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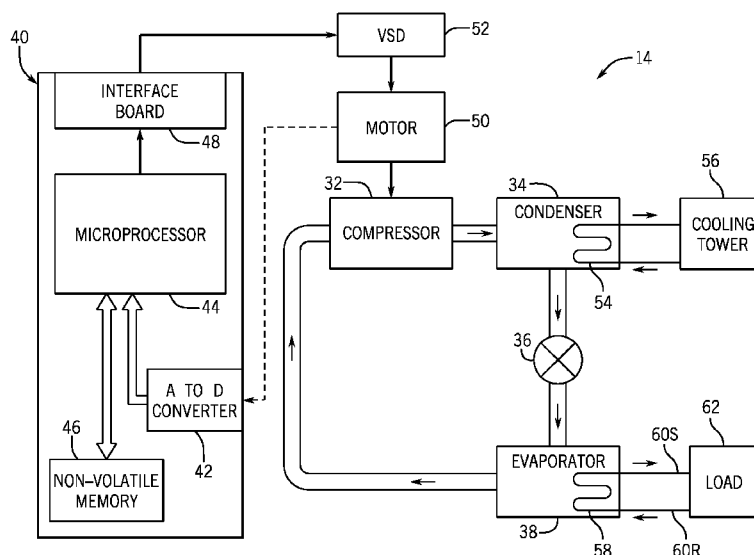


FIG. 3

(57) Abstract: A compression system for a heating, ventilation, air conditioning, and refrigeration (HVAC&R) system includes a compressor configured to direct a working fluid through a vapor compression circuit, and an axial flux motor coupled to the compressor and configured to drive rotation of the compressor.

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AXIAL FLUX MOTOR FOR HVAC&R SYSTEM

Description

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority from and the benefit of U.S. Provisional Application No. 63/471,449, entitled "AXIAL FLUX MOTOR FOR HVAC&R SYSTEM,"
5 filed June 6, 2023, which is herein incorporated by reference in its entirety for all purposes.

BACKGROUND

10 This section is intended to introduce the reader to various aspects of art that may be related to various aspects of the present disclosure, which are described below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present disclosure. Accordingly, it should be understood that these
15 statements are to be read in this light, and not as admissions of prior art.

Heating, ventilation, air conditioning, and refrigeration (HVAC&R) systems, or vapor compression systems, are utilized in residential, commercial, and industrial environments to control environmental properties, such as temperature and
20 humidity, for occupants of the respective environments. The HVAC&R system circulates a working fluid (e.g., refrigerant), which changes phases between vapor, liquid, and combinations thereof in response to exposure to different temperatures and pressures associated with operation of the HVAC&R system. For example, the HVAC&R system may include one or more compressors configured
25 to circulate the working fluid through a working fluid circuit, which may include a heat exchanger configured to transfer heat between the working fluid and another fluid (e.g., cooling fluid) flowing through the heat exchanger. Typically, the compressor is operated via a motor. Some motors include rotating

components that operate to rotate the compressors, thereby enabling the compressors to compress the working fluid and deliver the working fluid to other components of the vapor compression system. Unfortunately, existing motors are susceptible to various inefficiencies that may reduce efficiency of the HVAC&R system and/or may reduce a useful life of components of the HVAC&R system.

SUMMARY

A summary of certain embodiments disclosed herein is set forth below. It should be understood that these aspects are presented merely to provide the reader with a brief summary of these certain embodiments and that these aspects are not intended to limit the scope of this disclosure. Indeed, this disclosure may encompass a variety of aspects that may not be set forth below.

In an embodiment, a compression system for a heating, ventilation, air conditioning, and refrigeration (HVAC&R) system includes a compressor configured to direct a working fluid through a vapor compression circuit, and an axial flux motor coupled to the compressor and configured to drive rotation of the compressor.

In another embodiment, a heating, ventilation, air conditioning, and refrigeration (HVAC&R) system includes a compressor configured to direct a working fluid through a vapor compression circuit, a condenser configured to place the working fluid in a first heat exchange relationship, an evaporator configured to place the working fluid in a second heat exchange relationship, and an axial flux motor coupled to the compressor and configured to drive rotation of the compressor to force flow of the working fluid through the vapor compression circuit.

In another embodiment, a compression system for a heating, ventilation, air conditioning, and refrigeration (HVAC&R) system includes a compressor configured to direct a working fluid through a vapor compression circuit, an axial flux motor coupled to the compressor and configured to drive rotation of the compressor, and a controller. The axial flux motor includes a first rotor including a first set of magnets, a second rotor including a second set of magnets, and a stator including one or more electromagnets and one or more electrical windings disposed around the one or more electromagnets. The controller is configured to activate or deactivate the one or more electromagnets via respective signals sent

through the one or more electrical windings to cause the first rotor and the second rotor to rotate about an axis of rotation of the axial flux motor.

BRIEF DESCRIPTION OF THE DRAWINGS

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Various aspects of this disclosure may be better understood upon reading the following detailed description and upon reference to the drawings in which:

FIG. 1 is a perspective view of an embodiment of a building including a heating, ventilating, air conditioning, and/or refrigeration (HVAC&R) system in a commercial setting, in accordance with an aspect of the present disclosure;

FIG. 2 is a perspective view of an embodiment of a vapor compression system, in accordance with an aspect of the present disclosure;

FIG. 3 is a schematic of an embodiment of a vapor compression system, in accordance with an aspect of the present disclosure;

FIG. 4 is a schematic of an embodiment of a vapor compression system, in accordance with an aspect of the present disclosure;

FIG. 5 is a perspective view of an embodiment of a motor and a compressor for an HVAC&R system, in accordance with an aspect of the present disclosure;

FIG. 6 is an exploded perspective view of an embodiment of a motor for a compressor of an HVAC&R system, in accordance with an aspect of the present disclosure;

FIG. 7 is a schematic of an embodiment of a motor and a compressor for a vapor compression system of an HVAC&R system, in accordance with an aspect of the present disclosure; and

FIG. 8 is a schematic of an embodiment of a motor and a compressor for a vapor compression system of an HVAC&R system, in accordance with an aspect of the present disclosure.

DETAILED DESCRIPTION

One or more specific embodiments of the present disclosure will be described below. These described embodiments are examples of the presently disclosed techniques. Additionally, in an effort to provide a concise description of these
5 embodiments, all features of an actual implementation may not be described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions may be made to achieve the developers' specific goals, such as compliance with system-related and business-related
10 constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

15 When introducing elements of various embodiments of the present disclosure, the articles "a," "an," and "the" are intended to mean that there are one or more of the elements. The terms "comprising," "including," and "having" are intended to be inclusive and mean that there may be additional elements other than the listed
20 elements. Additionally, it should be understood that references to "one embodiment" or "an embodiment" of the present disclosure are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features.

25 As used herein, the terms "approximately," "generally," "substantially," and so forth, are intended to convey that the property value being described may be within a relatively small range of the property value, as those of ordinary skill would understand. For example, when a property value is described as being "approximately" equal to (or, for example, "substantially similar" to) a given
30 value, this is intended to convey that the property value may be within +/- 5%, within +/- 4%, within +/- 3%, within +/- 2%, within +/- 1%, or even closer, of the given value. Similarly, when a given feature is described as being "substantially parallel" to another feature, "generally perpendicular" to another feature, and so forth, this is intended to convey that the given feature is within
35 +/- 5%, within +/- 4%, within +/- 3%, within +/- 2%, within +/- 1%, or even closer, to having the described nature, such as being parallel to another feature,

being perpendicular to another feature, and so forth. Further, it should be understood that mathematical terms, such as "planar," "slope," "perpendicular," "parallel," and so forth are intended to encompass features of surfaces or elements as understood to one of ordinary skill in the relevant art, and should not be rigidly interpreted as might be understood in the mathematical arts. For example, two components having respective axes that are "parallel" with one another is intended to encompass the axes of the components extending substantially parallel to each other (e.g., within related tolerances) without definitively being mathematically parallel.

As briefly discussed above, a heating, ventilation, air conditioning, and/or refrigeration (HVAC&R) system may be configured to operate to satisfy heating and/or cooling demands, such as those within a building, home, industrial facility, or other suitable structure. For example, the HVAC&R system may include a vapor compression system (e.g., a chiller system, heat pump system) that transfers thermal energy between a working fluid (e.g., water, refrigerant, heat transfer fluid) and a fluid to be conditioned (e.g., air, water, or brine). The vapor compression system may include one or more vapor compression circuits (e.g., heat pumps) that each include a condenser and an evaporator that are fluidly coupled to one another via one or more conduits (e.g., vapor compression circuit, working fluid circuit, refrigeration circuit). Further, each vapor compression circuit may include a compressor configured to pressurize and circulate the working fluid through the circuit and, thus, enable the transfer of thermal energy between the working fluid and the fluid to be conditioned via the condenser and/or the evaporator. To facilitate different operating modes (e.g., cooling mode, heating mode, standby mode, idle mode), the vapor compression system may include several controllable features or components, such as valves, expansion devices, a coil fan, a condenser pump, and/or an evaporator pump. The vapor compression system may include a controller configured to determine the mode of operation of the vapor compression system and to control the compressor, valves, expansion devices, pumps, fan, and so forth to operate the vapor compression system in the desired mode. In certain embodiments, the vapor compression system may be a heat pump system configured to facilitate a flow of working fluid through the vapor compression circuit in different directions for different operating modes. In other embodiments, the flow of working fluid through the vapor compression circuit may be in the same direction during multiple (e.g., all) modes of operation.

