



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
12.02.2025 Bulletin 2025/07

(51) International Patent Classification (IPC):
F25B 49/02 ^(2006.01)

(21) Application number: **24193293.8**

(52) Cooperative Patent Classification (CPC):
F25B 49/02; F25B 2341/0012; F25B 2341/0015

(22) Date of filing: **07.08.2024**

(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 ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
GE KH MA MD TN

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(30) Priority: **07.08.2023 US 202363517961 P**

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(54) **SYSTEM AND METHOD FOR CONTROLLING A PLURALITY OF EJECTORS IN AN EJECTOR REFRIGERATION CIRCUIT**

(57) A system (100) for controlling a plurality of ejectors (101) in an ejector refrigeration circuit includes the plurality of ejectors (101) and a controller (104). Each of the plurality of ejectors (101) include a primary high pressure input port (101a), a secondary low pressure input port (101b), and an output port (101c). The controller (104) is coupled to each of the plurality of ejectors (101) and adapted to generate a plurality of maps (200, 200A, 200B, 200C) based on a set of predefined conditions. Each of the plurality of maps (200, 200A, 200B,

200C) is associated with a corresponding temperature of a heat rejecting heat exchanger (105). The controller (104) identifies a first map (200A) from the plurality of maps (200, 200A, 200B, 200C) associated with a first temperature of the heat rejecting heat exchanger (105) and an input signal from a first ejector (101') indicative of a flow rate of a refrigerant fluid through the first ejector (101'). Finally, the controller (104) adjusts opening percentages of the plurality of ejectors (101) based on the identified first map (200A).

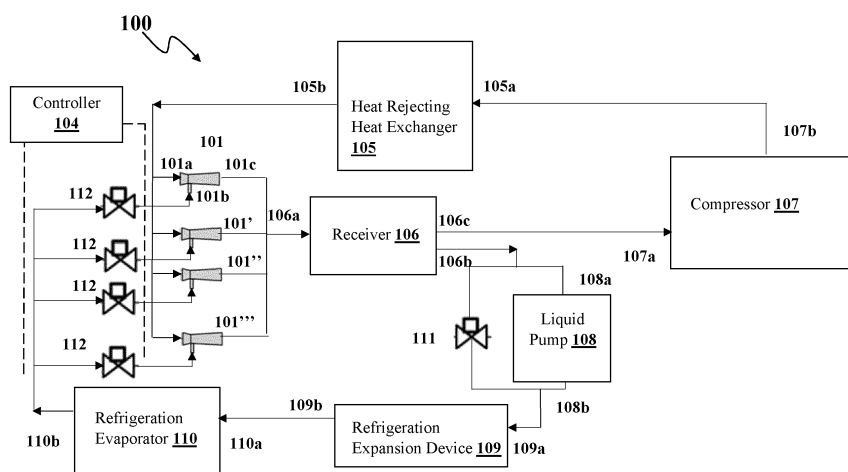


FIG. 1A

Description

FIELD OF THE INVENTION

[0001] The disclosure generally relates to ejector refrigeration circuits. More particularly, the disclosure relates to a system for controlling a plurality of ejectors in an ejector refrigeration circuit.

BACKGROUND

[0002] Ejectors are sometimes used to improve overall efficiency of commercial refrigeration systems. The ejectors improve efficiency in the refrigeration system by utilizing a high pressure to help compress a low pressure gas, instead of relying solely on a compressor.

[0003] Typically, the ejectors may be located between an outlet of a condenser and an inlet of a receiver tank. The ejectors include a primary high pressure inlet, a secondary low pressure inlet, and an outlet. When an ejector is used as part of the refrigeration system, the cooled refrigerant from the condenser enters each of the ejectors at the high pressure inlet and is expanded to a lower pressure at the outlet of each of the ejectors. At the outlet of the ejectors, the refrigerant flow will typically be both liquid and gaseous phase. The gaseous phase will be fed back to a compressor, while the liquid phase is fed through another expansion valve and then the evaporator. The fluid that leaves the evaporator then flows to the low pressure inlet of the ejector. The inclusion of the ejectors reduces a load on the compressor as the compressor can operate at a lower pressure difference and use less energy since the ejectors have partially compressed the refrigerant vapors to the intermediate pressure level.

[0004] Existing control systems dynamically control the ejectors in a multi-ejector refrigeration circuit. However, when the ejectors are operated, if the high pressure fluid and the outlet fluid flow back to the secondary low pressure inlet, a large loss of compressor efficiency will result. Therefore, an improved ejector control system that optimizes machine performance while avoiding ejector reverse flow is desirable.

SUMMARY

[0005] This summary is provided to introduce a selection of concepts in a simplified format that are further described in the detailed description of the disclosure. This summary is not intended to identify key or essential inventive concepts of the disclosure, nor is it intended for determining the scope of the disclosure.

