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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.

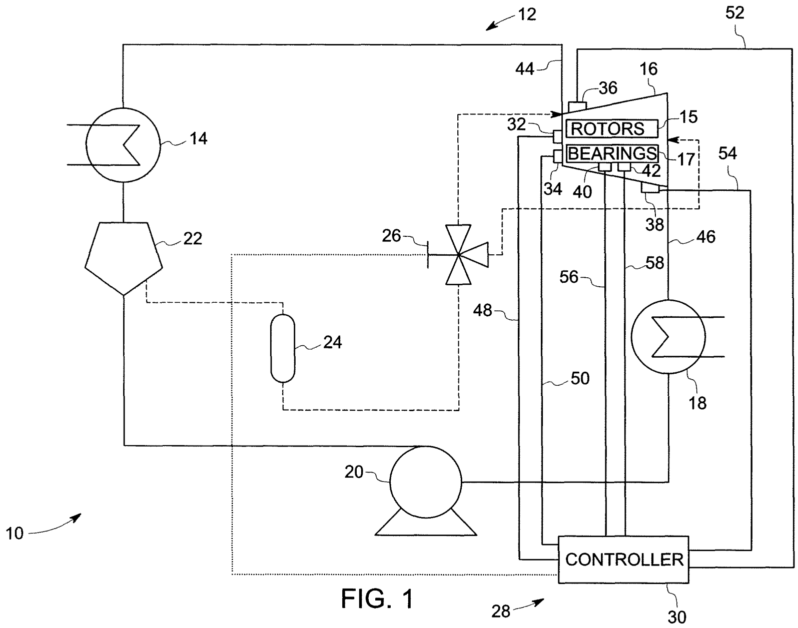

FIG. 1

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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 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 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 predefined 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 temporarily. 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;

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

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;

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;

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.

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.

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.

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.

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.

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;

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;

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;

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.

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.

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.

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.

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 parameters related to the screw expander;

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).

6. The method of claim 5, further comprising controlling the flow of lubricant from the feed tank (24) to the screw expander (16) via a flow control device.

7. The method of any preceding claim, further comprising measuring one or more parameters related to the screw expanders (16) comprising casing temperature, expander speed, expander inlet pressure, expander outlet pressure, bearing temperature, bearing vibration, or combinations thereof.

8. The method of any preceding claim, 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 (16) based on one or more parameters related to the screw expander (16).

9. 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 more parameters related to the screw expander (16);
a separator (22) disposed between an evaporator (14) and a fluid feed pump (20); wherein the separator (22) is configured to receive at least a portion of a mixture of condensed working fluid and lubricant fed from the fluid feed pump (20) and separate the lubricant from the working fluid;
a flow control device disposed between the separator (22) and the screw expander (16) and configured to control the flow of the lubricant from the separator (22) to the screw expander (16);
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 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).

