.07.2009

(84) Designated Contracting States:

AT BE BG CH CY CZ DE DK EE ES FI FR GB GR  
HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL  
PT RO SE SI SK SM TR

#### Designated Extension States:

**Designated  
ALBARS**

(30) Priority: 07-08-2008 US 187426

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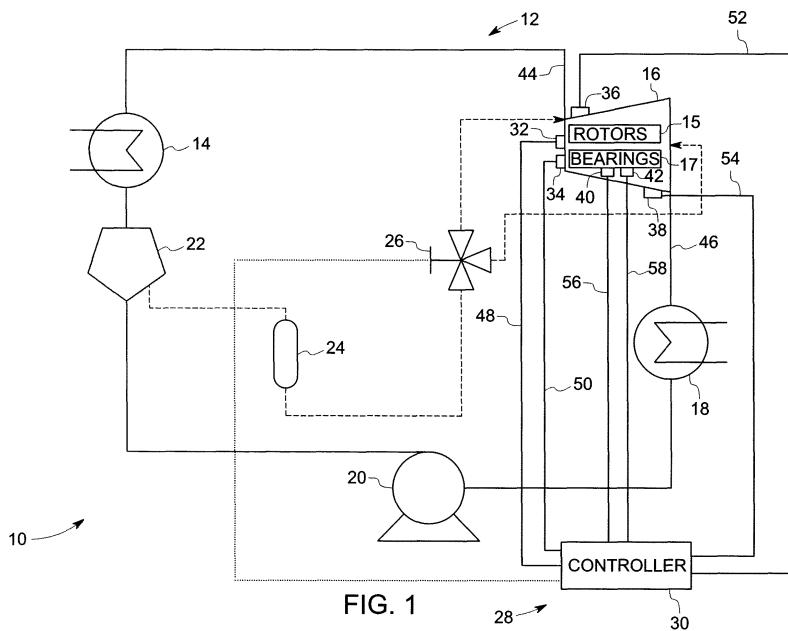
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(54) **Method for lubricating screw expanders and system for controlling lubrication**

(57) A method for lubricating a screw expander (16) includes condensing a mixture of working fluid and lubricant fed from the screw expander (16), through a condenser (18). At least a portion of the mixture of working fluid and lubricant fed from the condenser (18) is pressurized from a first pressure to a second pressure through a pump (20). The method also includes separating the lubricant from the condensed working fluid of the at least

portion of the mixture via a separator (22) and feeding the lubricant to the screw expander (16); or separating the lubricant from the working fluid of the at least portion of the mixture via an evaporator (14) and feeding the lubricant to the screw expander (16); or feeding the at least portion of the mixture of condensed working fluid and lubricant to the screw expander (16); or combinations thereof.



## Description

**[0001]** The embodiments disclosed herein relate generally to the field of a rankine cycle system and, more particularly, to a system and method for lubricating a screw expander in a rankine cycle system.

**[0002]** Unlike the traditional steam rankine cycle, the organic rankine cycle (ORC) uses a higher molecular mass organic fluid. ORC allows heat recovery from low temperature sources such as industrial waste heat, geothermal heat, solar ponds, or the like. The low temperature heat is converted into useful work, that can itself be converted into electricity. In ORC, the working fluid is pumped to an evaporator where working fluid is evaporated, passes through a turbine and is finally recondensed.

**[0003]** In an ideal organic rankine cycle, the expansion is isentropic and the evaporation and condensation processes are isobaric. In real organic rankine cycle, the presence of irreversibilities lowers the cycle efficiency. The irreversibilities may occur in expanders and also in heat exchangers. During expansion, only a portion of the energy recoverable from the enthalpy difference is transformed into useful work. Efficiency of the expander is defined by comparison with an isentropic expansion. In the heat exchangers, the sinuous path flow of the working fluid ensures a better heat exchange but causes pressure drops, and lowers the amount of power recoverable from the cycle.

**[0004]** Usage of screw expanders in ORC enable a low capital expenditure (CAPEX), competitive cost of electricity, and effective operation. In most cases, screw expanders can be coupled directly to a generator, without an intermediate reduction gearbox. This not only saves cost but also reduces losses compared to turbines with gearboxes. Non-synchronized screw expanders require oil to be injected into an inlet of the expander to lubricate the rotors and bearings of the screw expanders. Conventional oil lubrication systems separate oil from the working fluid downstream from the expander. At the cycle point downstream from the expander, the working fluid is in a gaseous state and has a lower density. The oil is in liquid state. In conventional systems, demisters are used to separate the oil from the working fluid. The demisters have a significant size to accommodate the lower density of the working fluid and to achieve lower pressure drops in the cycle. After the oil is separated from the working fluid, the oil has to be cooled and pressurized to a higher pressure for injection into the expander. An additional oil pump is needed for pressurizing the oil to a higher pressure and an oil cooler is required for cooling the oil. Such systems are complex and have a large footprint. The flow of lubricant is passively controlled via a nozzle or shim for enabling sufficient flow at all operating conditions. However such passive control leads to an excessive lubrication at operating conditions other than design-point operation causing reduction in cycle efficiency.

**[0005]** It would be desirable to have a simple and efficient system and method for lubricating screw expanders in an organic rankine cycle system.

**[0006]** In accordance with one exemplary embodiment of the present invention, a method for lubricating a screw expander using a mixture of working fluid and lubricant in an organic rankine cycle system is disclosed. The method includes condensing the mixture of working fluid and lubricant fed from the screw expander, through a condenser. At least a portion of the mixture of working fluid and lubricant fed from the condenser is pressurized from a first pressure to a second pressure through a pump. The method can also include separating the lubricant from the condensed working fluid of at least a portion of the mixture via a separator and feeding the lubricant to the screw expander; or separating the lubricant from the working fluid of at least a portion of the mixture via an evaporator and feeding the lubricant to the screw expander; or feeding at least a portion of the mixture of condensed working fluid and lubricant to the screw expander; or combinations thereof.

**[0007]** In accordance with another exemplary embodiment of the present invention, a method for lubricating a screw expander includes sensing one or more parameters related to the screw expander. The method also includes controlling the feed of the lubricant, at least a portion of the mixture of condensed working fluid and lubricant, or combinations thereof to the screw expander based on one or more parameters related to the screw expanders.

**[0008]** In accordance with another exemplary embodiment of the present invention, a control system for controlling lubrication of a screw expander is disclosed. The control system includes a plurality of sensors configured for sensing one or more parameters related to the screw expander. A separator is disposed between an evaporator and a fluid feed pump. The separator is configured to receive at least a portion of a mixture of condensed working fluid and lubricant fed from the fluid feed pump and to separate the lubricant from the working fluid. A flow control device is disposed between the separator and the screw expander and configured to control the flow of the lubricant from the separator to the screw expander. A controller is coupled to the plurality of sensors and the flow control device. The controller is configured to receive output signals indicative of one or more parameters related to the screw expander from the plurality of sensors and control the flow control device based on the sensor output signals.