To compress the working fluid, the compressor may be coupled to a motor configured to drive or power the compressor. For example, the motor may include a rotor shaft supported by a bearing assembly within a motor housing. The rotor shaft may be coupled to a shaft of the compressor, and the shaft of the compressor may be coupled to an impeller of the compressor. In some embodiments, the motor may rotate the rotor shaft, which enables rotation of the shaft of the compressor and the impeller, and thereby enables the compressor to compress the working fluid and drive flow of the working fluid through the working fluid circuit. However, to sufficiently compress the working fluid to a desired operating pressure, the compressor may be configured to operate at high speeds. Traditional HVAC&R systems typically employ certain motors, such as a radial flux motor, to operate the compressor.

Unfortunately, existing motors (e.g., radial flux motors) utilized in HVAC&R systems may be associated with various inefficiencies, higher operating costs, low relative torque to weight ratio to operate the compressor, among other shortcomings. For example, compressors having radial flux motors may include a gear box configured to enable operation of the radial flux motor and/or the compressor. Radial flux motors may also generate flux paths that extend along a stator of the motor, which is generally disposed radially outward from the rotor, and also extend perpendicularly to an axis of rotation of the radial flux motor and/or compressor. Additionally, radial flux motors may include a relatively large number of components configured to operate the radial flux motor. The high number of components may be associated with an increased amount of iron and/or copper in the radial flux motor, which may also result in various inefficiencies. Further still, the stator of the radial flux motor may include two ends disposed on opposite sides of the radial flux motor, and electrical windings may be oriented around (e.g., circumferentially around) the ends of the radial flux motor. Due to the geometry of the stator in a radial flux motor, the windings may bend around the ends of the stator. However, such bends around the stator may cause electrons flowing within the windings to interfere with one another, thereby resulting in efficiency losses. The efficiency losses may be increased as an amount of iron and/or copper within the motor increases. That is, due to the geometry and/or orientation of the stator in a radial flux motor, copper and/or iron ions within components of the radial flux motor may interfere with electrons flowing through the windings, thereby resulting in additional efficiency losses. Thus, existing radial flux motors (e.g., utilized with compressors of HVAC&R

systems) may suffer from various inefficiencies due to the increased flux path lengths, increased amounts of copper and/or iron, and/or bends of the electrical windings along the ends of the stator. Additionally, radial flux motors may include gear boxes and/or may occupy larger footprints, which may result in increased costs associated with manufacture of the radial flux motor and/or increased space occupied by the HVAC&R system.

Accordingly, embodiments of the present disclosure are directed toward an HVAC&R system that includes a compressor with an axial flux motor that is configured to drive the compressor and enable a flow of working fluid through a vapor compression circuit. For example, present embodiments include an axial flux motor having a housing that defines a volume in which components of the axial flux motor are disposed. The axial flux motor may also include a rotor shaft, a rotor, and a stator having windings disposed about, around, and/or on a stator core (e.g., iron stator core, around teeth of the stator core) to define one or more electromagnetics of the stator. In some embodiments, the axial flux motor may include two rotors and/or two stators. The stator(s) and rotor(s) are positioned adjacent to one another and axially offset from one another along a central axis of the axial flux motor (e.g., a rotational axis of the rotor). For example, some embodiments of the axial flux motor may include one stator captured (e.g., sandwiched) between two rotors. Alternatively, the axial flux motor may include one rotor captured (e.g., sandwiched) between two stators. The one or more rotors may be coupled to the rotor shaft and may include magnets (e.g., permanent magnets) coupled thereto and configured to bias the rotors in a particular direction (e.g., rotational direction) based on electrical signals (e.g., current) passed through the windings of the stator. For example, a controller may be configured to transmit electrical signals through the windings of the stator such that the electromagnets of the stator are activated and/or energized, thereby causing the magnets of the rotors to be attracted or repelled toward or away from the activated electromagnets. Further, the rotor shaft of the axial flux motor may be coupled to a shaft of the compressor, such that rotation of the rotor shaft causes the shaft of the compressor to rotate to compress and/or drive the working fluid through the vapor compression circuit.

By utilizing an axial flux motor, a degree of complexity and/or a length of flux paths may be reduced compared to radial flux motors, thereby reducing an amount of losses associated with the length of the flux paths. For example, in

radial flux motors, a flux path may span from a first rotor pole to a first stator tooth disposed on a first end of the stator, through the stator core to a second stator tooth disposed on a second end of the stator, and ultimately return to a second rotor pole. Thus, the flux paths may follow a two-dimensional path and may extend generally perpendicularly to an axis of rotation of the radial flux motor. Conversely, the flux paths of axial flux motors may extend generally along (e.g., parallel to) an axis of rotation of the axial flux motor and may extend for shorter distances compared to the flux paths in radial flux motors. Further, because the flux paths in axial flux motors extend generally along (e.g., parallel to, in alignment with) an axis of rotation of the axial flux motor, the magnetic flux path may be unidimensional, thereby enabling the utilization of various materials (e.g., grain-oriented steel) in the manufacture and assembly of axial flux motors that offer increased amounts of permeability relative to materials utilized in traditional radial flux motors. In this way, electrons traveling through the windings of the stator may travel for shorter distances and/or may travel through components having a reduced amount of copper and/or iron in axial flux motors relative to radial flux motors, thereby reducing an amount of losses associated with larger travel distances and/or increased amounts of copper and/or iron. Additionally, because the electrons traverse a shorter path in axial flux motors compared to radial flux motors, a strength of a magnetic field between the stator and rotors may be increased compared to radial flux motors, thereby increasing efficiency and power density.

Further, it is now recognized that the orientation of the windings in the axial flux motor may provide certain advantages in HVAC&R systems. For example, the orientation of the windings relative to the stator in the axial flux motor may reduce an amount of bending of the windings around ends of the stator (e.g., overhang) compared to that of radial flux motors. In this way, losses associated with electrons interfering with one another around the bends of the stator (as in radial flux motors) may be reduced, thereby enabling increased efficiency of the axial flux motor and therefore the compressor of the HVAC&R system. The reduced amount of overhang may also enable an increase in a number of turns in the windings, thereby increasing the torque to weight ratio of axial flux motors and/or reduce an amount of heat generated by the electrons interfering with one another around the bends of the stator. Additionally, the windings of axial flux motors may be in direct contact with the stator, thereby facilitating more efficient cooling relative to radial flux motors that dissipate heat through the stator core,

which is typically composed of materials having low thermal conductivity. Accordingly, a demand for cooling of components of the HVAC&R system may be reduced, which may enable more efficient and cost-effective operation of the HVAC&R system.

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Further still, axial flux motors may include fewer components and may occupy a reduced footprint relative to radial flux motors, thereby increasing an amount of available space for other components of the HVAC&R system (e.g., and/or reducing an amount of space occupied by the HVAC&R system), enabling improved arrangements of HVAC&R system components, and/or increasing a torque to weight ratio (e.g., increasing density of power) of the HVAC&R system. For example, axial flux motors may not include a gear box that may otherwise result in reduced efficiency of the compressor. Additionally, by employing fewer components, axial flux motors may be associated with reduced amounts of iron and/or copper relative to radial flux motors, which can result in increased efficiency as iron losses are reduced.

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Turning now to the drawings, FIG. 1 is a perspective view of an embodiment of an environment for a heating, ventilation, air conditioning, and refrigeration (HVAC&R) system 10 in a building 12 for a typical commercial setting. The HVAC&R system 10 may include a vapor compression system 14 (e.g., chiller system, heat pump system) that supplies a chilled liquid, which may be used to cool the building 12. The HVAC&R system 10 may also include a boiler 16 to supply warm liquid to heat the building 12 and an air distribution system which circulates air through the building 12. The air distribution system can also include an air return duct 18, an air supply duct 20, and/or an air handler 22. In some embodiments, the air handler 22 may include a heat exchanger that is connected to the boiler 16 and the vapor compression system 14 by conduits 24. The heat exchanger in the air handler 22 may receive either heated liquid from the boiler 16 or chilled liquid from the vapor compression system 14, depending on the mode of operation of the HVAC&R system 10. The HVAC&R system 10 is shown with a separate air handler on each floor of building 12, but in other embodiments, the HVAC&R system 10 may include air handlers 22 and/or other components that may be shared between or among floors.

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FIGS. 2 and 3 are embodiments of the vapor compression system 14 that can be used in the HVAC&R system 10. The vapor compression system 14 may circulate

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a working fluid (e.g., refrigerant) through a circuit starting with a compressor 32. The circuit may also include a condenser 34, an expansion valve(s) or device(s) 36, and a liquid chiller or an evaporator 38. The vapor compression system 14 may further include a control panel 40 that has an analog to digital (A/D) converter 42, a microprocessor 44, a non-volatile memory 46, and/or an interface board 48. Some examples of fluids that may be used as working fluids in the vapor compression system 14 are water vapor, R-718, hydrofluorocarbon (HFC) based working fluids, for example, R-410A, R-407, R-134a, hydrofluoro olefin (HFO), "natural" working fluids like ammonia (NH₃), R-717, carbon dioxide (CO₂), R-744, or hydrocarbon based working fluids, or any other suitable working fluid.

In some embodiments, the vapor compression system 14 may use one or more of a variable speed drive (VSDs) 52, a motor 50, the compressor 32, the condenser 34, the expansion valve or device 36, and/or the evaporator 38. The motor 50 may drive the compressor 32 and may be powered by a variable speed drive (VSD) 52. The VSD 52 receives alternating current (AC) power having a particular fixed line voltage and fixed line frequency from an AC power source, and provides power having a variable voltage and frequency to the motor 50. In other embodiments, the motor 50 may be powered directly from an AC or direct current (DC) power source. The motor 50 may include any type of electric motor that can be powered by a VSD or directly from an AC or DC power source, such as a switched reluctance motor, an induction motor, an electronically commutated permanent magnet motor, or another suitable motor.