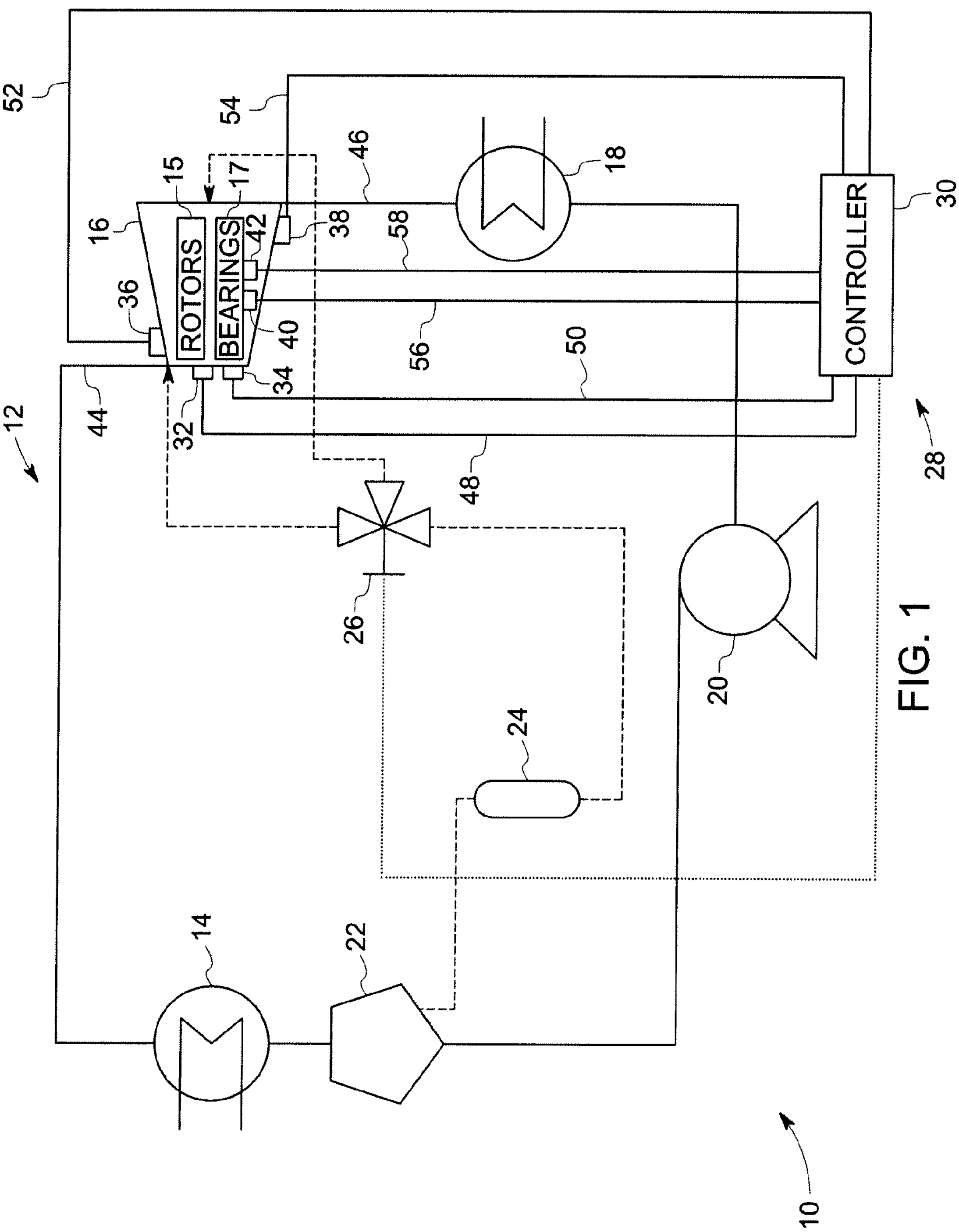
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FIG. 1