**[0009]** In accordance with another exemplary embodiment of the present invention, a control system includes a plurality of sensors configured for sensing one or more parameters related to a screw expander. A flow control device is configured to receive a portion of a mixture of condensed working fluid and oil from a condenser and feed the portion of the mixture of working fluid and oil to the screw expander. The flow control device is configured to control the flow of the portion of the mixture of working

fluid and oil from the condenser to the screw expander. A controller is coupled to the plurality of sensors and the flow control device. The controller is configured to receive output signals indicative of one or more parameters related to the screw expander from the plurality of sensors and control the flow control device based on the output signals.

**[0010]** Various features, aspects, and advantages of the present invention will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

FIG. 1 is a diagrammatical view of an organic rankine cycle system having a screw expander and a control system configured to control flow of a lubricant to the screw expander in accordance with an exemplary embodiment of the present invention;

FIG. 2 is a diagrammatical view of an organic rankine cycle system having a screw expander in accordance with an exemplary embodiment of the present invention;

FIG. 3 is a diagrammatical view of an organic rankine cycle system having a screw expander in accordance with an exemplary embodiment of the present invention;

FIG. 4 is a diagrammatical view of an organic rankine cycle system having a control system configured to control flow of lubricant to a screw expander in accordance with an exemplary embodiment of the present invention; and

FIG. 5 is a diagrammatical view of an organic rankine cycle system having a control system configured to control flow of lubricant to a screw expander in accordance with an exemplary embodiment of the present invention.

**[0011]** As discussed in detail below, various embodiments of the present invention provide a method for lubricating an expansion machine, for example, a screw expander using a mixture of working fluid and lubricant in an organic rankine cycle system. The method includes condensing the mixture of working fluid and lubricant fed from the screw expander through a condenser. The mixture of working fluid and lubricant fed from the condenser is pressurized from a first pressure to a second pressure through a pump. The lubricant is separated from the condensed working fluid and fed to the screw expander. Alternatively, a portion of the mixture of the condensed working fluid and lubricant is fed to the expander. In certain embodiments, the feeding of the separated lubricant or the portion of the mixture of condensed working fluid and lubricant to the screw expander is controlled based

on one or more parameters related to the screw expanders. In some embodiments, a control system for controlling lubrication of a screw expander in an organic rankine cycle system is disclosed. The lubrication system does not include complex oil separation and feed systems. The lubrication system includes lesser number of components, resulting in a reduction in the overall system footprint.

**[0012]** Referring to FIG. 1, an exemplary expansion system 10 is illustrated. In the illustrated embodiment the expansion system is a waste heat recovery system. The illustrated waste heat recovery system 10 includes an organic rankine cycle system 12. An organic working fluid is circulated through the organic rankine cycle system 12. In certain exemplary embodiments, the organic working fluid may include cyclohexane, cyclopentane, thiophene, ketones, aromatics, or combinations thereof. In certain other exemplary embodiments, the organic working fluid may include propane, butane, pentafluoro-propane, pentafluoro-butane, pentafluoro-polyether, other refrigerants, or combinations thereof. It should be noted herein that this list of organic working fluids is not inclusive and other organic working fluids applicable to organic rankine cycles are also envisaged. In certain other exemplary embodiments, the organic working fluid includes a binary fluid. The binary fluid may include cyclohexane-propane, cyclohexane-butane, cyclopentane-butane, or cyclopentane-pentafluoropropane, for example. In the exemplary embodiments discussed below, the organic working fluid circulated through organic rankine cycle system 12 includes a mixture of working fluid or fluids and a lubricant i.e. lubrication oil (that is, it comprises a two-phase mixture).

**[0013]** The organic rankine cycle system 12 includes an evaporator 14 coupled to a heat source (not shown), for example an exhaust unit of a heat source (for example, an engine). In the illustrated embodiment, the evaporator 14 receives heat from the heat source and generates an organic working fluid vapor. In one embodiment, the heat source may include a top cycle of a cascading rankine cycle system. The organic working fluid vapor is passed through an expander 16 to drive a generator unit (not shown). In one embodiment, the expander 16 includes a screw-type expander. As mentioned previously, lubrication oil is used for lubricating one or more rotors 15 and bearings 17 of the expanders. After passing through the expander 16, the mixture of vaporized organic working fluid and oil (at a relatively lower pressure and lower temperature) is passed through a condenser 18. The mixture of vaporized organic working fluid and oil is condensed into a liquid, which liquid is then pumped via a fluid feed pump 20 to the evaporator 14. In one embodiment, the pump 20 is a variable speed pump. The pump 20 receives the mixture of condensed organic working fluid and oil at a first pressure and pressurizes the mixture to a relatively higher second pressure. The cycle may then be repeated. The illustrated waste heat recovery system facilitates effective heat removal from

the heat source. The waste heat is converted into electricity via the organic rankine cycle system.

**[0014]** In the illustrated embodiment, an oil separator 22 is disposed between the pump 20 and the evaporator 14. The oil separator 22 receives the mixture of condensed organic working fluid and oil and separates the oil from the working fluid. The separated oil may be stored in an oil feed tank 24 temporarily. It should be noted herein that in the separated oil may not always be pure oil and can be an oil enriched fluid stream. The stored oil is then fed from the oil feed tank 24 to the screw expander 16 via a flow control device such as a three-way valve 26 for lubricating the rotors 15, bearings 17, or combinations thereof. In another embodiment, the flow control device may include a two-way valve. The flow control device is configured to control the flow of lubricating oil from the oil feed tank 24 to the screw expander 16.

**[0015]** The system 10 also includes a control system 28 having a controller 30 and a plurality of sensors including but not limited to a first temperature sensor 32, speed sensor 34, inlet pressure sensor 36, outlet pressure sensor 38, a second temperature sensor 40, and a vibration sensor 42. The first temperature sensor 32 is configured to detect the casing temperature of the expander 16. The speed sensor 34 is configured to detect the speed of the expander 16. The inlet pressure sensor 36 is coupled to an inlet 44 of the expander 16 and configured to detect an inlet pressure of the working fluid at the inlet 44 of the expander 16. The outlet pressure sensor 38 is coupled to an outlet 46 of the expander 16 and configured to detect an outlet pressure of the working fluid at the outlet 46 of the expander 16. The second temperature sensor 40 is configured to detect the temperature of the bearings 17. The vibration sensor 42 is configured to detect vibration of the bearings 17. It should be noted herein that the number of sensors and location of sensors in the expander 16 may vary depending on the application. The bearing temperature may also be detected indirectly based on the casing temperature. The controller 30 is configured to receive output signals 48, 50, 52, 54, 56, and 58 from the sensors 32, 34, 36, 38, 40 and 42 respectively and control the valve 26 based on the output signals 48, 50, 52, 54, 56, and 58. In other words, the flow of lubricating oil to the expander 16 is controlled based on one or more sensed parameters of the expander 16. The flow of lubricating oil is controlled based on variation of one or more sensed parameters of expander including but not limited to casing temperature, expander speed, inlet pressure, outlet pressure, bearing temperature, and bearing vibrations with respect to a pre-defined threshold limit. In some embodiments, when the one or more sensed parameters of the expander 16 exceeds the predefined threshold limit, the controller 30 increases the opening of the valve 26 so as to increase the supply of lubricating oil to the expander 16. In some other embodiments, when one or more sensed parameters is below the predefined threshold limit, the controller 30 reduces the opening of the valve 26 so as to reduce

the supply of lubricating oil to the expander 16. This active control ensures sufficient lubrication of the screw expander. As a result, efficiency of the cycle is enhanced.

