(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 483 526 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
15.05.2019 Bulletin 2019/20

(51) Int Cl.:
F25B 43/00 *(2006.01)* ***F25B 43/04*** *(2006.01)*

(21) Application number: **18205213.4**

(22) Date of filing: **08.11.2018**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **09.11.2017 US 201762584012 P**

(71) Applicant: **Carrier Corporation**
Jupiter, FL 33478 (US)

(72) Inventors:
- **RANJAN, Rajiv**
  East Hartford, CT Connecticut 06108 (US)
- **FENG, Yinshan**
  East Hartford, CT Connecticut 06108 (US)
- **VERMA, Parmesh**
  East Hartford, CT Connecticut 06108 (US)
- **DARDAS, Zissis A.**
  East Hartford, CT Connecticut 06108 (US)

(74) Representative: **Schmitt-Nilson Schraud Waibel Wohlfrom**
Patentanwälte Partnerschaft mbB
Pelkovenstraße 143
80992 München (DE)

(54) LOW PRESSURE REFRIGERANT SYSTEM

(57) Disclosed is a refrigeration system including a heat transfer fluid circulation loop configured to allow a refrigerant to circulate therethrough, a purge outlet from the heat transfer fluid circulation loop, and at least one gas permeable membrane having a first side in communication with the purge outlet. The membrane includes a porous inorganic material with pores of a size to allow passage of contaminants through the membrane and restrict passage of the refrigerant through the membrane. A retentate return flow path connects the first side of the membrane to the heat transfer fluid circulation loop.

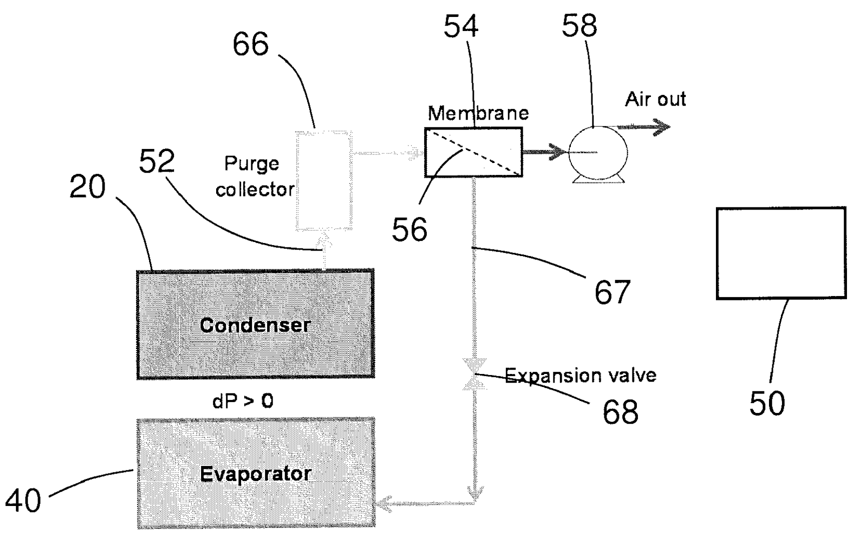

FIG. 2

EP 3 483 526 A1

Description

BACKGROUND

[0001] This disclosure relates generally to chiller systems used in air conditioning systems, and more particularly to a purge system for removing contaminants from a refrigeration system.

[0002] Chiller systems such as those utilizing centrifugal compressors may include sections that operate below atmospheric pressure. As a result, leaks in the chiller system may draw air into the system, contaminating the refrigerant. This contamination degrades the performance of the chiller system. To address this problem, existing low pressure chillers include a purge unit to remove contamination. Existing purge units use a vapor compression cycle to separate non-condensable contaminant gas from the refrigerant. Existing purge units are complicated and lose refrigerant in the process of removing contamination.

BRIEF DESCRIPTION

[0003] Disclosed is a refrigeration system including a heat transfer fluid circulation loop configured to allow a refrigerant to circulate therethrough, a purge outlet from the heat transfer fluid circulation loop, and at least one gas permeable membrane having a first side in communication with the purge outlet. The membrane includes a porous inorganic material with pores of a size to allow passage of contaminants through the membrane and restrict passage of the refrigerant through the membrane. A retentate return flow path connects the first side of the membrane to the heat transfer fluid circulation loop.

[0004] In some embodiments, the enclosure includes a vapor compression heat transfer fluid circulation loop including a compressor, a heat rejection heat exchanger, an expansion device, and a heat absorption heat exchanger, connected together in order by conduit and having the refrigerant disposed therein. In an operational state, the refrigerant is at a pressure less than atmospheric pressure in at least a portion of the fluid circulation loop.

[0005] In any one or combination of the foregoing embodiments, the retentate return flow path includes a control device.

[0006] In any one or combination of the foregoing embodiments, the system is configured for continuous purge operation.

[0007] In any one or combination of the foregoing embodiments, the system further includes a prime mover configured to move gas from a second side of the membrane to an exhaust port leading outside the refrigeration system, and a controller configured to operate the refrigeration system in response to a cooling demand signal, and to operate the prime mover in response to a purge signal.

[0008] In any one or combination of the foregoing embodiments including a control device, the controller is further configured to operate the control device in response to the purge signal.

[0009] In some embodiments, the prime mover includes a vacuum pump in communication with the second side of the membrane.

[0010] In any one or combination of the foregoing embodiments, the system further includes a purge gas collector between the purge outlet and the membrane.

[0011] In any one or combination of the foregoing embodiments, the retentate return flow path includes an expansion device and returns retentate to the fluid circulation loop to the heat absorption heat exchanger or to the compressor inlet.