The compressor 32 compresses a working fluid vapor and delivers the vapor to the condenser 34 through a discharge passage. In some embodiments, the compressor 32 may be a centrifugal compressor. The working fluid vapor delivered by the compressor 32 to the condenser 34 may transfer heat to a cooling fluid (e.g., water or air) in the condenser 34. The working fluid vapor may condense to a working fluid liquid in the condenser 34 as a result of thermal heat transfer with the cooling fluid. The liquid working fluid from the condenser 34 may flow through the expansion device 36 to the evaporator 38. In the illustrated embodiment of FIG. 3, the condenser 34 is water cooled and includes a tube bundle 54 connected to a cooling tower 56, which supplies the cooling fluid to the condenser.

The liquid working fluid delivered to the evaporator 38 may absorb heat from another cooling fluid, which may or may not be the same cooling fluid used in the condenser 34. The liquid working fluid in the evaporator 38 may undergo a phase change from the liquid working fluid to a working fluid vapor. As shown in the illustrated embodiment of FIG. 3, the evaporator 38 may include a tube bundle 58 having a supply line 60S and a return line 60R connected to a cooling load 62. The cooling fluid of the evaporator 38 (e.g., water, ethylene glycol, calcium chloride brine, sodium chloride brine, or any other suitable fluid) enters the evaporator 38 via return line 60R and exits the evaporator 38 via supply line 60S. The evaporator 38 may reduce the temperature of the cooling fluid in the tube bundle 58 via thermal heat transfer with the working fluid. The tube bundle 58 in the evaporator 38 can include a plurality of tubes and/or a plurality of tube bundles. In any case, the vapor working fluid exits the evaporator 38 and returns to the compressor 32 by a suction line to complete the cycle.

FIG. 4 is a schematic of the vapor compression system 14 with an intermediate circuit 64 incorporated between the condenser 34 and the expansion device 36. The intermediate circuit 64 may have an inlet line 68 that is directly fluidly connected to the condenser 34. In other embodiments, the inlet line 68 may be indirectly fluidly coupled to the condenser 34. As shown in the illustrated embodiment of FIG. 4, the inlet line 68 includes a first expansion device 66 positioned upstream of an intermediate vessel 70. In some embodiments, the intermediate vessel 70 may be a flash tank (e.g., a flash intercooler). In other embodiments, the intermediate vessel 70 may be configured as a heat exchanger or a "surface economizer." In the illustrated embodiment of FIG. 4, the intermediate vessel 70 is used as a flash tank, and the first expansion device 66 is configured to lower the pressure of (e.g., expand) the liquid working fluid received from the condenser 34. During the expansion process, a portion of the liquid may vaporize, and thus, the intermediate vessel 70 may be used to separate the vapor from the liquid received from the first expansion device 66.

Additionally, the intermediate vessel 70 may provide for further expansion of the liquid working fluid because of a pressure drop experienced by the liquid working fluid when entering the intermediate vessel 70 (e.g., due to a rapid increase in volume experienced when entering the intermediate vessel 70). The vapor in the intermediate vessel 70 may be drawn by the compressor 32 through a suction line 74 of the compressor 32. In other embodiments, the vapor in the intermediate

vessel may be drawn to an intermediate stage of the compressor 32 (e.g., not the suction stage). The liquid that collects in the intermediate vessel 70 may be at a lower enthalpy than the liquid working fluid exiting the condenser 34 because of the expansion in the expansion device 66 and/or the intermediate vessel 70. The liquid from intermediate vessel 70 may then flow in line 72 through a second expansion device 36 to the evaporator 38.

It should be appreciated that any of the features described herein may be incorporated with the vapor compression system 14 or any other suitable HVAC&R systems. For example, the present techniques may be incorporated with any HVAC&R system having a compressor, such as the compressor 32. The discussion below describes the present techniques incorporated with embodiments of the compressor 32 configured as a single stage compressor. However, it should be noted that the systems and methods described herein may be incorporated with other embodiments of the compressor 32 and HVAC&R system 10.

As noted above, present embodiments are directed toward an HVAC&R system having an axial flux motor configured to operate to drive a compressor, such as the compressor 32. For example, FIG. 5 is a perspective view of a portion of an embodiment of the HVAC&R system 10, illustrating a compression system 99 having a motor 100 (e.g., axial flux motor) configured to drive the compressor 32 of the HVAC&R system 10. The motor 100 includes a housing 102 configured to couple to the compressor 32. In accordance with the present techniques, the motor 100 (e.g., housing 102) may be directly coupled to the compressor 32 (e.g., without an intervening gearbox), which may enable more efficient operation of the compressor 32, as well as more compact packaging of the HVAC&R system 10. During operation of the compressor 32, the axial flux motor 100 may rotate a rotor shaft at various rotation rates or speeds along an axis of rotation 104 of the axial flux motor 100 to power or drive a shaft (and thus an impeller) of the compressor 32. It should be appreciated that the axis of rotation 104 may correspond to an axis of rotation of components of the compressor 32 (e.g., an impeller of the compressor 32).

The axial flux motor 100 may be communicatively coupled, via connections 106, to a control system 150 (e.g., controller, control panel 40) configured to control operation of the motor 100. The control system 150 may include processing

circuitry 152 and a memory 154 (e.g., memory device) configured to store instructions that, when executed by the processing circuitry 152, cause the processing circuitry 152 to operate the motor 100 at a particular speed to satisfy load demands of the compressor 32. For example, based on control signals
5 received from the control system 150 (or another suitable control device or system), the motor 100 may actuate rotation of the rotor shaft from a resting state (e.g., corresponding to zero revolutions per minute [RPM]) to an activated or operating state (e.g., corresponding to approximately 500 RPM, 1000 RPM, 2500 RPM, 5000 RPM, and/or another suitable speed), as described in greater
10 detail below.

As noted above, by incorporating the axial flux motor 100 with the HVAC&R system 10 to drive operation of the compressor 32, the compressor 32 may not include a gear box, which may reduce costs associated with manufacture and
15 assembly of the HVAC&R system 10. Losses (e.g., efficiency losses) associated with inclusion of a gear box are also avoided, resulting in more efficient operation of the compressor 32 and the HVAC&R system 10. Additionally, flux paths of the motor 100 may be simplified and flux path lengths of the motor 100 may be reduced, thereby reducing passive losses associated with the more complex
20 and/or longer relative flux paths seen in radial flux motors. That is, electrons traveling along flux paths within the axial flux motor 100 may travel for shorter distances and/or may travel through components having a reduced amount of iron relative to radial flux motors, thereby reducing an amount of losses associated with increased travel distances and/or increased amounts of iron.
25 Further still, by utilizing the axial flux motor 100, heat dissipation losses may be reduced, as well as iron core losses, thereby increasing an efficiency associated with the motor 100.

For example, the axial flux motors 100 discussed herein may employ fewer
30 components having a reduced amount of iron relative to radial flux motors. By reducing an amount of iron associated with the axial flux motor, iron losses may be reduced. Additionally, in radial flux motors, flux paths may travel through the core in multiple (e.g., two or more) dimensions across an axis of rotation of the radial flux motor (e.g., across an iron core), whereas in axial flux motors, the flux
35 paths travel through the core in a single dimension that is substantially parallel to the axis of rotation. In this way, axial flux motors may be associated with reduced iron losses compared to radial flux motors due to the orientation of the

flux paths traveling through the core in a single dimension. Furthermore, as discussed below, the windings of the stator of the axial flux motor 100 may be oriented such that coil overhang and/or bending of the windings around ends of the stator may be reduced and/or substantially eliminated. For example, as
5 discussed above, radial flux motors may include a stator having windings bending around (e.g., axially outward from) opposite ends of the stator. Because the windings bend around the ends of the stator, electrons traveling through the windings may communicate and/or interfere with one another, thereby resulting in reduced efficiency. Thus, the configuration of the axial flux motor 100 may
10 eliminate coil overhang and/or bending of the windings around ends of the stator, thereby reducing copper losses and increasing efficiency relative to a radial flux motor.

Additionally, the axial flux motor 100 may be better suited in the HVAC&R
15 systems utilizing low pressure working fluids. That is, the axial flux motor 100 may enable direct drive of the compressor 32, more efficient operation at part loads and/or lower compressor 32 speeds, and/or may be particularly suited for low pressure working fluids, such as R1233zd, that may be circulated through a working fluid circuit by the compressor 32. Thus, utilization of the axial flux
20 motor 100 may enable improved operation of the HVAC&R system 10 utilizing low global warming potential (GWP) working fluids. In this way, the present techniques enable a reduction in generation of greenhouse gases and emissions, thereby mitigating climate change.

25 It may be beneficial to operate the compressor 32 with lower impeller tip speeds when using low pressure working fluid. Additionally, due to the low pressure working fluid flow, the density of the working fluid may also be reduced. As a result, impeller sizes may be increased to increase a surface area of the impeller, thereby enabling the impeller to direct the low pressure working fluid into a
30 volute of the compressor 32 to compress the low pressure working fluid. Thus, the axial flux motor 100 may be particularly well-suited for HVAC&R systems employing low pressure working fluids (e.g., low GWP working fluids) because the axial flux motor 100 is configured to operate with higher torque to weight ratios relative to radial flux motors, thereby enabling the axial flux motor 100 to
35 operate larger impellers at lower relative impeller tip speeds to sufficiently compress and direct the low pressure working fluid through the HVAC&R system 10. Furthermore, as noted above, driving compression of a low pressure working

fluid through a vapor compression circuit via the axial flux motor 100 may enable operation of the HVAC&R system 10 with a lower environmental impact (e.g., reduced greenhouse gas emissions).