**[0016]** The controller 30 may also be used to adjust the predefined threshold limits based on one or more parameters related to the organic rankine system. The parameters may include but are not limited to the temperature of the working fluid at the exit of the expander, pressure of the working fluid at the exit of the expander, type of working fluid, type of expansion system, system efficiency, amount of heat extracted from the heat source, back flow temperature of the heat source, lubrication conditions, condensation temperature, or a combination thereof.

**[0017]** Conventional lubrication systems separate oil from the working fluid downstream from the expander. At the cycle point downstream from the expander, the working fluid is in a gaseous state and has a lower density. The oil is in liquid state. The conventional lubrication systems are complex and have a bigger footprint. Moreover, such passive control leads to an excessive lubrication at operating conditions other than design-point operation causing reduction in cycle efficiency. In accordance with certain embodiments of the present invention, the existing fluid feed pump 20 itself of the rankine cycle is used to increase the pressure of the mixture of condensed working fluid and oil fed from the condenser 18. Thereafter, the oil is separated from the condensed working fluid via the separator 22. As a result, no separate oil pump is required since the oil is already at a higher pressure after exiting the pump 20. If the oil pressure is not sufficient (e.g. due to higher pressure drops in the system) an additional oil pump may be used between the separator 22 and the valve 26. A simple three-way valve 26 or a two-way valve is sufficient to regulate the flow of working fluid from the separator 22 to the expander 16. At the cycle point downstream from the condenser 18, the working fluid is in a liquid state and has a higher density. The oil is in liquid state. This enables simpler lubrication systems with a smaller footprint.

**[0018]** Referring to FIG. 2, an organic rankine cycle system 12 in accordance with another exemplary embodiment of the present invention is illustrated. In the illustrated embodiment, the mixture of vaporized organic working fluid and oil at a relatively lower pressure and lower temperature is passed through the condenser 18. The mixture of vaporized organic working fluid and oil is condensed into a liquid, which liquid is then pumped via the fluid feed pump 20 to the evaporator 14. The pump 20 receives the mixture of condensed organic working fluid and oil at a first pressure and pressurizes the mixture to a relatively higher second pressure.

**[0019]** In the illustrated embodiment, the oil separator 22 is disposed between the pump 20 and the evaporator 14. The oil separator 22 receives the mixture of condensed organic working fluid and oil and separates the oil from the working fluid. The separated oil or oil-enriched fluid stream may be stored in the oil feed tank 24 tempo-

rarily. The stored oil is then fed from the oil feed tank 24 to the screw expander 16 via flow control device such as a lubrication pump 60 for lubricating the rotors 15, bearings 17, or combinations thereof. The lubrication pump 60 is configured to control the flow of lubricating oil from the oil feed tank 24 to the screw expander 16.

**[0020]** In the illustrated embodiment, the controller (illustrated in FIG. 1) may be configured to receive output signals from the sensors and control the lubrication pump 60 based on the sensor output signals. In some embodiments, when the one or more sensed parameters of the expander 16 exceeds the predefined threshold limit, the controller may increase the speed of the lubrication pump 60 so as to increase the supply of lubricating oil to the expander 16. In some other embodiments, when one or more sensed parameters are below the predefined threshold limit, the controller reduces the speed of the lubrication pump 60 so as to reduce the supply of lubricating oil to the expander 16. If the pressure of the working fluid-oil mixture exiting from the fluid feed pump 20 is not sufficient due to higher pressure drops in the system 12, the provision of an additional lubrication pump 60 enables to increase the pressure of lubricating oil supplied to the expander 16.

**[0021]** With reference to both FIGS. 1 and 2, in some embodiments, the separator 22 may not be used. In such embodiments, the oil-fluid mixture from the fluid feed pump 20 is passed through the evaporator 14. The working fluid is vaporized and the liquid oil is drained from the evaporator 14 to an optional oil cooler. The lubrication pump 60 may be used to feed the oil from the oil cooler to the expander 16. In one embodiment, the lubricating oil is supplied only to the inlet 44 of the expander 16 for lubricating the rotors 15. In another embodiment, the lubricating oil is used only for lubricating the bearings 17. In yet another embodiment, the lubricating oil is used for lubricating both rotors 15 and bearings 17 of the expander 16. In certain embodiments, if the lubricating oil is used only for lubricating the bearings 17, the working fluid may be used for lubricating the rotors 15 and vice versa.

**[0022]** Referring to FIG. 3, an organic rankine cycle system 12 in accordance with another exemplary embodiment of the present invention is illustrated. In the illustrated embodiment, the mixture of vaporized organic working fluid and oil at a relatively lower pressure and lower temperature is passed through the condenser 18. The mixture of vaporized organic working fluid and oil is condensed into a liquid, which is then pumped via the fluid feed pump 20 to the evaporator 14.

**[0023]** In the illustrated embodiment, a portion of the mixture of condensed working fluid and oil from the condenser 18 is directed from a predefined location 62 between the condenser 18 and the fluid feed pump 20, to the expander 16 via the lubrication pump 60 for lubricating the rotors 15, bearings 17, or combinations thereof. The lubrication pump 60 is configured to control the flow of the portion of working fluid-oil mixture from the location 62 to the screw expander 16. Here again, similar to the

previous embodiment, the controller may be configured to receive output signals from the sensors and control the lubrication pump 60 based on the sensor output signals. In the illustrated embodiment, even though an additional lubrication pump 60 is used, no oil separator is used between the fluid feed pump 20 and the evaporator 14 since a portion of the oil-fluid mixture from the condenser 18 is directly supplied to the expander 16 for lubrication. In another exemplary embodiment, the oil separator (illustrated in FIG. 2) may be disposed at the location 62 between the condenser 18 and the fluid feed pump 20. The oil separator receives the mixture of condensed organic working fluid and oil and separates the oil from the working fluid. The separated oil may then be fed to the screw expander 16 via the lubrication pump 60 for lubricating the rotors 15, bearings 17, or combinations thereof.

**[0024]** Referring to FIG. 4, an organic rankine cycle system 12 in accordance with another exemplary embodiment of the present invention is illustrated. In the illustrated embodiment, a portion of the mixture of condensed working fluid and oil from the condenser 18 is directed from a location 62 between the condenser 18 and the fluid feed pump 20, to the expander 16 via the lubrication pump 60 and the three-way valve 26 for lubricating the rotors 15, bearings 17, or combinations thereof. The lubrication pump 60 and the three-way valve 26 are configured to control the flow of the portion of the working fluid-oil mixture from the location 62 to the screw expander 16.

**[0025]** The controller 30 is coupled to both the valve 26 and the lubrication pump 60. Here again, similar to the previous embodiment, the controller 30 is configured to receive output signals 48, 50, 52, 54, 56, and 58 from the sensors 32, 34, 36, 38, 40 and 42 respectively and control the lubrication pump 60 and valve 26 based on the sensor output signals 48, 50, 52, 54, 56, and 58. In some embodiments, the valve 26 may be regulated for supplying the fluid-oil mixture to the inlet 44 of the expander 16 for lubricating only the rotors 15. In certain other embodiments, the valve 26 may be regulated for directing the fluid-oil mixture to the expander 16 in such a way so as to use the fluid-oil mixture directly for lubricating the bearings 17. In some embodiments, both the

rotors 15 and bearings 17 are lubricated using the fluid-oil mixture. The controller 30 facilitates to control the flow of fluid-oil mixture to various locations of the expander 16.