[0012] In any one or combination of the foregoing embodiments, the at least one gas permeable membrane includes a plurality of gas permeable membranes in serial or parallel communication between the purge outlet and the exhaust port. In some embodiments, the system includes a retentate return flow path operably coupling the first side of each of plurality of membranes to the fluid circulation loop

[0013] In any one or combination of the foregoing embodiments, the contaminants includes nitrogen, oxygen, or water.

[0014] In any one or combination of the foregoing embodiments, the system further includes a pressure sensor operably coupled to the fluid circulation loop, and the controller generates the purge signal in response to output from the pressure sensor.

[0015] In any one or combination of the foregoing embodiments, the pressure sensor is operably coupled to the condenser or to the outlet of the compressor.

[0016] In any one or combination of the foregoing embodiments, the system further includes a temperature sensor operably coupled to the fluid circulation loop, and the controller generates the purge signal in response to output from the temperature sensor.

[0017] In any one or combination of the foregoing embodiments, the temperature sensor is operably coupled to the condenser or evaporator.

[0018] In any one or combination of the foregoing embodiments, the system further includes a refrigerant gas detection sensor operably coupled to second side of the membrane, and the controller generates the purge signal in response to output from the refrigerant gas detection sensor.

[0019] In any one or combination of the foregoing embodiments, the controller is configured to generate the purge signal based at least in part on a timer setting.

[0020] In any one or combination of the foregoing embodiments, the controller is configured to, in response to the purge signal, operate the control device to provide a varying flow rate or pressure drop through the control device.

[0021] In any one or combination of the foregoing embodiments, the controller is configured to, in response to the purge signal, vary prime mover pressure in coordination with varying control device setting. In some embodiments, the control device includes a control valve, and the controller is configured to, in response to the purge signal, alternately operate the prime mover with the control valve closed and suspend operation of the prime mover with the control valve open.

[0022] In any one or combination of the foregoing embodiments, the controller is configured, in response to the purge signal, to operate the prime mover at a constant pressure.

[0023] In any one or combination of the foregoing embodiments, the controller is configured, in response to the purge signal, to operate the prime mover at a varying pressure.

[0024] In any one or combination of the foregoing embodiments, the purge outlet is operably coupled to the condenser.

[0025] Also disclosed is a method of operating the refrigeration system of any one or combination of the foregoing embodiments, including circulating the refrigerant through the vapor compression heat transfer fluid circulation loop in response to the cooling demand signal under conditions in which the refrigerant is at a pressure less than atmospheric pressure in at least a portion of the fluid circulation loop, and operating the prime mover and the control device with the controller as configured.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] The following descriptions should not be considered limiting in any way. With reference to the accompanying drawings, like elements are numbered alike:

FIG. 1 is a schematic depiction of a vapor compression heat transfer refrigerant fluid circulation loop;

FIG. 2 is schematic depiction of an example embodiment of a purge system and relevant components of a vapor compression heat transfer refrigerant fluid circulation loop, with membrane unit retentate directed to the system evaporator;

FIG. 3 is schematic depiction of another example embodiment of a purge system and relevant components of a vapor compression heat transfer refrigerant fluid circulation loop, with membrane retentate directed to the condenser;

FIG. 4 is a schematic depiction of another example embodiment of a purge system and relevant components of a vapor compression heat transfer refrigerant fluid circulation loop, with membrane units in a cascade configuration; and

FIG. 5 is a schematic depiction of another example embodiment of a purge system and relevant components of a vapor compression heat transfer refrigerant fluid circulation loop, with condenser pressure-based control.

DETAILED DESCRIPTION

[0027] A detailed description of one or more embodiments of the disclosed apparatus and method are presented herein by way of exemplification and not limitation with reference to the Figures.

[0028] With reference to FIG. 1, a refrigerant enclosure in the form of a heat transfer fluid circulation loop is shown in block diagram form in FIG. 1. As shown in FIG. 1, a compressor 10 pressurizes heat transfer fluid in its gaseous state, which both heats the fluid and provides pressure to circulate it throughout the system. In some embodiments, the heat transfer fluid, or refrigerant, comprises an organic compound. In some embodiments, the refrigerant comprises a hydrocarbon or substituted hydrocarbon. In some embodiments, the refrigerant comprises a halogen-substituted hydrocarbon. In some embodiments, the refrigerant comprises a fluoro-substituted or chloro-fluoro-substituted hydrocarbon. The hot pressurized gaseous heat transfer fluid exiting from the compressor 10 flows through conduit 15 to heat exchanger condenser 20, which functions as a heat exchanger to transfer heat from the heat transfer fluid to the surrounding environment, resulting in condensation of the hot gaseous heat transfer fluid to a pressurized moderate temperature liquid. The liquid heat transfer fluid exiting from the condenser 20 flows through conduit 25 to expansion valve 30, where the pressure is reduced. The reduced pressure liquid heat transfer fluid exiting the expansion valve 30 flows through conduit 35 to heat exchanger evaporator 40, which functions as a heat exchanger to absorb heat from the surrounding environment and boil the heat transfer fluid. Gaseous heat transfer fluid exiting the evaporator 40 flows through conduit 45 to the compressor 10, thus completing the heat transfer fluid loop. The heat transfer system has the effect of transferring heat from the environment surrounding the evaporator 40 to the environment surrounding the condenser 20. The thermodynamic properties of the heat transfer fluid must allow it to reach a high enough temperature when compressed so that it is greater than the environment surrounding the condenser 20, allowing heat to be transferred to the surrounding environment. The thermodynamic properties of the heat transfer fluid must also have a boiling point at its post-expansion pressure that allows the temperature surrounding the evaporator 40 to provide heat to vaporize the liquid heat transfer fluid.