FIG. 6 is an exploded perspective view of an embodiment of the motor 100 (e.g., axial flux motor) configured to operate the compressor 32. The housing 102 defines a volume 108 (e.g., cavity) configured to house components of the motor 100. For example, a rotor shaft 110, a first rotor 112, a second rotor 114, and a stator 116 may be disposed within the volume 108. Based on electrical signals sent to windings 118 of the stator 116 from the control system 150, the first and second rotors 112, 114 may rotate about the axis of rotation 104 of the motor 100 to cause rotation the rotor shaft 110. For example, the stator 116 may include one or more windings 118 (e.g., coils) disposed around a stator core 119 to define one or more electromagnets 120 configured to receive an electrical current from the control system 150. Upon directing current to flow through windings 118 of the electromagnets 120, the one or more electromagnets 120 may be activated, thereby enabling the first and second rotors 112, 114 to rotate about the axis of rotation 104. For example, each of the first and second rotors 112, 114 may include one or more fixed magnets 122 (e.g., permanent magnets, rare earth magnets) configured to bias the rotors 112, 114 in a particular direction based on interaction between the magnets 122 and an electrical field generated via the one or more electromagnets 120 of the stator 116. As illustrated, the rotors 112, 114 may be coupled to the rotor shaft 110, such that as the rotors 112, 114 are rotated, the rotor shaft 110 also rotates. The rotor shaft 110 may be coupled to a shaft of the compressor 32 which may be configured to drive an impeller of the compressor 32. Thus, rotation of the rotor shaft 110 may drive rotation of the shaft of the compressor 32, thereby enabling the compressor 32 to compress a working fluid through a vapor compression circuit, such as the vapor compression circuit 14.

During operation of the motor 100, flux paths 124 may be generated between the first and second rotors 112, 114 and the stator 116, thereby causing the rotors 112, 114 to rotate about the axis of rotation 104. In certain embodiments, the magnets 122 of the rotors 112, 114 may be arranged about the axis of rotation 104 in an alternating configuration such that each adjacent magnet 122 is associated with a different polarity (e.g., north polarity, south polarity). For example, a first magnet 122A of the first rotor 112 may be associated with a

north polarity (e.g., north pole configuration), and thus, each of the two magnets 122 adjacent to the first magnet 122A may be associated with a south polarity (e.g., south pole configuration). Meanwhile, the windings 118 of each of the magnets 120 may enable each of the magnets 120 to alternate polarity depending on a direction of the electrical signal (e.g., phase signal) directed through the windings 118. For example, the controller 150 may be configured to modify a polarity of each of the respective magnets 120 based on a direction of the phase signal sent through the corresponding windings 118 of an associated magnet 120. Thus, each of the magnets 120 may be energized with an electrical signal having a particular direction (e.g., via the controller 150), thereby enabling a desired polarity of a particular magnet 120 to be achieved.

As an example, during operation, a first set of coils 118A associated with electromagnet 120A may receive a signal from the controller 150. The signal may be directed through the coils 118A in a particular direction such that the electromagnet 120A has a north pole configuration. Meanwhile, the first magnet 122A on the first rotor 112 may have a south pole configuration. Thus, upon sending the activation signal through the windings 118A of the electromagnet 120A in the particular direction, the first magnet 122A may be attracted toward the electromagnet 120A, thereby generating a tangential force 130 on the first rotor 112 to cause the first rotor 112 to rotate. Simultaneously, as the first rotor 112 rotates, a second magnet 122B positioned adjacent to the first magnet 122A (and thus having a north pole configuration), may align (e.g., along the axis of rotation 104) with the electromagnet 120A. Because the second magnet 122B has a north pole configuration and because the electromagnet 120A has a north pole configuration, the two magnets may repel each other, thereby creating an additional tangential force 132 on the first rotor 112. Each of the tangential forces 130, 132 may be added together, thereby enabling rotation of the rotor 112 relative to the stator 116.

Once the magnet 122A aligns with the electromagnet 120A along the axis of rotation 104, the net force on the magnet 122A of the rotor 112 may be zero. However, the rotor 112 may continue to rotate due to inertia. As the rotor 112 continues to rotate, the controller 150 may send a signal to deactivate the windings 118A of the electromagnet 120A, and may send an additional signal to activate the windings 118B of the electromagnet 120B. The signal may travel through the windings 118B of the electromagnet 120B such that the

electromagnet 120B has a north pole configuration. Thus, similar to the example above, the magnet 122A (which may have a south pole configuration) may be attracted to the electromagnet 120B while the magnet 122B (which may have a north pole configuration) may be repelled from the electromagnet 120B, thereby generating the tangential forces 130, 132 that enable the rotor 112 to continue rotating. It should be appreciated that, in certain embodiments, the controller 150 may incrementally adjust (e.g., gradually adjust, adjust in a step-wise fashion) a magnitude of the activation and/or deactivation signal (e.g., a magnitude of the phase signal) sent to a respective set of windings 118. For example, during activation of a particular electromagnet 120 (e.g., during activation of windings 118 of an electromagnet 120), a magnitude of the activation signal may increase from zero to an upper threshold limit, and during deactivation of a particular electromagnet (e.g., during deactivation of windings 118 of an electromagnet 120), a magnitude of the deactivation signal may decrease from an upper threshold limit to zero. In this way, transient outputs of torque may be reduced, thereby resulting in a more consistent torque output.

In certain embodiments, various sensors 160 may be employed by the motor 100 to determine a position of the magnets 122 of the rotors 112, 114 relative to the electromagnets 120 of the stator 116. For example, the sensors 160 may include motion and/or position sensors configured to detect a position of the magnets 122 of the rotors 112, 114. In certain embodiments, the sensors 160 may be coupled (e.g., mounted) on the stator 116. The sensors 160 may be communicatively coupled to the controller 150, thereby enabling the controller 150 to receive data and/or feedback from the sensors 160 and, in response, determine when to send activation and/or deactivation signals to respective windings 118 of the electromagnets 120. Using the example above, the controller 150, based on feedback from the sensors 160, may determine to decrease the phase signal sent to the electromagnet 120A and increase a phase signal sent to the subsequent electromagnet 120 (e.g., magnet 120 adjacent magnet 120A) based the first magnet 122A of the first rotor 112 aligning with the electromagnet 120A along the axis of rotation 104.

In certain embodiments, the fixed magnets 122 may be disposed a threshold distance 162 from the axis of rotation 104 of the motor 100. The distance may be greater than a distance between fixed magnets on a rotor of a radial flux motor and the axis of rotation of the radial flux motor. By placing the fixed magnets 122

a threshold distance away from the axis of rotation 104 of the motor 100, a torque to weight ratio of the motor 100 may be increased. For example, a magnitude of the torque of the motor 100 may be a function of a tangential force generated (e.g., a magnetic force generated via interaction between the
5 electromagnets 120 and the fixed magnets 122) multiplied by a distance between the tangential force and the axis of rotation 104. Thus, by placing the magnets 122 a threshold distance from the axis of rotation 104, the distance between the magnets 122 and the axis of rotation 104 may be increased, thereby increasing the torque of the motor 100.

10 As illustrated, the flux paths 124 may generally extend in a direction substantially similar (e.g., along) to the direction of the axis of rotation 104. For example, in certain embodiments, the flux paths 124 may generally extend in a direction that is substantially parallel to the axis of rotation 104. In this way, flux path lengths
15 may be reduced relative to flux path lengths in radial flux motors, thereby resulting in increased efficiency. Additionally, due to the arrangement of the components of the axial flux motor 100, the axial flux motor 100 may be oriented such that the axis of rotation 104 is oriented along a vertical axis, thereby decreasing an angle of compressor suction (e.g., from 90 degrees to 45 degrees,
20 from 90 degrees to zero degrees) and/or increasing an angle of compressor discharge (e.g., from 45 degrees to 90 degrees). In this way, flow losses (e.g., pressure drop, fluidic restrictions, etc.) induced and/or imparted to a working fluid directed through the compressor 32 (e.g., via bends in suction conduit extending to the compressor 32) may be reduced, which may result in more
25 efficient operation of the compressor 32 and the HVAC&R system 10 generally.

For example, FIG. 7 is a schematic view of an embodiment of the HVAC&R system 10 having the axial flux motor 100 oriented along a vertical axis 200 (e.g., axis of rotation 104 of the axial flux motor 100 oriented along the vertical axis 200) of
30 the HVAC&R system 10 and configured to drive the compressor 32. As illustrated in FIG. 7, by employing the axial flux motor 100 to operate the compressor 32 in accordance with the present techniques, a suction line 202 (e.g., suction conduit) extending from the evaporator 38 to a suction side (e.g., inlet) of the compressor 32 may be oriented linearly along the vertical axis 200 of the HVAC&R system 10
35 and generally in alignment with the axis of rotation 104. In this way, by employing the axial flux motor 100 to drive the compressor 32 and orienting the axis of rotation 104 of the axial flux motor 100 along the vertical axis 200, an

elbow or bend in the suction line 202 may be substantially reduced and/or eliminated, thereby enabling the compressor 32 to more efficiently draw the working fluid from the evaporator 38 and into an inlet (e.g., a suction side) of the compressor 32. For example, the compressor 32 may draw (e.g., linearly draw) the working fluid into the compressor 32 from the evaporator 38 with reduced flow losses relative to systems incorporating a bent or arcuate suction conduit. Thus, the HVAC&R system 10 may be operated more efficiently, such as with reduced energy consumption and reduced generation of corresponding emissions.