**[0026]** Referring to FIG. 5, an organic rankine cycle system 12 in accordance with another exemplary embodiment of the present invention is illustrated. In the illustrated embodiment, a portion of the mixture of condensed working fluid and oil from the condenser 18 is directed from a location 62 between the condenser 18 and the fluid feed pump 20, to the expander 16 via the lubrication pump 60 and a first and second smaller flow control valves 64, 66 for lubricating the rotors 15, bearings 17, or combinations thereof. The lubrication pump 60 and the flow control valves 64, 66 are configured to

control the flow of the portion of the working fluid-oil mixture from the location 62 to the screw expander 16. In the illustrated embodiment, the valve 64 is configured to control the flow of fluid-oil mixture to the inlet 44 of the expander for lubricating the rotors 15. The other valve 66 is configured to control the flow of oil-fluid mixture to the expander 16 for lubricating the bearings.

**[0027]** The controller 30 is coupled to the valves 64, 66 and the lubrication pump 60. Here again, similar to the previous embodiment, the controller 30 is configured to receive output signals 48, 50, 52, 54, 56, and 58 from the sensors 32, 34, 36, 38, 40 and 42 respectively and control the lubrication pump 60 and valves 64, 66 based on the sensor output signals 48, 50, 52, 54, 56, and 58. The controller 30 regulates the opening/closing of the valves 64, 66 for controlling the supply of the fluid-oil mixture to the expander 16 for lubricating only the rotors 15 and bearings. The controller 30 facilitates to control the flow of fluid-oil mixture to various locations of the expander 16.

**[0028]** With reference to FIGS. 1-5, in some embodiments, the oil or oil enriched fluid stream from the separator 22 is used for lubricating only the bearings 17 and portion of the mixture of working fluid and oil from the condenser 18 may be used for lubricating the rotors 15. In certain other embodiments, the oil from the separator 22 is used for lubricating only the rotors 15 and portion of the mixture of working fluid and oil from the condenser 18 may be used for lubricating the bearings 17. All such permutations and combinations of the above illustrated embodiments are envisaged.

**[0029]** While only certain features of the invention have been illustrated and described herein, many modifications and changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.

**[0030]** Various aspects and embodiments of the present invention are defined by the following numbered clauses:

1. A method for lubricating a screw expander using a mixture of working fluid and lubricant in an organic rankine cycle system, the method comprising:

condensing the mixture of working fluid and lubricant fed from the screw expander, through a condenser;

pressurizing at least a portion of the mixture of working fluid and lubricant fed from the condenser from a first pressure to a second pressure through a pump;

separating the lubricant from the condensed working fluid of the at least portion of the mixture via a separator and feeding the lubricant to the screw expander; or separating the lubricant from

the working fluid of the at least portion of the mixture via an evaporator and feeding the lubricant to the screw expander; or feeding the at least portion of the mixture of condensed working fluid and lubricant to the screw expander; or combinations thereof.

2. The method of clause 1, wherein the lubricant comprises oil.

3. The method of any preceding clause, wherein the pump comprises a fluid feed pump configured to circulate at least a portion of the mixture of working fluid and lubricant through the organic rankine cycle system.

4. The method of any preceding clause, comprising separating the lubricant from the condensed working fluid of the at least portion of the mixture through the separator disposed between the fluid feed pump and the evaporator.

5. The method of any preceding clause, further comprising feeding the separated lubricant to a feed tank configured for temporarily storing the lubricant.

6. The method of any preceding clause, further comprising feeding the lubricant from the feed tank to the screw expander.

7. The method of any preceding clause, further comprising controlling the flow of lubricant from the feed tank to the screw expander via a flow control device.

8. The method of any preceding clause, wherein the pump comprises a lubrication pump configured to feed the at least portion of the mixture of condensed working fluid and lubricant from a predefined location between the condenser and the fluid feed pump to the screw expander.

9. The method of any preceding clause, comprising feeding the separated lubricant, or the at least portion of the mixture of condensed working fluid and lubricant, or combinations thereof to the screw expander for lubricating one or more rotors, bearings disposed in the screw expander.

10. The method of any preceding clause, further comprising measuring one or more parameters related to the screw expanders comprising casing temperature, expander speed, expander inlet pressure, expander outlet pressure, bearing temperature, bearing vibration, or combinations thereof.

11. The method of any preceding clause, further comprising controlling the feed of the lubricant, the at least portion of the mixture of condensed working

fluid and lubricant, or combinations thereof to the screw expander based on one or more parameters related to the screw expander.

12. A method for lubricating a screw expander using a mixture of working fluid and lubricant in an organic rankine cycle system, the method comprising:

sensing one or more parameters related to the screw expander; 10

condensing the mixture of working fluid and oil fed from the screw expander, through a condenser; 15

pressurizing at least a portion of the mixture of condensed working fluid and oil fed from the condenser from a first pressure to a second pressure through a pump; 20

separating the lubricant from the condensed working fluid of the at least portion of the mixture via a separator and feeding the lubricant to the screw expander; or separating the lubricant from the working fluid of the at least portion of the mixture via an evaporator and feeding the lubricant to the screw expander; or feeding the at least portion of the mixture of condensed working fluid and lubricant to the screw expander; or combinations thereof; 25

controlling the feed of the lubricant, the at least portion of the mixture of condensed working fluid and lubricant, or combinations thereof to the screw expander based on one or more parameters related to the screw expander. 30

13. The method of clause 12, wherein one or more parameters related to the screw expanders comprises casing temperature, expander speed, expander inlet pressure, expander outlet pressure, bearing temperature, bearing vibration, or combinations thereof. 40

14. The method of clause 12 or 13, comprising separating the lubricant from the condensed working fluid of the at least portion of the mixture through a separator disposed between a fluid feed pump and the evaporator. 45

15. The method of any of clauses 12 to 14, further comprising feeding the separated lubricant to a feed tank configured for temporarily storing the lubricant. 50

16. The method of any of clause 12 to 15, further comprising controlling the flow of lubricant from the feed tank to the screw expander via a flow control device. 55

17. The method of any of clauses 12 to 16, further comprising controlling the flow of the at least portion of the mixture of condensed working fluid and lubricant to the screw expander via a flow control device.