[0029] With reference now to FIG. 2, there is shown an example embodiment of a purge system connected to a vapor compression heat transfer fluid circulation loop such as FIG. 1 (not all components of FIG. 1 shown). As shown in FIG. 2, a purge collector 66 receives purge gas comprising refrigerant gas and contaminants (e.g., nitrogen, oxygen) from a purge connection 52 connected to the condenser 20. The purge gas is directed from the purge collector 66 to a first side of a membrane 56 in a membrane separator 54. A prime mover such as a vacuum pump 58 connected to the membrane separator 54 provides a driving force to pass the contaminant molecules through the membrane 56 and exit the system from a second side of the membrane 56 through an outlet. In some embodiments, the prime mover can be in the fluid loop, e.g., a refrigerant pump or compressor. Retentate comprising refrigerant gas (and optionally other components including but not limited to oil(s) or other contaminants that did (e.g., nitrogen, gas remains on the first side of the membrane 56 and returns to the fluid circulation loop through a connection 67 that bypasses the condenser 20. A controller 50 receives system data (e.g., pressure, temperature, mass flow rates) and system or operator control (e.g., on/of, receipt of cooling demand signal), and utilizes electronic control components (e.g., a microprocessor) to control system components such as various pumps, valves, switches.

[0030] In some embodiments, the connection of the purge connection 52 to the condenser can be made at a high point of the condenser structure. In some embodiments, the purge collector 66 can provide a technical effect of promoting higher concentrations of contaminants at the membrane separator 54, which can promote more effective mass transfer and separation. This effect can occur through a stratification of gas in the purge collector 66 in which lighter contaminants concentrate toward the top of the purge collector 66 and heavier refrigerant gas concentrates toward the bottom of the purge collector 66. In some embodiments, the purge collector 66 can be any kind of vessel or chamber with a volume or cross-sectional open space to provide for collection of purge gas and for a low gas velocity during operation of the purge system vacuum pump 58 to promote stratification. Stratification can also occur at any time when the purge system is not operating (including during operation of the refrigeration system fluid circulation loop), as the purge collector 66 remains in fluid communication with the purge connection 52 with essentially stagnant gas in the purge collector 66. Other embodiments can also be employed to promote higher concentrations of contaminants at the membrane separator 54, as discussed in more detail below.

[0031] With reference again to FIG. 2, the connection 67 returns retentate gas from the first side of membrane 56 to the refrigerant fluid circulation loop at the evaporator 40, through a control device such as expansion valve 68 utilized to accommodate the pressure differential between the first side of the membrane 56 (which is close to the pressure at the condenser 20) and pressure at the evaporator 40. It should be noted that the control device can control either or both flow through or pressure drop across the control device, and expansion valve 68 is shown as an integrated control device unit that performs both functions for ease of illustration, but could be separate components such as a control valve and an expansion orifice. Other types of expansion devices can also be used, including but not limited to capillaries, solenoids, thermostatic, or electronic expansion devices. In some embodiments, utilization of a bypass refrigerant return can provide a technical effect of promoting greater concentrations of contaminants at the first side of membrane 56 by removing gas at the membrane 56 that is concentrated with refrigerant after removal of contaminant molecules through the membrane 56, so that refrigerant-concentrated gas can be displaced with gas from the purge collector 66 that has a higher concentration of contaminants. In alternative embodiments as shown in FIG. 3, the connection 67 can return retentate gas to the colder side of the condenser 20 or the inlet of the compressor 10, in which case an expansion device may not be needed due to lower pressure differential compared to that of a bypass return to the evaporator 40. In such as case, the connection 67 can utilize a control device such as a control or shut-off valve 69 that does not provide gas expansion.

[0032] The membrane 56 comprises a porous inorganic material. Examples of porous inorganic materials can include ceramics such as metal oxides or metal silicates, more specifically aluminosilicates (e.g., Chabazite Framework (CHA) zeolite, Linde type A (LTA) zeolite, porous carbon, porous glass, clays (e.g., Montmorillonite, Halloysite). Porous inorganic materials can also include porous metals such as platinum and nickel. Hybrid inorganic-organic materials such as a metal organic framework (MOF) can also be used. Other materials can be present in the membrane such as a carrier in which a microporous material can be dispersed, which can be included for structural or process considerations.

[0033] Metal organic framework materials are well-known in the art, and comprise metal ions or clusters of metal ions coordinated to organic ligands to form one-, two- or three-dimensional structures. A metal-organic framework can be characterized as a coordination network with organic ligands containing voids. The coordination network can be characterized as a coordination compound extending, through repeating coordination entities, in one dimension, but with cross-links between two or more individual chains, loops, or spiro-links, or a coordination compound extending through repeating coordination entities in two or three dimensions. Coordination compounds can include coordination polymers with repeating coordination entities extending in one, two, or three dimensions. Examples of organic ligands include but are not limited to bidentate carboxylates (e.g., oxalic acid, succinic acid, phthalic acid isomers, etc.), tridentate carboxylates (e.g., citric acid, trimesic acid), azoles (e.g., 1,2,3-triazole), as well as other known organic ligands. A wide variety of metals can be included in a metal organic framework. Examples of specific metal organic framework materials include but are not limited to zeolitic imidazole framework (ZIF), HKUST-1.