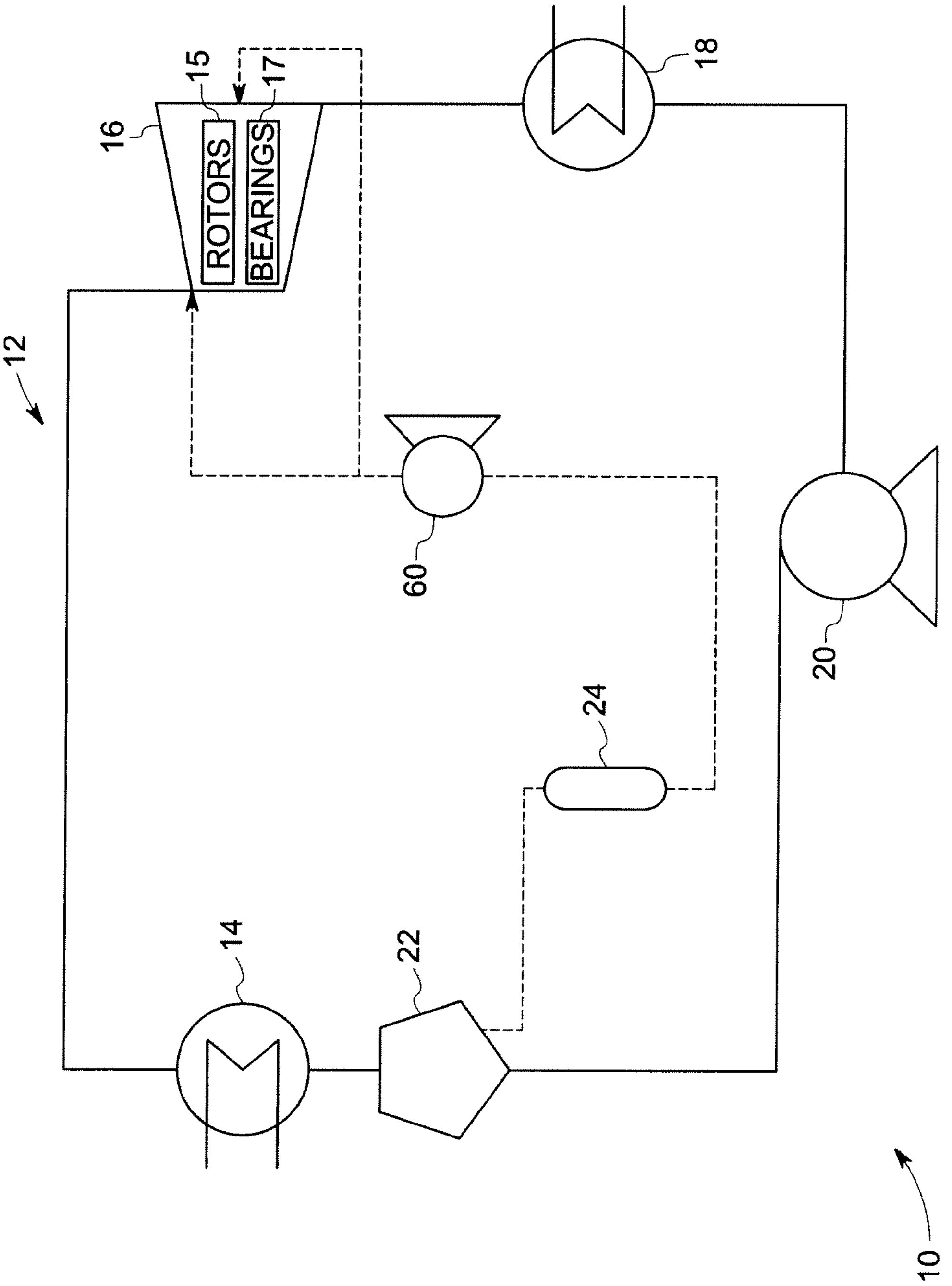

FIG. 2