18. A control system for controlling lubrication of a screw expander using a mixture of working fluid and lubricant circulated in an organic rankine cycle system, the control system comprising:

a plurality of sensors configured for sensing one or more parameters related to the screw expander; 10

a separator disposed between an evaporator and a fluid feed pump; wherein the separator is configured to receive at least a portion of a mixture of condensed working fluid and lubricant fed from the fluid feed pump and separate the lubricant from the working fluid; 15

a flow control device disposed between the separator and the screw expander and configured to control the flow of the lubricant from the separator to the screw expander; 20

a controller coupled to the plurality of sensors and the flow control device; wherein the controller is configured to receive output signals indicative of one or more parameters related to the screw expander from the plurality of sensors and control the flow control device based on the sensor output signals. 25

19. The control system of clause 18, further comprising a feed tank configured for receiving lubricant from the separator and for temporarily storing the lubricant. 30

20. The control system of clause 18 or 19, wherein the flow control device comprises one or more flow control valves, a lubrication pump, or combinations thereof. 40

21. The control system of any of clauses 18 to 20, wherein one or more parameters related to the screw expander comprises casing temperature, expander speed, expander inlet pressure, expander outlet pressure, bearing temperature, bearing vibration, or combinations thereof. 45

22. A control system for controlling lubrication of a screw expander using a mixture of working fluid and lubricant circulated in an organic rankine cycle system, the control system comprising:

a plurality of sensors configured for sensing one or more parameters related to the screw expander; 50

a flow control device configured to receive a portion of a mixture of condensed working fluid and oil from a condenser and feed the portion of the mixture of working fluid and oil to the screw expander; wherein the flow control device is configured to control the flow of the portion of the mixture of working fluid and oil from the condenser to the screw expander; and

a controller coupled to the plurality of sensors and the flow control device; wherein the controller is configured to receive output signals indicative of one or more parameters related to the screw expander from the plurality of sensors and control the flow control device based on the output signals.

23. The control system of clause 22, wherein the flow control device comprises one or more flow control valves, a lubrication pump, or combinations thereof.

24. The control system of clause 22 or 23, wherein one or more parameters related to the screw expander comprises casing temperature, expander speed, expander inlet pressure, expander outlet pressure, bearing temperature, bearing vibration, or combinations thereof.

## Claims

1. A method for lubricating a screw expander (16) using a mixture of working fluid and lubricant in an organic rankine cycle system (12), the method comprising:

condensing the mixture of working fluid and lubricant fed from the screw expander (16), through a condenser (18);  
 pressurizing at least a portion of the mixture of working fluid and lubricant fed from the condenser (18) from a first pressure to a second pressure through a pump (20);  
 separating the lubricant from the condensed working fluid of the at least portion of the mixture via a separator (22) and feeding the lubricant to the screw expander (16); or separating the lubricant from the working fluid of the at least portion of the mixture via an evaporator (14) and feeding the lubricant to the screw expander (16);  
 or feeding the at least portion of the mixture of condensed working fluid and lubricant to the screw expander (16); or combinations thereof.

2. The method of claim 1, wherein the pump (20) comprises a fluid feed pump (20) configured to circulate at least a portion of the mixture of working fluid and lubricant through the organic rankine cycle system (12).

3. The method of claim 2, comprising separating the lubricant from the condensed working fluid of the at least portion of the mixture through the separator (22) disposed between the fluid feed pump (20) and the evaporator (14).

4. The method of any preceding claim, further comprising feeding the separated lubricant to a feed tank (24) configured for temporarily storing the lubricant.

5. The method of claim 4, further comprising feeding the lubricant from the feed tank (24) to the screw expander (16).

10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200 205 210 215 220 225 230 235 240 245 250 255 260 265 270 275 280 285 290 295 300 305 310 315 320 325 330 335 340 345 350 355 360 365 370 375 380 385 390 395 400 405 410 415 420 425 430 435 440 445 450 455 460 465 470 475 480 485 490 495 500 505 510 515 520 525 530 535 540 545 550 555 560 565 570 575 580 585 590 595 600 605 610 615 620 625 630 635 640 645 650 655 660 665 670 675 680 685 690 695 700 705 710 715 720 725 730 735 740 745 750 755 760 765 770 775 780 785 790 795 800 805 810 815 820 825 830 835 840 845 850 855 860 865 870 875 880 885 890 895 900 905 910 915 920 925 930 935 940 945 950 955 960 965 970 975 980 985 990 995 1000 1005 1010 1015 1020 1025 1030 1035 1040 1045 1050 1055 1060 1065 1070 1075 1080 1085 1090 1095 1100 1105 1110 1115 1120 1125 1130 1135 1140 1145 1150 1155 1160 1165 1170 1175 1180 1185 1190 1195 1200 1205 1210 1215 1220 1225 1230 1235 1240 1245 1250 1255 1260 1265 1270 1275 1280 1285 1290 1295 1300 1305 1310 1315 1320 1325 1330 1335 1340 1345 1350 1355 1360 1365 1370 1375 1380 1385 1390 1395 1400 1405 1410 1415 1420 1425 1430 1435 1440 1445 1450 1455 1460 1465 1470 1475 1480 1485 1490 1495 1500 1505 1510 1515 1520 1525 1530 1535 1540 1545 1550 1555 1560 1565 1570 1575 1580 1585 1590 1595 1600 1605 1610 1615 1620 1625 1630 1635 1640 1645 1650 1655 1660 1665 1670 1675 1680 1685 1690 1695 1700 1705 1710 1715 1720 1725 1730 1735 1740 1745 1750 1755 1760 1765 1770 1775 1780 1785 1790 1795 1800 1805 1810 1815 1820 1825 1830 1835 1840 1845 1850 1855 1860 1865 1870 1875 1880 1885 1890 1895 1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070 2075 2080 2085 2090 2095 2100 2105 2110 2115 2120 2125 2130 2135 2140 2145 2150 2155 2160 2165 2170 2175 2180 2185 2190 2195 2200 2205 2210 2215 2220 2225 2230 2235 2240 2245 2250 2255 2260 2265 2270 2275 2280 2285 2290 2295 2300 2305 2310 2315 2320 2325 2330 2335 2340 2345 2350 2355 2360 2365 2370 2375 2380 2385 2390 2395 2400 2405 2410 2415 2420 2425 2430 2435 2440 2445 2450 2455 2460 2465 2470 2475 2480 2485 2490 2495 2500 2505 2510 2515 2520 2525 2530 2535 2540 2545 2550 2555 2560 2565 2570 2575 2580 2585 2590 2595 2600 2605 2610 2615 2620 2625 2630 2635 2640 2645 2650 2655 2660 2665 2670 2675 2680 2685 2690 2695 2700 2705 2710 2715 2720 2725 2730 2735 2740 2745 2750 2755 2760 2765 2770 2775 2780 2785 2790 2795 2800 2805 2810 2815 2820 2825 2830 2835 2840 2845 2850 2855 2860 2865 2870 2875 2880 2885 2890 2895 2900 2905 2910 2915 2920 2925 2930 2935 2940 2945 2950 2955 2960 2965 2970 2975 2980 2985 2990 2995 3000 3005 3010 3015 3020 3025 3030 3035 3040 3045 3050 3055 3060 3065 3070 3075 3080 3085 3090 3095 3100 3105 3110 3115 3120 3125 3130 3135 3140 3145 3150 3155 3160 3165 3170 3175 3180 3185 3190 3195 3200 3205 3210 3215 3220 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8225 8230 8235 8240 8245 8250 8255 8260 8265 8270 8275 8280 8285 8290 8295 8300 8305 8310 8315 8320 8325 8330 8335 8340 8345 8350 8355 8360 8365 8370 8375 8380 8385 8390 8395 8400 8405 8410 8415 8420 8425 8430 8435 8440 8445 8450 8455 8460 8465 8470 8475 8480 8485 8490 8495 8500 8505 8510 8515 8520 8525 8530 8535 8540 8545 8550 8555 8560 8565 8570 8575 8580 8585 8590 8595 8600 8605 8610 8615 8620 8625 8630 8635 8640 8645 8650 8655 8660 8665 8670 8675 8680 8685 8690 8695 8700 8705 8710 8715 8720 8725 8730 8735 8740 8745 8750 8755 8760 8765 8770 8775 8780 8785 8790 8795 8800 8805 8810 8815 8820 8825 8830 8835 8840 8845 8850 8855 8860 8865 8870 8875 8880 8885 8890 8895 8900 8905 8910 8915 8920 8925 8930 8935 8940 8945 8950 8955 8960 8965 8970 8975 8980 8985 8990 8995 9000 9005 9010 9015 9020 9025 9030 9035 9040 9045 9050 9055 9060 9065 9070 9075 9080 9085 9090 9095 9100 9105 9110 9115 9120 9125 9130 9135 9140 9145 9150 9155 9160 9165 9170 9175 9180 9185 9190 9195 9200 9205 9210 9215 9220 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on the sensor output signals (48, 50, 52, 54, 56, 58).