[0034] In some embodiments, pore sizes can be characterized by a pore size distribution with an average pore size from 2.5 Å to 10.0 Å, and a pore size distribution of at least 0.1 Å. In some embodiments, the average pore size for the porous material can be in a range with a lower end of 2.5 Å to 4.0 Å and an upper end of 2.6 Å to 10.0 Å. Å. In some embodiments, the average pore size can be in a range having a lower end of 2.5 Å, 3.0 Å, 3.5 Å, and an upper end of 3.5 Å, 5.0 Å, or 6.0 Å. These range endpoints can be independently combined to form a number of different ranges, and all ranges for each possible combination of range endpoints are hereby disclosed. Porosity of the material can be in a range having a lower end of 5 %, 10%, or 15 %, and an upper end of 85 %, 90 %, or 95 % (percentages by volume). These range endpoints can be independently combined to form a number of different ranges, and all ranges for each possible combination of range endpoints are hereby disclosed.

[0035] The above microporous materials can be can be synthesized by hydrothermal or solvothermal techniques (e.g., sol-gel) where crystals are slowly grown from a solution. Templating for the microstructure can be provided by a secondary building unit (SBU) and the organic ligands. Alternate synthesis techniques are also available, such as physical vapor deposition or chemical vapor deposition, in which metal oxide precursor layers are deposited, either as a primary microporous material, or as a precursor to an MOF structure formed by exposure of the precursor layers to sublimed ligand molecules to impart a phase transformation to an MOF crystal lattice.

[0036] In some embodiments, the above-described inorganic or MOF membrane materials can provide a technical effect of promoting separation of contaminants (e.g., nitrogen, oxygen, water) from refrigerant gas, which is condensable. Other microporous materials, such as porous polymers can be subject to solvent interaction with the matrix material, which can interfere with effective separation. In some embodiments, the capabilities of the materials described herein can provide a technical effect of promoting the implementation of a various example embodiments of refrigeration systems with purge, as described in more detail with reference to the example embodiments below.

[0037] The membrane material can be self-supporting or it can be supported, for example, as a layer on a porous support or integrated with a matrix support material. In some embodiments, thickness of a support for a supported membrane can range from 50 nm to 1000 nm, more specifically from 100 nm to 750 nm, and even more specifically from 250 nm to 500 nm. In the case of tubular membranes, fiber diameters can range from 100 nm to 2000 nm, and fiber lengths can range from 0.2 m to 2 m.

[0038] In some embodiments, the microporous material can be deposited on a support as particles in a powder or dispersed in a liquid carrier using various techniques such as spray coating, dip coating, solution casting, etc. The dispersion can contain various additives, such as dispersing aids, rheology modifiers, etc. Polymeric additives can be used; however, a polymer binder is not needed, although a polymer binder can be included and in some embodiments is included such as with a mixed matrix membrane comprising a microporous inorganic material (e.g., microporous ceramic particles) in an organic (e.g., organic polymer) matrix. However, a polymer binder present in an amount sufficient to form a contiguous polymer phase can provide passageways in the membrane for larger molecules to bypass the molecular sieve particles. Accordingly, in some embodiments a polymer binder is excluded. In other embodiments, a polymer binder can be present in an amount below that needed to form a contiguous polymer phase, such as embodiments in which the membrane is in series with other membranes that may be more restrictive. In some embodiments, particles of the microporous material (e.g., particles with sizes of 0.01 μm to 10 mm, or in some embodiments from 0.5 μm to 10 μm, can be applied as a powder or dispersed in a liquid carrier (e.g., an organic solvent or aqueous liquid carrier) and coated onto the support followed by removal of the liquid. In some embodiments, the application of solid particles of microporous material from a liquid composition to the support surface can be assisted by application of a pressure differential across the support. For example a vacuum can be applied from the opposite side of the support as the liquid composition comprising the solid microporous particles to assist in application of the solid particles to the surface of the support. A coated layer of microporous material can be dried to remove residual solvent and optionally heated to fuse the microporous particles together into a contiguous layer. Various membrane structure configurations can be utilized, including but not limited to flat or planar configurations, tubular configurations, or spiral configurations.

[0039] In some embodiments, the microporous material can be configured as nanoplatelets such as zeolite nanosheets. Zeolite nanosheet particles can have thicknesses ranging from 2 to 50 nm, more specifically 2 to 20 nm, and even more specifically from 2 nm to 10 nm. The mean diameter of the nanosheets can range from 50 nm to 5000 nm, more specifically from 100 nm to 2500 nm, and even more specifically from 100 nm to 1000 nm. Mean diameter of an irregularly-shaped tabular particle can be determined by calculating the diameter of a circular-shaped tabular particle having the same surface area in the x-y direction (i.e., along the tabular planar surface) as the irregularly-shaped particle. Zeolite such as zeolite nanosheets can be formed from any of various zeolite structures, including but not limited to framework type MFI, MWW, FER, LTA, FAU, and mixtures of the preceding with each other or with other zeolite structures. In a more specific group of exemplary embodiments, the zeolite such as zeolite nanosheets can comprise zeolite structures selected from MFI, MWW, FER, LTA framework type. Zeolite nanosheets can be prepared using known techniques such as exfoliation of zeolite crystal structure precursors. For example, MFI and MWW zeolite nanosheets can be prepared by sonicating the layered precursors (multilamellar silicalite-1 and ITQ-1, respectively) in solvent. Prior to sonication, the zeolite layers can optionally be swollen, for example with a combination of base and surfactant, and/or melt-blending with polystyrene. The zeolite layered precursors are typically prepared using conventional techniques for preparation of microporous materials such as sol-gel methods.