In certain embodiments, a position of the condenser 34 may be adjusted to further reduce flow losses and/or pressure drops induced and/or imparted to the working fluid circulated through the HVAC&R system 10. For example, as illustrated in FIG. 7, the condenser 34 may be positioned higher along the vertical axis 200 relative to the evaporator 38. In this way, an elbow or bend in a discharge line 204 from a discharge side of the compressor 32 to the condenser 34 may be substantially reduced and/or eliminated, thereby enabling the compressor 32 to more efficiently discharge the working fluid toward the condenser 34. For example, the compressor 32 may discharge the working fluid into the condenser 34 with reduced flow losses and/or pressure losses relative to systems incorporating a bent or arcuate discharge conduit. Accordingly, the HVAC&R system 10 may be operated more efficiently, such as with reduced energy consumption and reduced generation of corresponding emissions.

In certain embodiments, the axis of rotation 104 of the motor 100 may extend at an angle (e.g., non-zero angle, an oblique angle) relative to the vertical axis 200. For example, FIG. 8 is a schematic view of an embodiment of the HVAC&R system 10 having the axial flux motor 100 oriented at an angle (e.g., non-zero angle, oblique angle, 45 degree angle) relative to the vertical axis 200 (e.g., oriented relative to a direction of gravity) of the HVAC&R system 10 and configured to drive the compressor 32. As illustrated in FIG. 8, by employing the axial flux motor 100 to operate the compressor 32, the suction line 202 from the evaporator 38 to the suction side of the compressor 32 may be oriented at an angle relative to the vertical axis 200 (e.g., 45 degree angle) and may extend linearly between the evaporator 36 and the suction side of the compressor 32. That is, an elbow or bend in the suction line 202 typically included in existing systems may be substantially reduced and/or eliminated, thereby enabling the compressor 32 to more efficiently draw the working fluid into the suction side of

the compressor 32. Similarly, the discharge line 204 may be oriented linearly from the discharge side of the compressor 32 to the condenser 34. That is, by orienting the axial flux motor 100 at an angle (e.g., non-zero) relative to the vertical axis, the compressor 32 may discharge (e.g., directly discharge) the working fluid to the condenser 34. That is, an elbow or bend in the discharge line 204 may be substantially reduced and/or eliminated, thereby enabling the compressor 32 to more efficiently discharge the working fluid to the condenser 34. As a result, the compressor 32 (e.g., the motor 100) and the HVAC&R system 10 may be operated with reduced energy consumption.

In embodiments in which the suction line 202 and/or discharge line 204 does include a bent or arcuate conduit, it should be appreciated that embodiments of the present disclosure may employ smaller build-up rates within the arcuate or bent sections of the conduits relative to traditional suction and/or discharge conduits. That is, the build-up rate of a bent or arcuate section of the suction line 202 and/or discharge line 204 may be less than a threshold build-up rate. In this way, flow losses associated with bent or arcuate sections of conduits having less than the threshold build-up rate may be reduced relative to bent or arcuate sections of conduits having greater than the threshold build-up rate.

The techniques presented and claimed herein are referenced and applied to material objects and concrete examples of a practical nature that demonstrably improve the present technical field and, as such, are not abstract, intangible or purely theoretical. Further, if any claims appended to the end of this specification contain one or more elements designated as "means for [perform]ing [a function]..." or "step for [perform]ing [a function]...", it is intended that such elements are to be interpreted under 35 U.S.C. 112(f). However, for any claims containing elements designated in any other manner, it is intended that such elements are not to be interpreted under 35 U.S.C. 112(f).

While only certain features and embodiments have been illustrated and described, many modifications and changes may occur to those skilled in the art (e.g., variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters (e.g., temperatures, pressures, etc.), mounting arrangements, use of materials, colors, orientations, etc.) without materially departing from the novel teachings and advantages of the subject matter recited in the claims. The order or sequence of any process or method

steps may be varied or re-sequenced according to alternative embodiments. 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 disclosure.

- 5 Furthermore, in an effort to provide a concise description of the exemplary embodiments, all features of an actual implementation may not have been described (i.e., those unrelated to the presently contemplated best mode of carrying out the disclosure, or those unrelated to enabling the claimed disclosure). It should be appreciated that in the development of any such actual
- 10 implementation, as in any engineering or design project, numerous implementation specific decisions may be made. Such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure, without undue experimentation.

TYCO FIRE & SECURITY GMBH

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AXIAL FLUX MOTOR FOR HVAC&R SYSTEM

Claims

1. A compression system for heating, ventilation, air conditioning, and refrigeration (HVAC&R) system, comprising:
 - a compressor configured to direct a working fluid through a vapor compression circuit; and
 - 5 - an axial flux motor coupled to the compressor and configured to drive rotation of the compressor.
2. The compression system of claim 1, wherein the axial flux motor comprises:
 - 10 - a rotor shaft coupled to a shaft of the compressor;
 - a first rotor comprising a first set of magnets;
 - a second rotor comprising a second set of magnets; and
 - a stator comprising:
 - one or more electromagnets; and
 - 15 - one or more electrical windings disposed around the one or more electromagnets, wherein activation of the one or more electromagnets is configured to cause the first rotor and the second rotor to rotate about an axis of rotation of the axial flux motor.
- 20 3. The compression system of claim 2, comprising a controller communicatively coupled to the one or more electrical windings, wherein the controller is configured to send respective signals to activate or deactivate the one or more electromagnets to cause
25 the first rotor and the second rotor to rotate about the axis of rotation of the axial flux motor.

4. The compression system of claim 3,
wherein the controller is configured to control a polarity of the one or
more electromagnets based on a direction of the respective signal sent
through the one or more electrical windings.
5. The compression system of claim 3 or 4,
wherein activation of the one or more electromagnets via the controller is
configured to generate magnetic flux lines between the first set of
magnets, the one or more electromagnets, and the second set of magnets.
6. The compression system of claim 5,
wherein the magnetic flux lines extend substantially parallel to the axis of
rotation of the axial flux motor.
7. The compression system of one of claims 3 to 6,
wherein the controller is configured to increase a magnitude of the
respective signal from zero to an upper threshold limit to activate an
electromagnet of the one or more electromagnets, and decrease the
magnitude of the respective signal from the upper threshold limit to zero
to deactivate the electromagnet of the one or more electromagnets.
8. The compression system of claim 7,
wherein the controller is configured to activate the one or more
electromagnets in a sequence such that a first electromagnet of the one or
more electromagnets in the sequence is activated and deactivated before a
second electromagnet of the one or more electromagnets in the sequence
is activated and deactivated.
9. The compression system of one of claims 1 to 8,
wherein the first set of magnets and the second set of magnets comprise
rare earth magnets.
10. A heating, ventilation, air conditioning, and refrigeration (HVAC&R)
system, comprising:
- a compressor configured to direct a working fluid through a vapor
compression circuit;

- a condenser configured to place the working fluid in a first heat exchange relationship;
- an evaporator configured to place the working fluid in a second heat exchange relationship; and
- 5 - an axial flux motor coupled to the compressor and configured to drive rotation of the compressor to force flow of the working fluid through the vapor compression circuit.

11. The HVAC&R system of claim 10,
10 wherein the axial flux motor comprises:

- a rotor shaft coupled to an impeller of the compressor;
- at least one rotor comprising one or more magnets; and
- a stator comprising one or more electromagnets and one or more electrical windings disposed around the one or more electromagnets.

12. The HVAC&R system of claim 11,
comprising a controller configured to send respective signals through the one or more electrical windings to energize the one or more electromagnets, wherein energization of the one or more electromagnets is
20 configured to cause the at least one rotor to rotate about an axis of rotation of the axial flux motor.

13. The HVAC&R system of claim 12,
wherein the one or more magnets are disposed a threshold distance away
25 from the axis of rotation of the axial flux motor.

14. The HVAC&R system of one of claims 10 to 13,
wherein an axis of rotation of the axial flux motor is oriented along a vertical axis.

15. The HVAC&R system of claim 14,
comprising a suction line disposed between the evaporator and a suction side of the compressor, wherein the suction line extends linearly along the vertical axis from the evaporator to the suction side of the compressor.

16. The HVAC&R system of claim 14 or 15,
wherein the condenser is positioned higher along the vertical axis relative
to the evaporator.

17. The HVAC&R system of one of claims 10 to 16,
wherein an axis of rotation of the axial flux motor is oriented at an angle
relative to a vertical axis extending through the axial flux motor and
oriented relative to a direction of gravity.

18. The HVAC&R system of claim 17,
comprising a discharge line disposed between a discharge side of the
compressor and the condenser, wherein the discharge line extends linearly
from the discharge side of the compressor to the condenser to linearly
direct the working fluid from the discharge side of the compressor into the
condenser.

19. A compression system for a heating, ventilation, air conditioning, and
refrigeration (HVAC&R) system, comprising:

- a compressor configured to direct a working fluid through a vapor
compression circuit;
- an axial flux motor coupled to the compressor and configured to drive
rotation of the compressor, wherein the axial flux motor comprises:
 - a first rotor comprising a first set of magnets;
 - a second rotor comprising a second set of magnets; and
 - a stator comprising one or more electromagnets and one or more
electrical windings disposed around the one or more
electromagnets; and
 - a controller communicatively coupled to the one or more electrical
windings and configured to activate or deactivate the one or more
electromagnets via respective signals sent through the one or more
electrical windings to cause the first rotor and the second rotor to
rotate about an axis of rotation of the axial flux motor.

20. The compression system of claim 19,
comprising one or more sensors communicatively coupled to the controller,
wherein the one or more sensors are configured to detect respective

positions of the first set of magnets and the second set of magnets relative to the one or more electromagnets, and wherein the controller is configured to control activation or deactivation of the one or more electromagnets based on the respective positions of the first set of magnets and the second set of magnets relative to the one or more electromagnets.