**10.** A control system for controlling lubrication of a screw expander (16) using a mixture of working fluid and lubricant circulated in an organic rankine cycle system (12), the control system comprising:

a plurality of sensors (32, 34, 36, 38, 40, 42) configured for sensing one or parameters related to the screw expander (16);  
a flow control device configured to receive a portion of a mixture of condensed working fluid and oil from a condenser (18) and feed the portion of the mixture of working fluid and oil to the screw expander (16); wherein the flow control device is configured to control the flow of the portion of the mixture of working fluid and oil from the condenser (18) to the screw expander (16); and  
a controller (30) coupled to the plurality of sensors (32, 34, 36, 38, 40, 42) and the flow control device; wherein the controller (30) is configured to receive output signals indicative of one or more parameters related to the screw expander (16) from the plurality of sensors (32, 34, 36, 38, 40, 42) and control the flow control device based on the output signals (48, 50, 52, 54, 56, 58).

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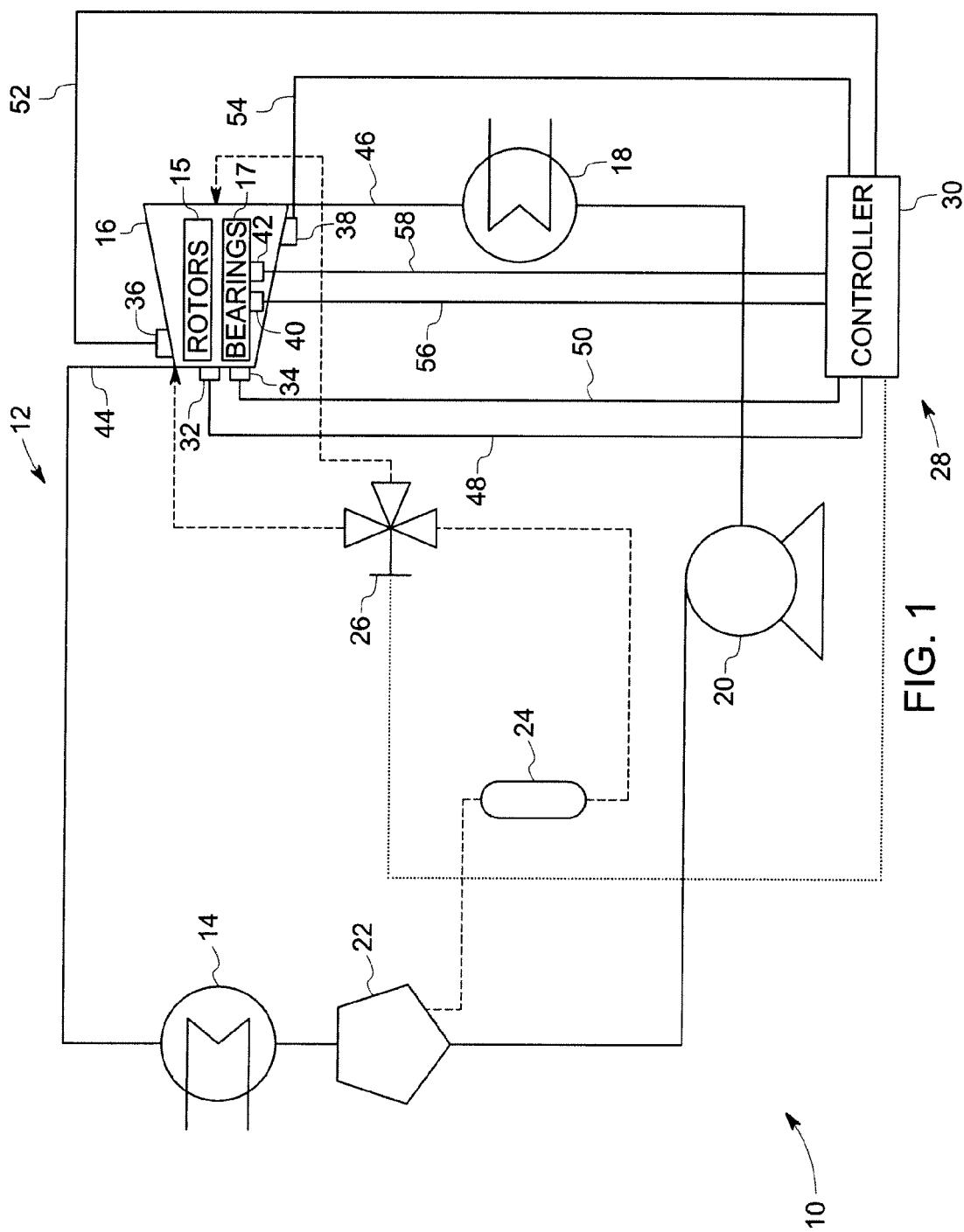