[0040] The above embodiments are examples of specific embodiments, and other variations and modifications may be made. For example, a single membrane is depicted for ease of illustration in the above-discussed Figures. However, multiple membranes (or membrane separation units) can be utilized, either in cascaded or parallel configurations. An example embodiment of a cascaded configuration is schematically depicted in FIG. 4. As shown in FIG. 4, membrane separation units 54a and 54b (with membranes 56a and 56b) are disposed in a cascaded configuration in which permeate from the separation unit 54a is fed to the first side of the second separation unit 54b. Retentate from the first side of the membranes 56a and 56b is routed through connections 67a and 67b to the refrigerant fluid circulation loop at the evaporator 40, with expansion valves 68a and 68b utilized to accommodate the pressure differential between the first side of the membrane 56 (which is close to the pressure at the condenser 20) and pressure at the evaporator 40. Other system variations such as centrifugal separators or chilling coils integrated with a purge chamber, pumped recycle of permeate back to the retentate (upstream) side of the membrane, cascaded multiple membranes, heated membranes, or alternative prime movers such as a thermal prime mover or a pump or compressor in the fluid circulation loop, are described in more detail in US patent application Serial No. / , entitled "Low Pressure Refrigeration System", filed on even date herewith under attorney docket number 98251US01 (U301399US), the disclosure of which is incorporated herein by reference in its entirety.

[0041] As mentioned above, the system includes a controller such as controller 50 for controlling the operation of the heat transfer refrigerant flow loop and the purge system. As mentioned above, a refrigeration or chiller system controller can operate the refrigerant heat transfer flow loop in response to a cooling demand signal, which can be generated externally to the system by a master controller or can be entered by a human operator. Some systems can be configured to operate the flow loop continuously for extended periods. The controller can also be configured to also operate the control device in the retentate return flow path, or the prime mover, or both the control device and the prime mover, in response to a purge signal. The purge signal can be generated from various criteria. In some embodiments, the purge signal can be in response to elapse of a predetermined amount of time (e.g., simple passage of time, or tracked operating hours) tracked by the controller circuitry. In some embodiments, the purge signal can be in response to human operator input. In some embodiments, the purge signal can be in response to measured parameters of the refrigerant fluid flow loop. For example, as shown in FIG. 5, a pressure sensor 80 at the condenser 20 (e.g., a condenser discharge pressure sensor) can provide a pressure signal to the controller 50, based on which the controller can generate a purge signal control the expansion valve 68 and/or the vacuum pump 58.

[0042] Various control schemes can be utilized for operating the vacuum pump 58 (or other prime mover) and the expansion valve 68 (or other control device). For example, in some embodiments, the controller 50 can be configured to operate the control device to provide a varying flow rate through the connection 67 during purge. In some embodiments, the controller 50 can be configured to operate a vacuum pump 58 or other prime mover at a constant pressure during purge. In some embodiments, the controller 50 can be configured to operate the vacuum pump 58 or other prime mover at varying pressure during purge. In some embodiments, the controller 50 can be configured to vary vacuum pressure or on/off status (with "off" including a vacuum shut-off valve (not shown)) during purge in coordination with varying settings of the control valve 68 or other control device. For example, in some embodiments, the controller 50 can be configured to alternately operate the vacuum pump 58 or other prime mover with the expansion valve 68 or other control device closed and suspend operation of the vacuum pump 58 or other prime mover with the expansion valve 68 or other control device open. In some embodiments, the expansion valve 68 or other control device can be left open while the vacuum pump 58 or other prime mover is cycled on or off or with varying output. In some embodiments, the vacuum pump 58 or other prime mover can be operated continuously or at constant pressure while the expansion valve 68 or other control device is cycled open and closed or to vary the flow rate or pressure drop across the control device.

[0043] The term "about", if used, is intended to include the degree of error associated with measurement of the particular quantity based upon the equipment available at the time of filing the application. For example, "about" can include a range of $\pm$ 8% or 5%, or 2% of a given value.

[0044] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the present disclosure. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, element components, and/or groups thereof.

[0045] While the present disclosure has been described with reference to an exemplary embodiment or embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the present disclosure. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the present disclosure without departing from the essential scope thereof. Therefore, it is intended that the present disclosure not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this present disclosure, but that the present disclosure will include all embodiments falling within the scope of the claims.

Claims

1. A refrigeration system comprising
a heat transfer fluid circulation loop configured to allow a refrigerant to circulate therethrough;
a purge outlet from the heat transfer fluid circulation loop;
at least one gas permeable membrane comprising a porous inorganic material with pores of a size to allow passage of contaminants through the membrane and restrict passage of the refrigerant through the membrane, said membrane having a first side in communication with the purge outlet; and
a retentate return flow path from the first side of the membrane to the heat transfer fluid circulation loop.

2. The refrigeration system of claim 1, wherein the heat transfer fluid circulation loop comprises a compressor, a heat rejection heat exchanger, an expansion device, and a heat absorption heat exchanger, connected together in order by conduit.

3. The refrigeration system of claims 1 or 2, wherein the retentate return flow path includes a control device.

4. The refrigeration system of any of claims 1-3, wherein the purge system is configured for continuous operation; and/or
further comprising a prime mover configured to move gas from a second side of the membrane to an exhaust port leading outside the refrigeration system, and a controller configured to operate the refrigeration system in response to a cooling demand signal, and to operate the prime mover in response to a purge signal.

5. The refrigeration system of claim 4 as it depends from claim 3, wherein the controller is further configured to operate the control device in response to the purge signal.

6. The refrigeration system of any preceding claim, wherein the prime mover comprises a vacuum pump in communication with the second side of the membrane; and/or
further comprising a purge gas collector between the purge outlet and the membrane.

7. The refrigeration system of any of claims 3-6, wherein the control device comprises an expansion device and returns retentate to the fluid circulation loop to the heat absorption heat exchanger or to the compressor inlet.

8. The refrigeration system of any preceding claim, wherein the at least one gas permeable membrane comprises a plurality of gas permeable membranes in serial or parallel communication between the purge outlet and the exhaust port; and/or
comprising a retentate return flow path operably coupling the first side of each of plurality of membranes to the fluid circulation loop.