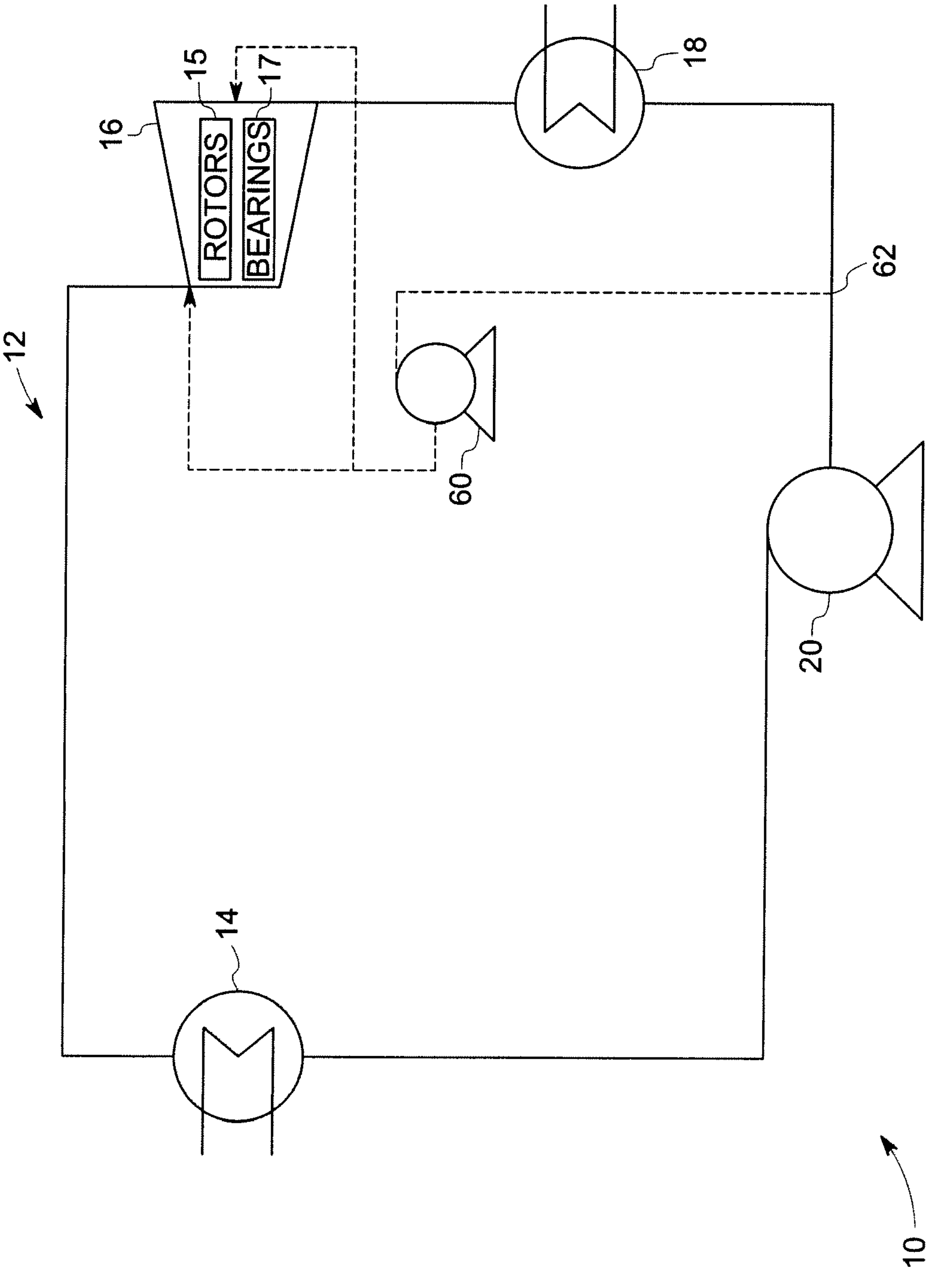

FIG. 3

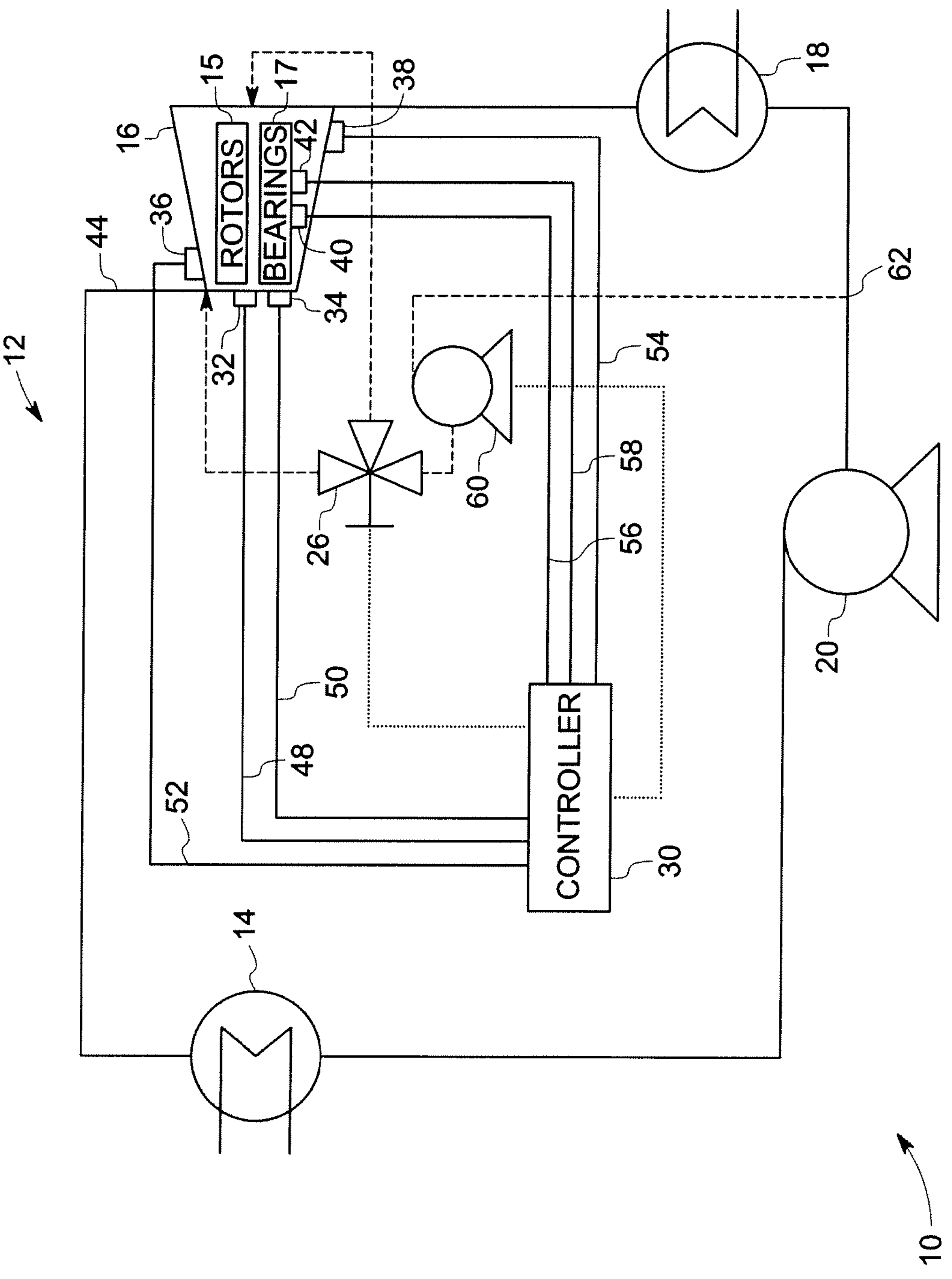
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FIG. 4