FIG. 1

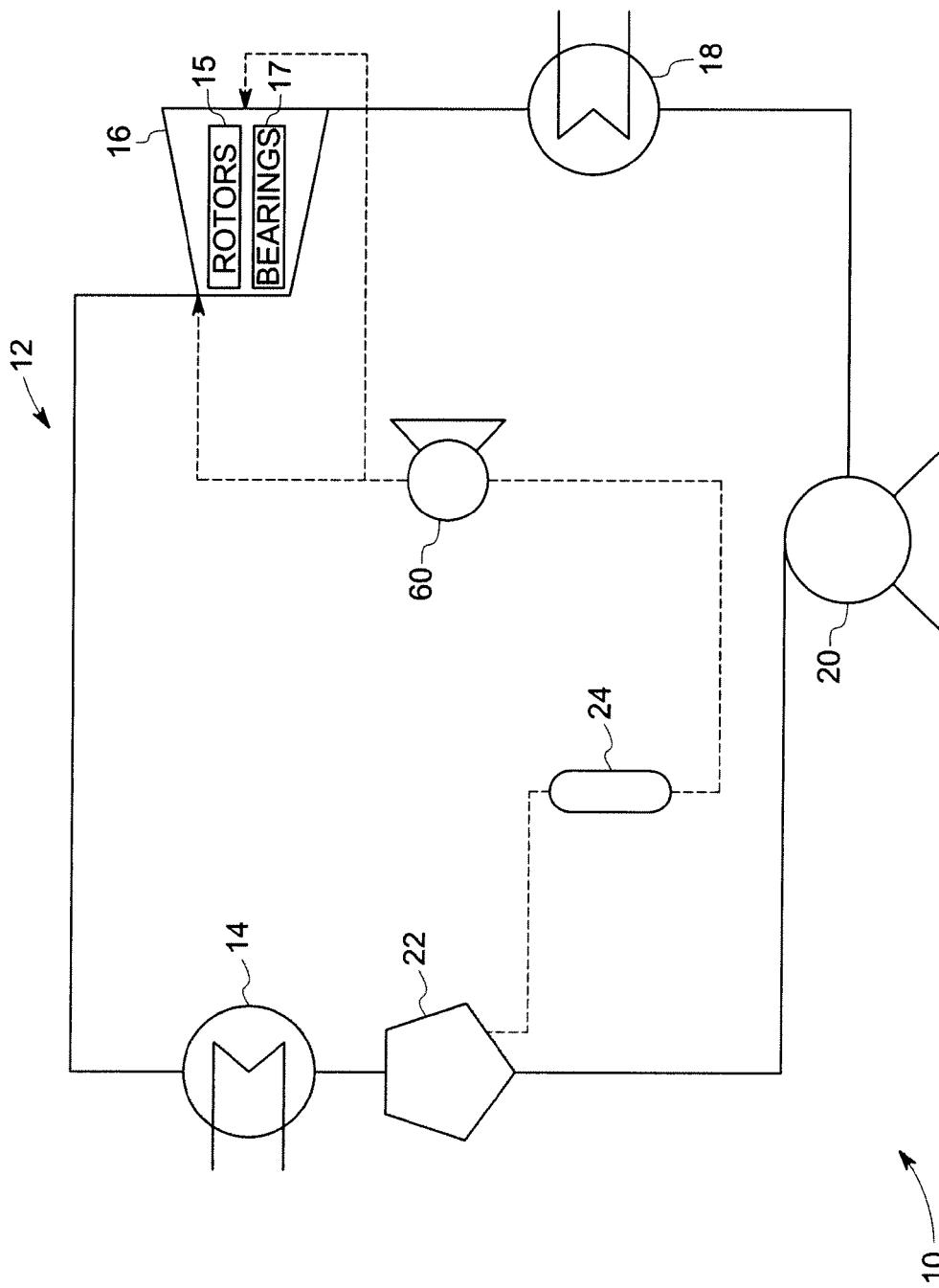


FIG. 2

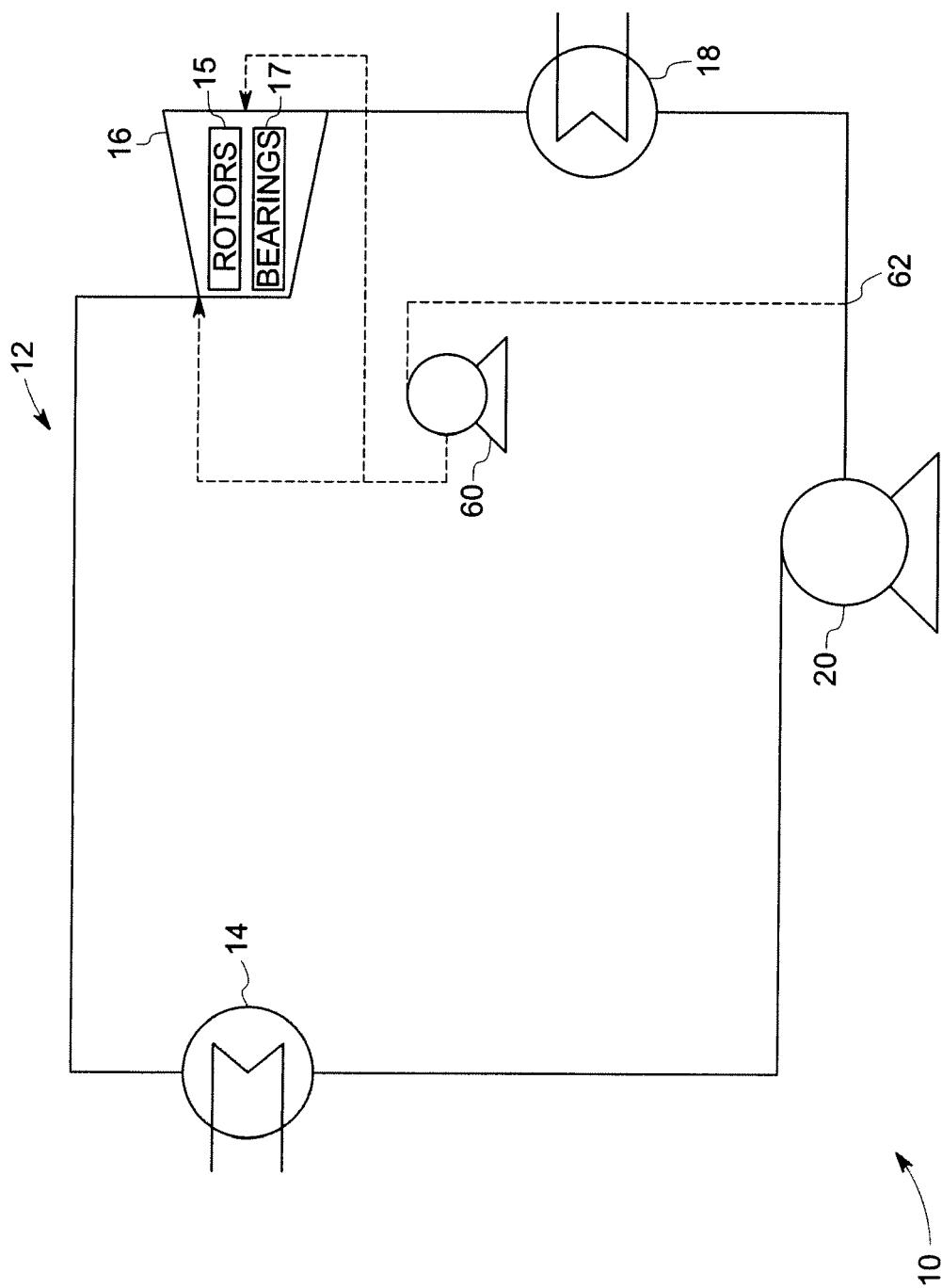


FIG. 3

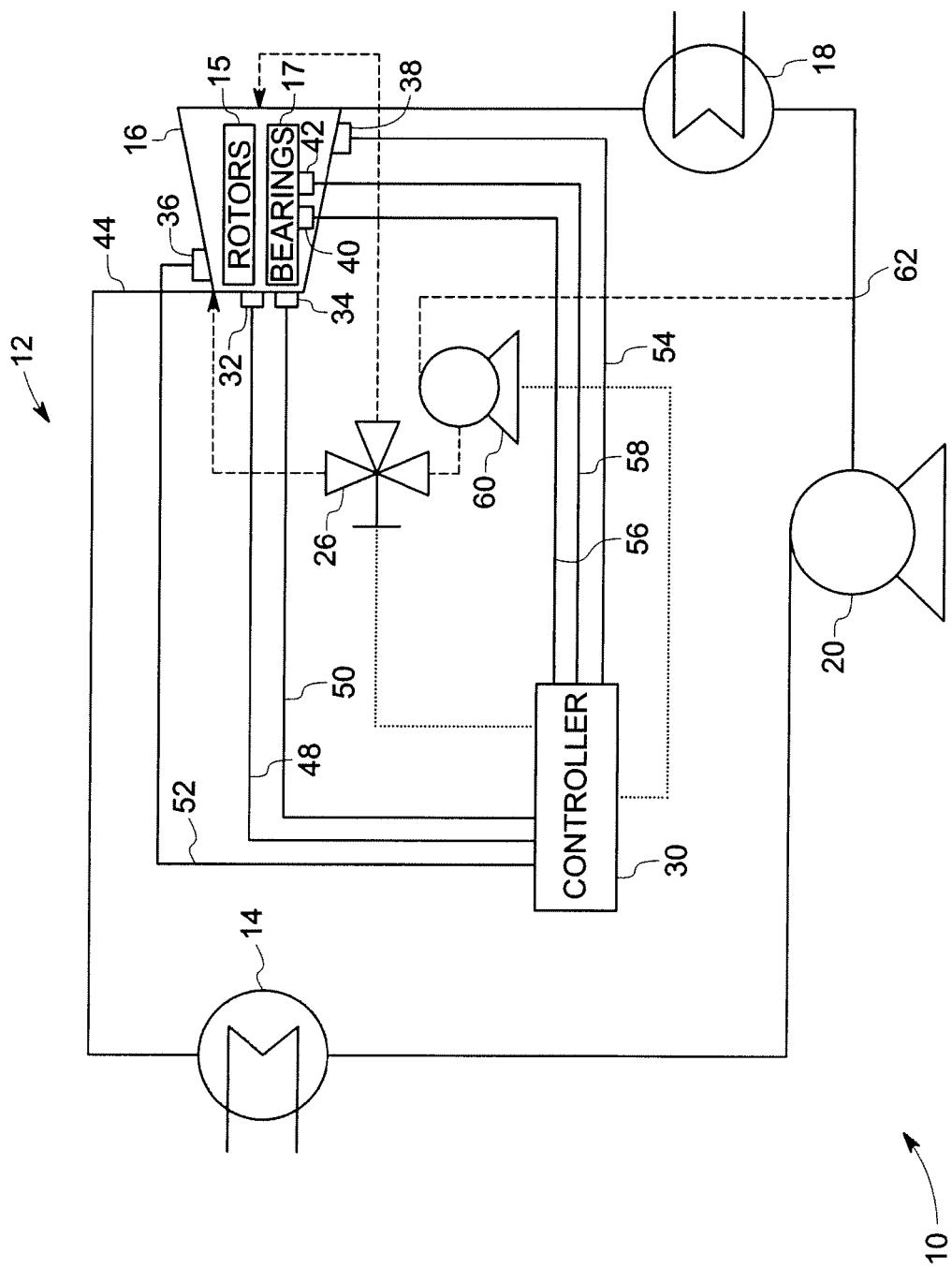


FIG. 4

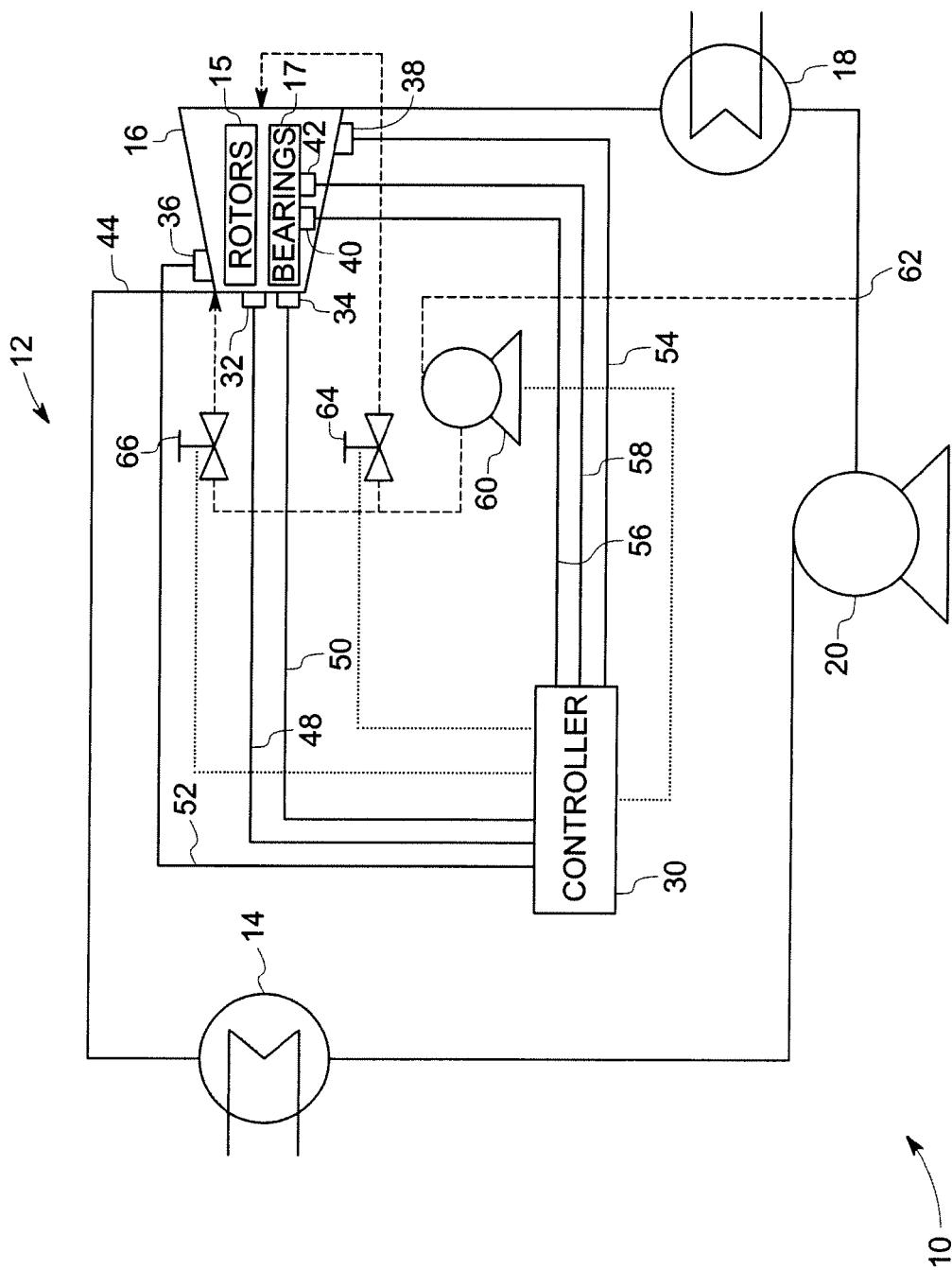


FIG. 5



## EUROPEAN SEARCH REPORT

Application Number  
EP 09 16 6581

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The present search report has been drawn up for all claims			
1	Place of search Munich	Date of completion of the search 20 January 2010	Examiner Zerf, Georges
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T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ..... & : member of the same patent family, corresponding document			

ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.

EP 09 16 6581

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