9. The refrigeration system of any preceding claim, wherein the contaminant comprises nitrogen, oxygen, or water.

10. The refrigeration system of any of claims 4-9, wherein the system further comprises a pressure sensor operably coupled to the fluid circulation loop, and the controller generates the purge signal in response to output from the pressure sensor; and/or
wherein the pressure sensor is operably coupled to the condenser or to the outlet of the compressor.

11. The refrigeration system of any of claims 4-10, wherein the system further comprises a temperature sensor operably coupled to the fluid circulation loop, and the controller generates the purge signal in response to output from the temperature sensor; and/or
wherein the temperature sensor is operably coupled to the condenser or evaporator.

12. The refrigeration system of any of claims 4-11, wherein the system further comprises a refrigerant gas detection sensor operably coupled to second side of the membrane, and the controller generates the purge signal in response to output from the refrigerant gas detection sensor; and/or
wherein the controller is configured to generate the purge signal based at least in part on a timer setting; and/or
wherein the controller is configured, in response to the purge signal, to operate the control device to provide a varying flow rate or pressure drop through the control device.

13. The refrigeration system of any of claims 5-12, wherein the controller is configured, in response to the purge signal, to vary prime mover pressure in coordination with varying the control device setting; and, particularly, wherein the control device includes a control valve, and the controller is configured, in response to the purge signal, to alternately operate the prime mover with the control valve closed and

suspend operation of the prime mover with the control valve open; and/or
wherein the controller is configured, in response to the purge signal, to operate the prime mover at a constant pressure; and, particularly, wherein the controller is configured, in response to the purge signal, to operate the prime mover at a varying pressure.

14. The refrigeration system of any preceding claim, wherein the purge outlet is operably coupled to the condenser.

15. A method of operating the refrigeration system of any of claims 4-14, comprising
circulating the refrigerant through the vapor compression heat transfer fluid circulation loop in response to the cooling demand signal under conditions in which the refrigerant is at a pressure less than atmospheric pressure in at least a portion of the fluid circulation loop; and
operating the prime mover and the control device, if present, with the controller as configured.