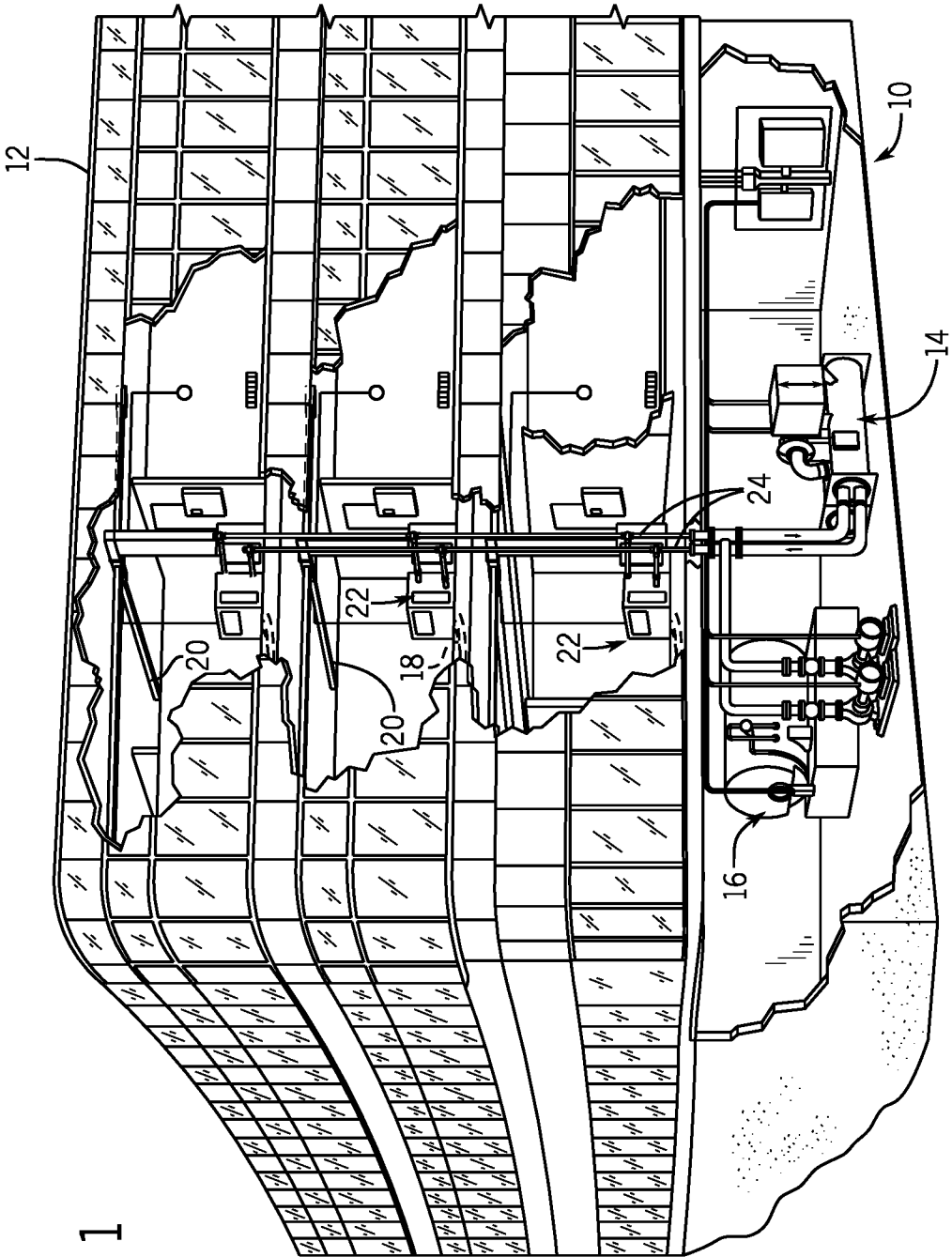


FIG. 1

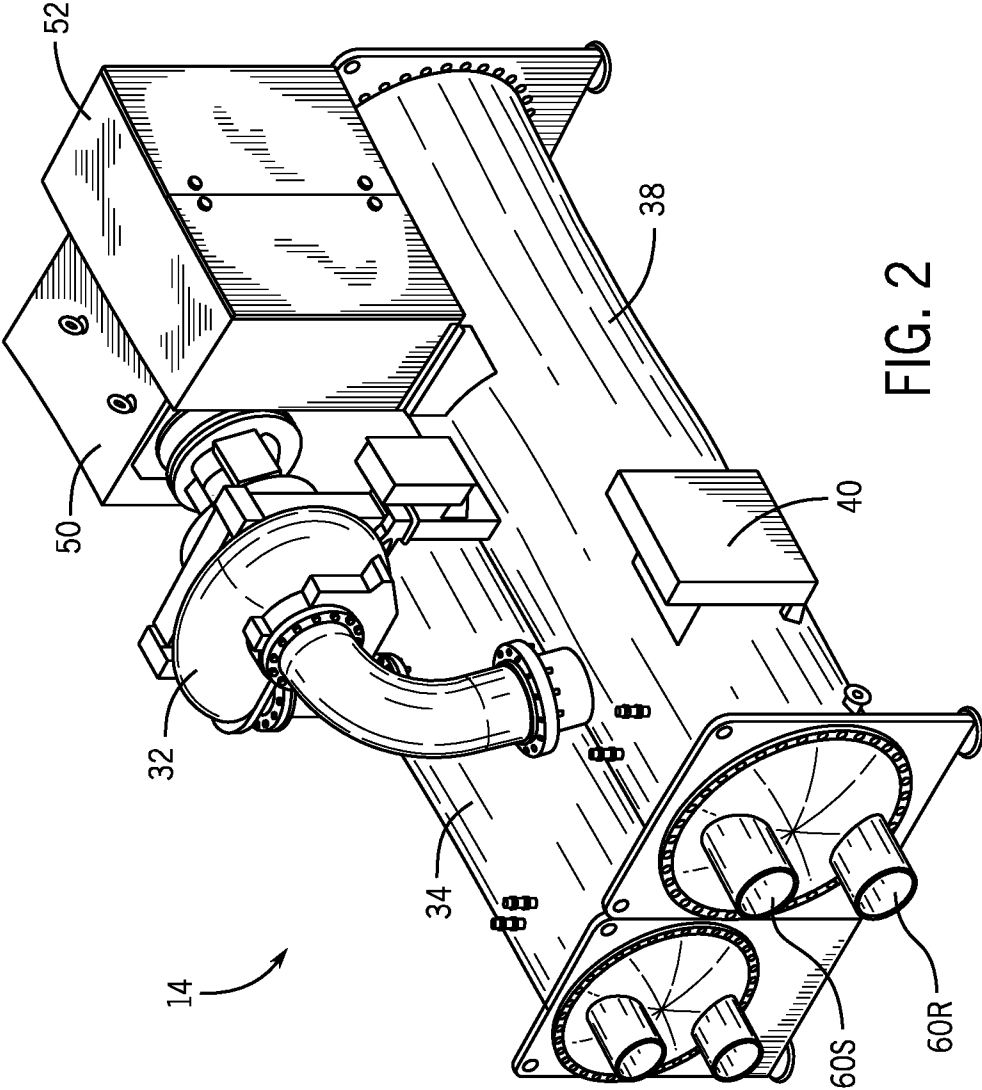


FIG. 2

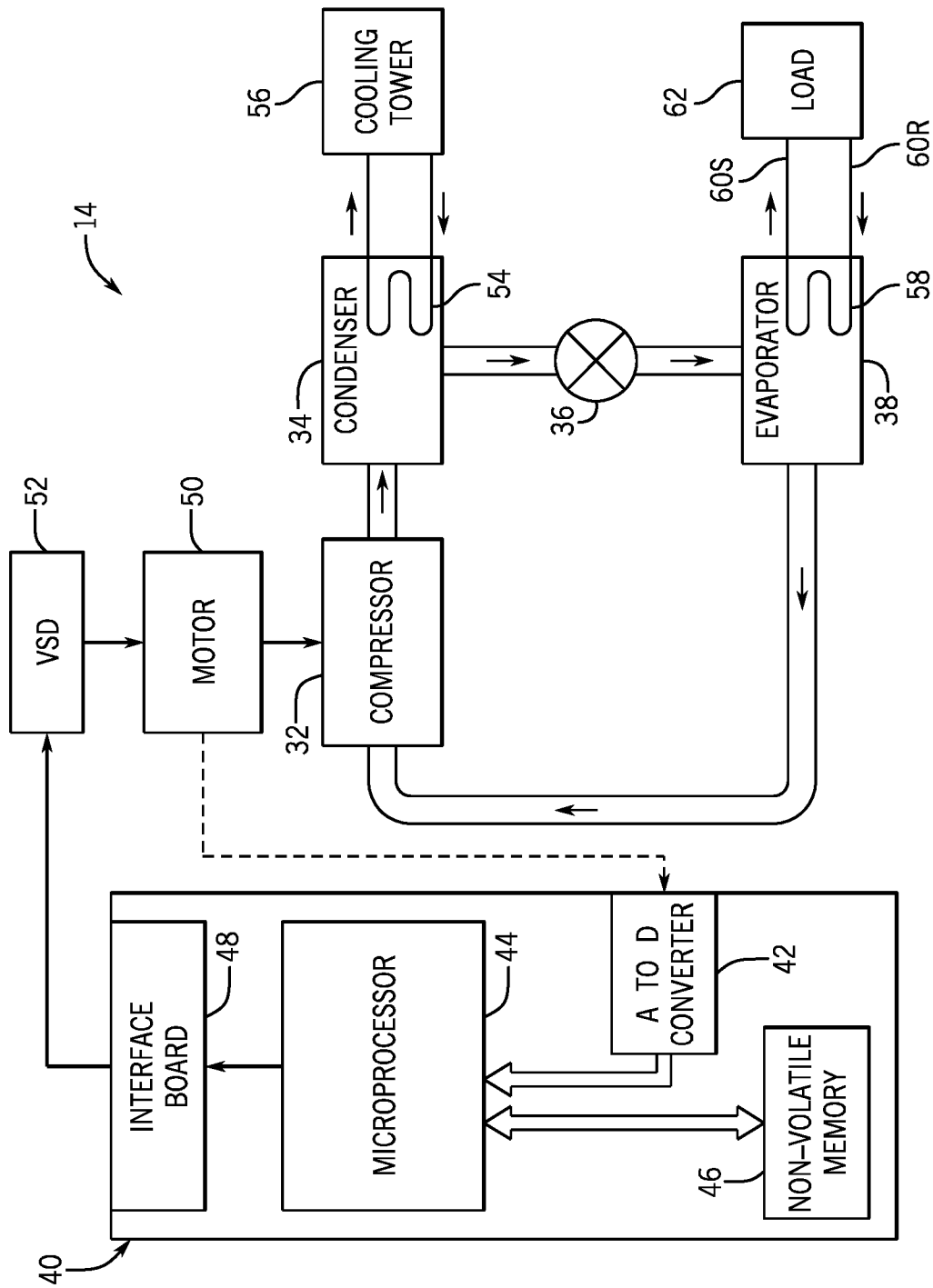


FIG. 3

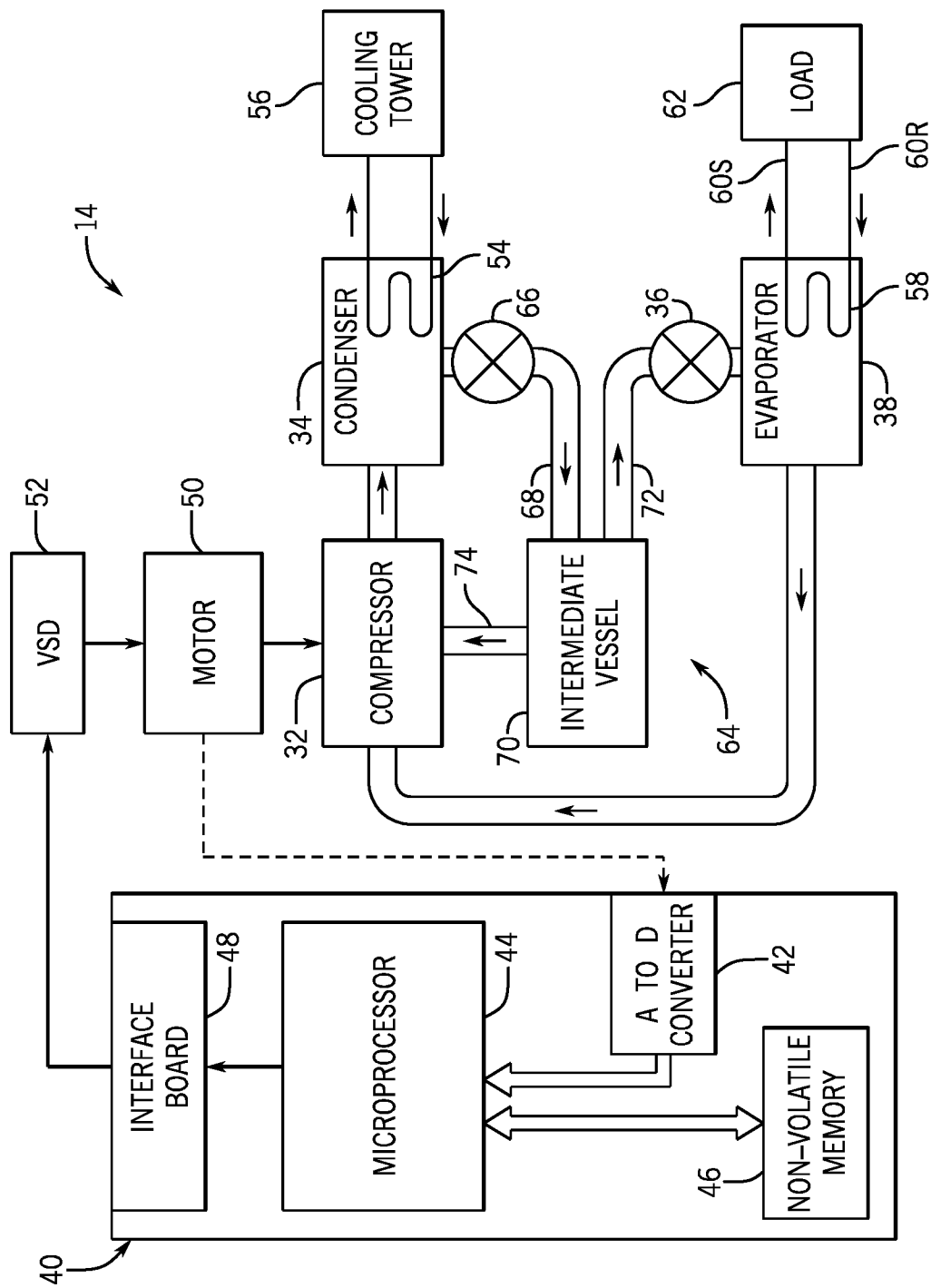


FIG. 4

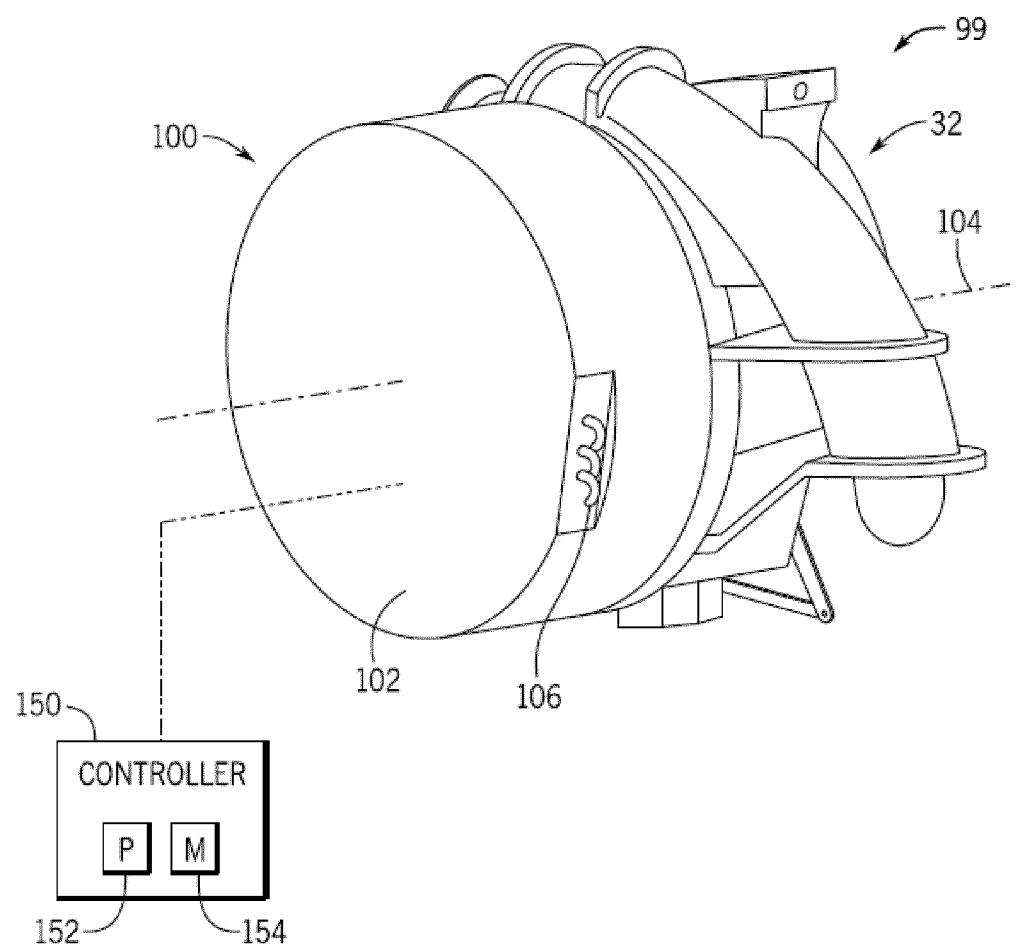


FIG. 5

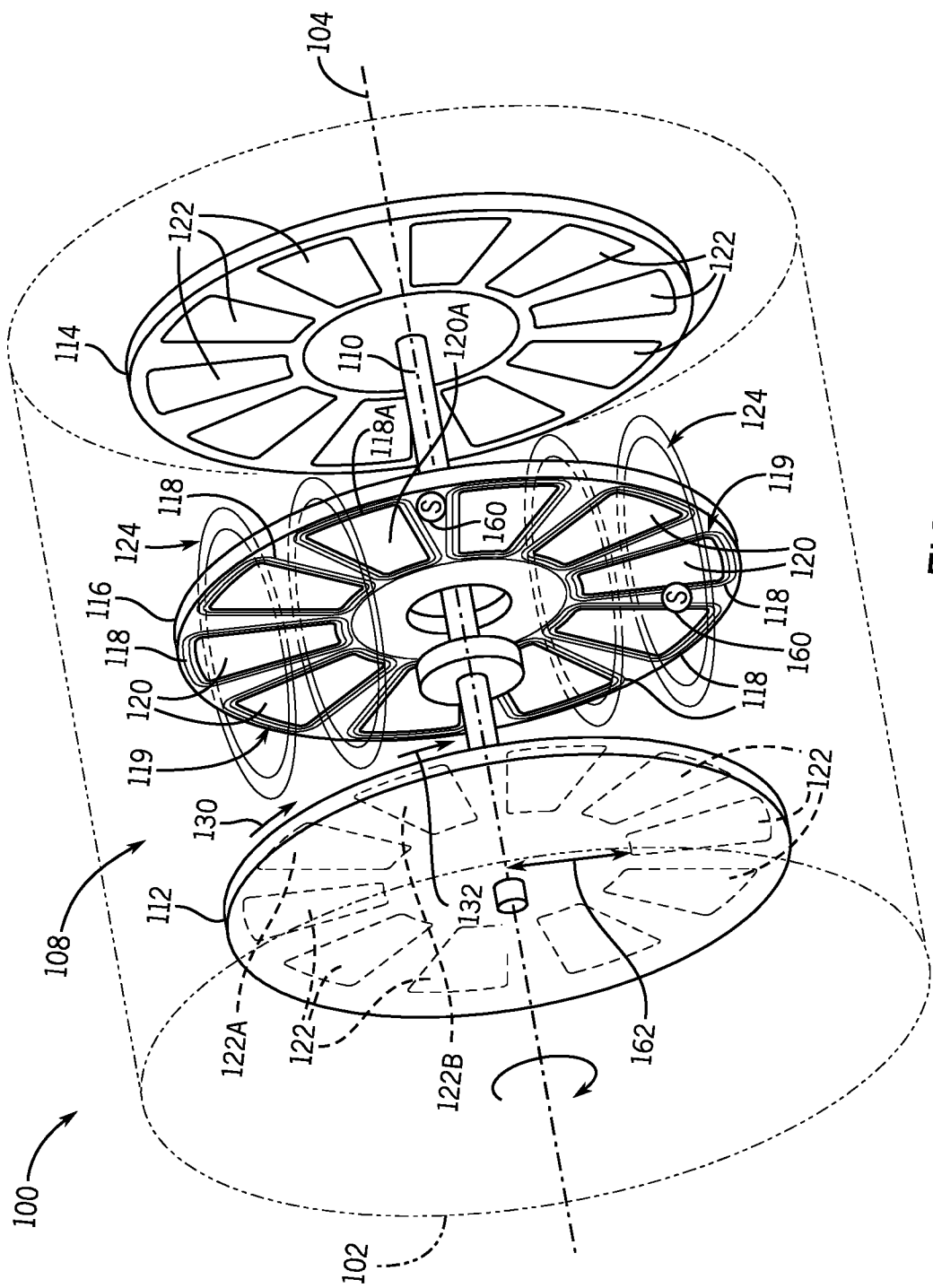


FIG. 6

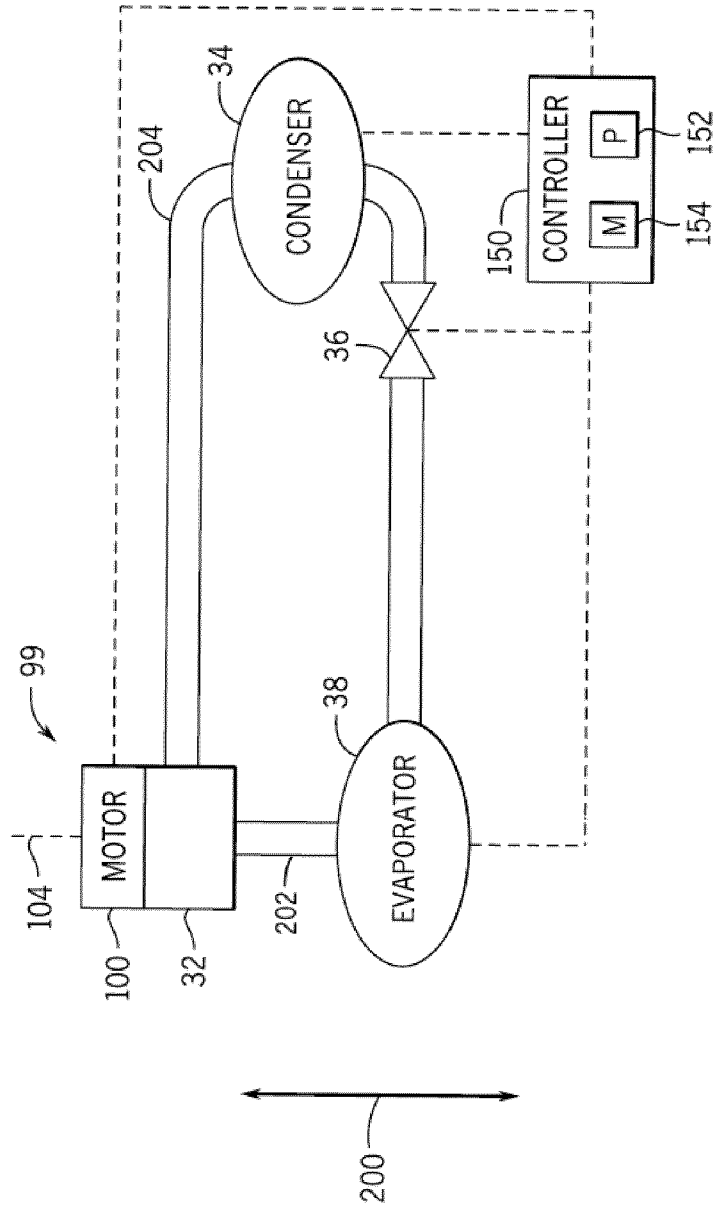


FIG. 7

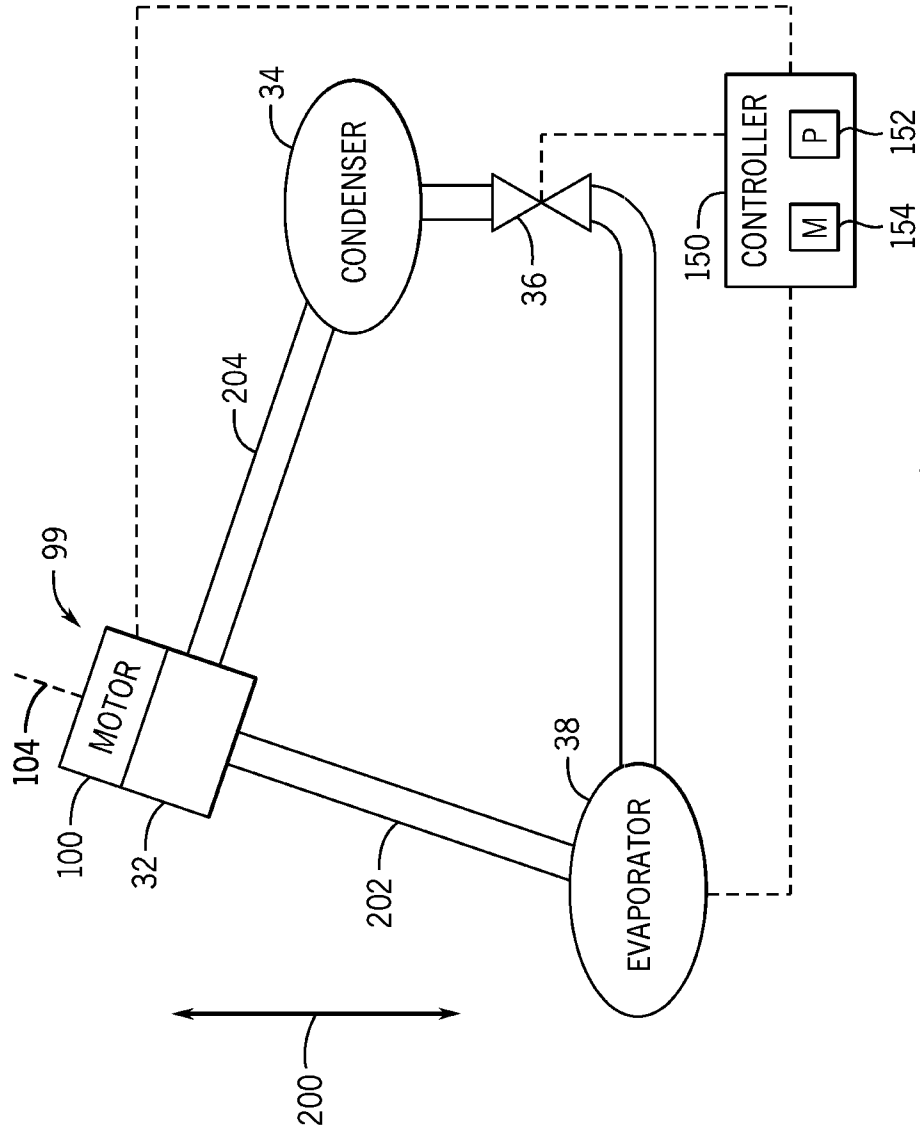


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/065614

A. CLASSIFICATION OF SUBJECT MATTER INV. H02K11/33 H02K16/02 H02K21/24 H02P1/00 H02K7/14 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) H02K H02P Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012/131945 A1 (HUANG BAIYING [JP] ET AL) 31 May 2012 (2012-05-31)	1,2,5,6,9-18
Y	paragraphs [0023], [0024]; figures 1,2a,3a,9,10 paragraph [0071] - paragraph [0082] paragraph [0029] - paragraph [0045] -----	3,4,7,8,19,20
X	US 2012/301334 A1 (HUANG BAIYING [JP] ET AL) 29 November 2012 (2012-11-29)	1,2
A	paragraph [0005] - paragraph [0010]; figure 8 paragraph [0047] - paragraph [0051] -----	3-20
Y	US 2011/083467 A1 (ASANO YOSHINARI [JP] ET AL) 14 April 2011 (2011-04-14) paragraphs [0268], [0269]; figures 9,10 paragraph [0274] -----	3,4,7,8,19,20
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 27 September 2024		Date of mailing of the international search report 08/10/2024
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Contreras Sampayo, J

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2024/065614

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