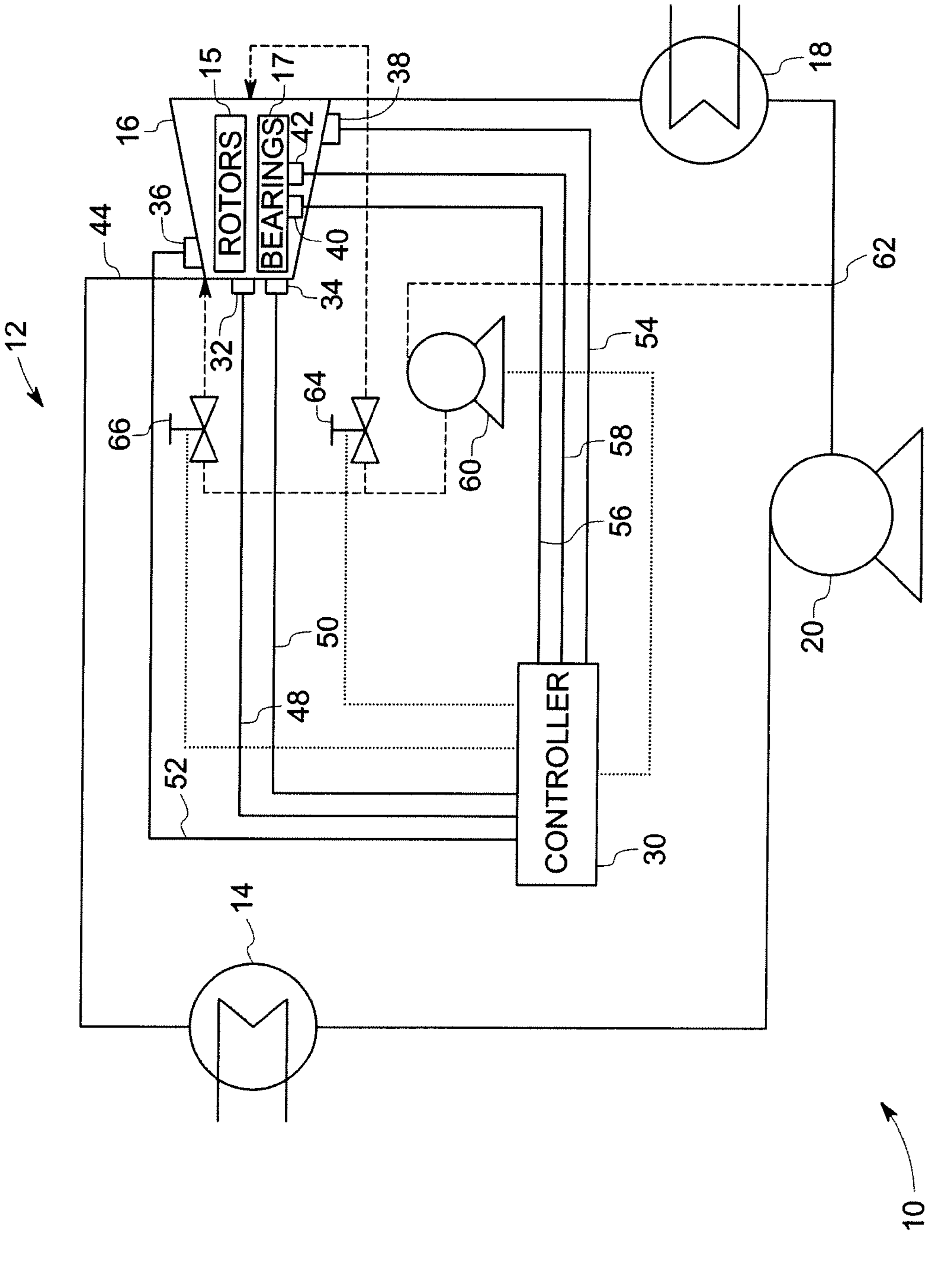
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FIG. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 09 16 6581

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	GB 2 427 002 A (UNIV CITY [GB]) 13 December 2006 (2006-12-13) * page 3, line 15 - page 8, line 26; claims; figures 1,2,5,6 * * abstract *	1,2,7,8, 10	INV. F01K25/06 F01K25/04 F01K21/00
X	US 4 008 573 A (PETRILLO VINCENT CARMEN) 22 February 1977 (1977-02-22) * column 1, line 46 - column 2, line 25; claims 1,2; figure; table * * abstract *	1,3-9	
X A	GB 2 436 129 A (UNIV CITY [GB]) 19 September 2007 (2007-09-19) * page 7, line 8 - page 22, line 16; claims; figures *	1,2,7,8, 10	
A	DE 10 2006 060435 A1 (DENSO CORP [JP]; NIPPON SOKEN [JP]) 26 July 2007 (2007-07-26) * paragraph [0061] - paragraph [0287]; claims; figures * * abstract *	1-10	TECHNICAL FIELDS SEARCHED (IPC) F01K
A,P	DE 10 2007 041944 B3 (MOTOREN UND KRAFTANLAGEN MBH G [DE]) 19 February 2009 (2009-02-19) * paragraph [0034] - paragraph [0046]; claims; figures * * abstract *	1-10	

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	20 January 2010	Zerf, Georges

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20-01-2010

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB 2427002 A	13-12-2006	CN 101194084 A	04-06-2008
		JP 2008542629 T	27-11-2008
		US 2009188253 A1	30-07-2009
US 4008573 A	22-02-1977	NONE	
GB 2436129 A	19-09-2007	WO 2007104970 A2	20-09-2007
DE 102006060435 A1	26-07-2007	NONE	
DE 102007041944 B3	19-02-2009	WO 2009030471 A2	12-03-2009

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82