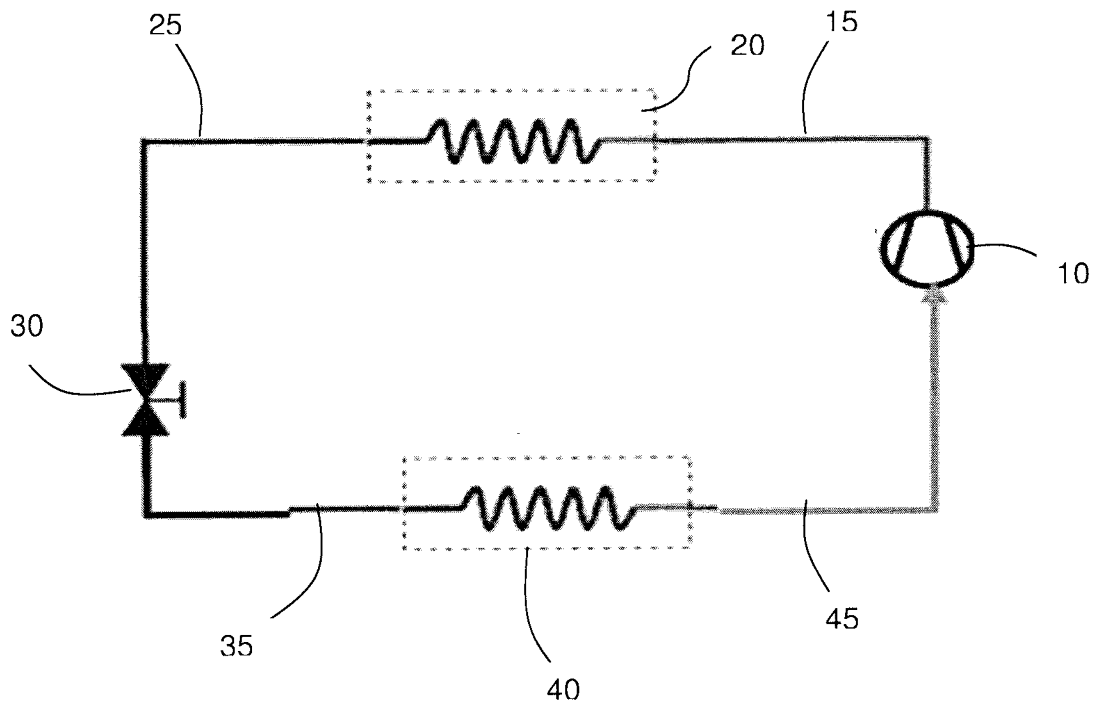

FIG. 1

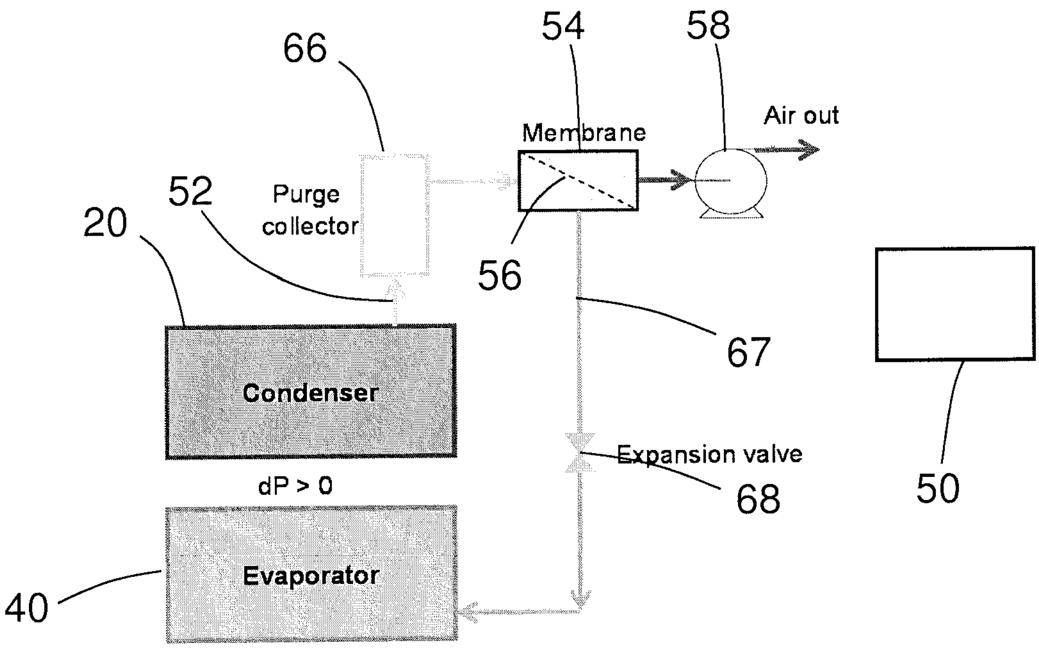
66
54
58
Membrane
Air out
52
Purge collector
20
56
67
Condenser
Expansion valve
dP > 0
68
50
Evaporator
40

FIG. 2

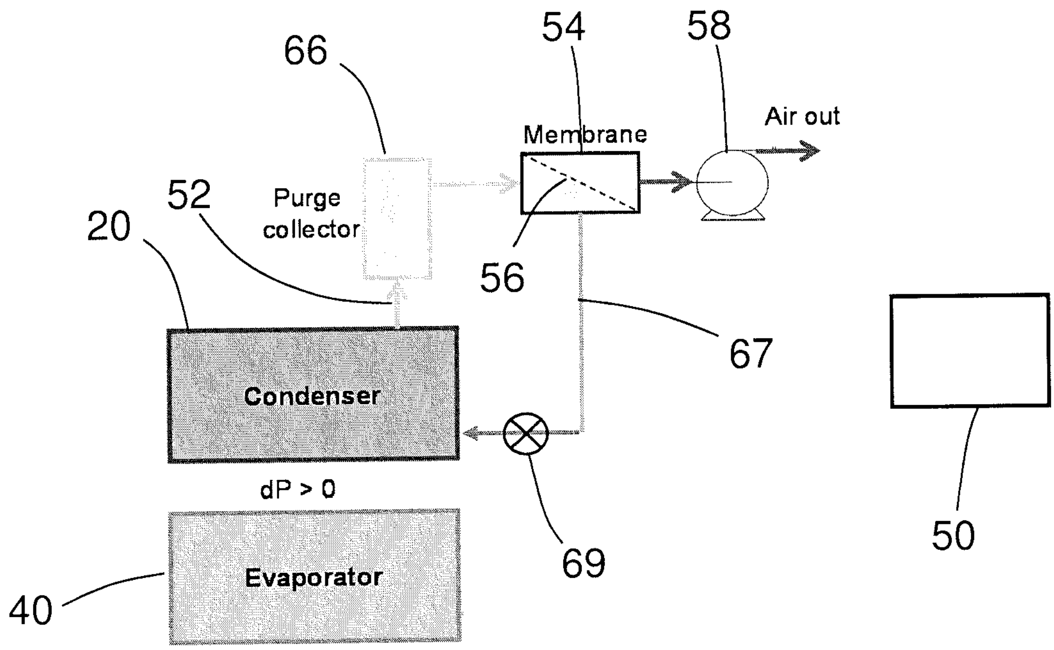
66
54
58
Membrane
Air out
52
Purge collector
20
56
67
Condenser
dP > 0
69
50
Evaporator
40

FIG. 3

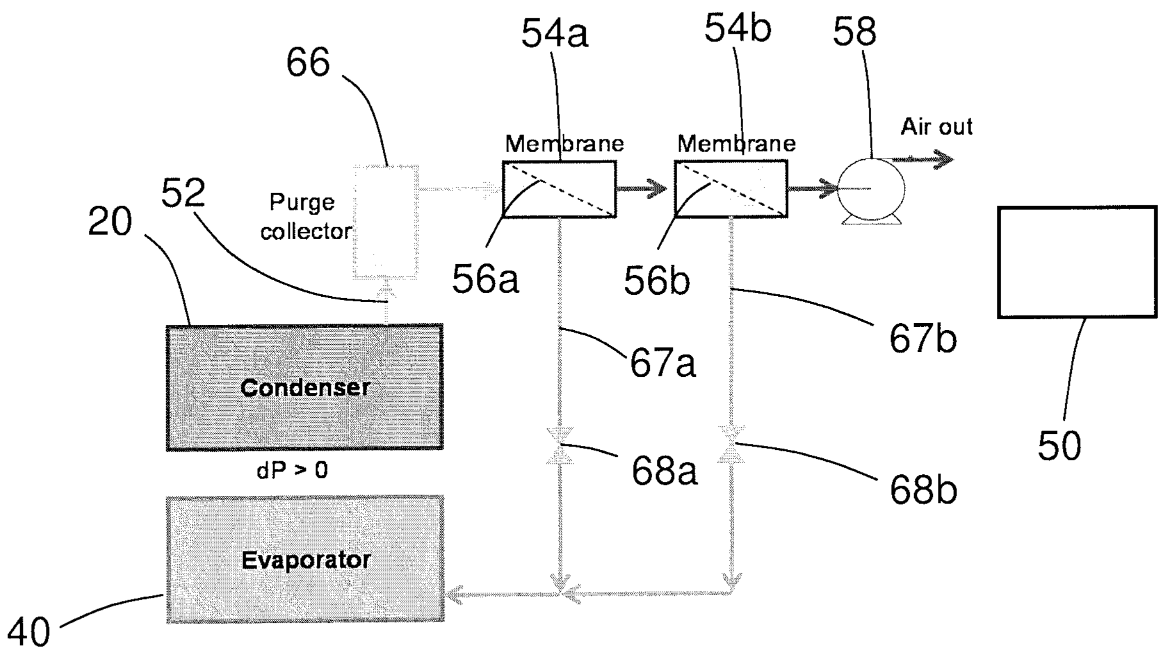
54a
54b
58
66
Membrane
Membrane
Air out
52
20
Purge collector
56a
56b
67b
67a
Condenser
50
68a
68b
dP > 0
Evaporator
40

FIG. 4

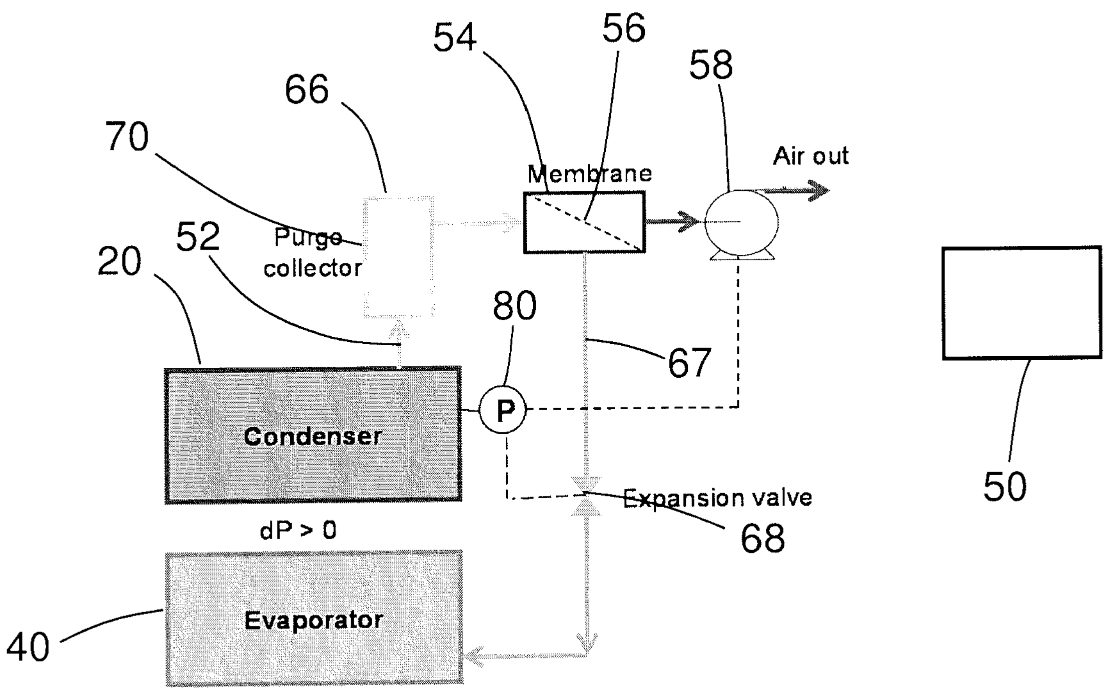
56
54
58
66
70
Membrane
Air out
Purge collector
52
20
80
67
P
Condenser
Expansion valve
68
50
dP > 0
Evaporator
40

FIG. 5

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 18 20 5213

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 A	US 5 062 273 A (LEE KUNG H [US] ET AL) 5 November 1991 (1991-11-05) * & associated description; column 5, line 66 - column 6, line 44 *	1-3,7-9, 14 4-6, 10-13,15	INV. F25B43/00 F25B43/04
X A	US 5 044 166 A (WIJMANS JOHANNES G [US] ET AL) 3 September 1991 (1991-09-03) * & associated desciption; figure 5 *	1-3,7-9, 14 4-6, 10-13,15	
A	US 2007/113581 A1 (YOSHIMI MANABU [JP] ET AL) 24 May 2007 (2007-05-24) * the whole document *	1-15	
A	WO 2015/020719 A1 (CARRIER CORP [US]) 12 February 2015 (2015-02-12) * the whole document *	1-15	

TECHNICAL FIELDS SEARCHED (IPC)

F25B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	28 February 2019	Gasper, Ralf

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
& : member of the same patent family, corresponding document

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 18 20 5213

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

28-02-2019

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 5062273	A	05-11-1991	NONE			
US 5044166	A	03-09-1991	CA	2076346	A1	06-09-1991
			EP	0518931	A1	23-12-1992
			US	5044166	A	03-09-1991
			WO	9114143	A1	19-09-1991
US 2007113581	A1	24-05-2007	AU	2004282456	A1	28-04-2005
			CN	1871481	A	29-11-2006
			EP	1681523	A1	19-07-2006
			JP	4007307	B2	14-11-2007
			JP	2005127566	A	19-05-2005
			KR	20060066132	A	15-06-2006
			US	2007113581	A1	24-05-2007
			WO	2005038360	A1	28-04-2005
WO 2015020719	A1	12-02-2015	CN	105683687	A	15-06-2016
			EP	3030850	A1	15-06-2016
			US	2016175740	A1	23-06-2016
			WO	2015020719	A1	12-02-2015

EPO FORM P0459

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