[0006] A system for controlling a plurality of ejectors in an ejector refrigeration circuit, is disclosed. The system includes a plurality of ejectors and a controller. Each of the plurality of ejectors have a primary high pressure input port, a secondary low pressure input port, and an output port. The controller is coupled to each of the

plurality of ejectors. The controller is adapted to generate a plurality of maps based on a set of predefined conditions such that each of the plurality of maps is associated with a corresponding temperature of a heat rejecting heat exchanger. Next, the controller identifies a first map from the plurality of maps associated with a first temperature of the heat rejecting heat exchanger and an input signal indicative of a flow rate of a refrigerant fluid through the first ejector. Finally, the controller adjusts opening percentages of the plurality of ejectors based on the identified first map.

[0007] In one or more embodiments according to the disclosure, each of the plurality of maps indicates a rate of change of the flow rate of the refrigerant fluid through each of the plurality of ejectors based on a change in the opening percentage of each of the plurality of ejectors during the corresponding temperature of the heat rejecting heat exchanger.

[0008] In one or more embodiments according to the disclosure, each of the plurality of maps comprise a plurality of stages and the opening percentage of at least the first ejector from the plurality of ejectors is greater than zero in each of the plurality of stages.

[0009] In one or more embodiments according to the disclosure, the plurality of stages includes at least a first stage, a second stage, and a third stage. During the first stage, the opening percentage of the plurality of ejectors excluding the first ejector equals zero. During the second stage, the opening percentage of the plurality of ejectors excluding the first ejector and a second ejector equals zero. Moreover, during the third stage, the opening percentage of the plurality of ejectors excluding the first ejector, the second ejector, and a third ejector equals zero.

[0010] In one or more embodiments according to the disclosure, the set of predefined conditions include the following:

- (a) the opening percentages of the plurality of ejectors increase within a stage;
- (b) when switching between the plurality of stages of each of the plurality of maps, the opening percentages of the plurality of ejectors are adjusted to keep the flow rate of the refrigerant fluid constant;
- (c) when switching between the plurality of stages of each of the plurality of maps, the opening percentages of the plurality of ejectors are greater than zero; and
- (d) a flow rate of the refrigerant fluid through the secondary low pressure input port of each of the plurality of ejectors is greater than zero.

[0011] In one or more embodiments according to the disclosure, each of the plurality of ejectors are controllable variable ejectors connected in a parallel configuration.

[0012] In one or more embodiments according to the disclosure, the plurality of ejectors have at least one of

different capacities and equal capacities.

[0013] In one or more embodiments according to the disclosure, the ejector refrigeration circuit includes a high pressure ejector circuit and a refrigerating evaporator flow path. The high pressure ejector circuit includes, in a direction of flow of a circulating refrigerant, the heat rejecting heat exchanger having an inlet side and an outlet side, the plurality of ejectors, a receiver, and at least one compressor. Each of the plurality of ejectors have the primary high pressure input port, the secondary low pressure input port, and the output port, such that the primary high pressure input port is in fluid communication with the outlet side of the heat rejecting heat exchanger. The receiver includes an inlet, a liquid outlet, and a gas outlet. The inlet is in fluid communication with the output port of each of the plurality of ejectors. The at least one compressor includes an inlet side and an outlet side. The inlet side of the at least one compressor is in fluid communication with the gas outlet of the receiver and the outlet side of the at least one compressor is in fluid communication with the inlet side of the heat rejecting heat exchanger. The refrigerating evaporator flow path includes, in the direction of flow of the circulating refrigerant, a liquid pump, at least one refrigeration expansion device, and at least one refrigeration evaporator. The liquid pump includes an inlet side and an outlet side such that the inlet side is in fluid communication with the liquid outlet of the receiver. The at least one refrigeration expansion device includes an inlet side and an outlet side. The inlet side of the at least one refrigeration expansion device is in fluid communication with the outlet side of the liquid pump. The at least one refrigeration evaporator includes an inlet side and an outlet side. The inlet side is in fluid communication with the outlet side of the at least one refrigeration expansion device and the outlet side is in fluid communication with the secondary low pressure input port of each of the plurality of ejectors.

[0014] In one or more embodiments according to the disclosure, the liquid pump includes a bypass-line having a switchable bypass valve for allowing refrigerant to selectively bypass the liquid pump by opening the switchable bypass valve.

[0015] A method for controlling a plurality of ejectors in an ejector refrigeration circuit is also disclosed. The method includes the steps of generating, via a controller, a plurality of maps based on a set of predefined conditions such that each of the plurality of maps is associated with a corresponding temperature of a heat rejecting heat exchanger. Next, the controller identifies a first map from the plurality of maps associated with a first temperature of the heat rejecting heat exchanger and an input signal indicative of a flow rate of a refrigerant fluid through the first ejector. Finally, the controller adjusts the opening percentages of the plurality of ejectors based on the identified first map.

[0016] In one or more embodiments according to the disclosure, each of the plurality of maps indicates a rate of change of the flow rate of the refrigerant fluid through

each of the plurality of ejectors based on a change in the opening percentage of each of the plurality of ejectors during the corresponding temperature of the heat rejecting heat exchanger.

[0017] In one or more embodiments according to the disclosure, each of the plurality of maps include a plurality of stages and the opening percentage of at least the first ejector from the plurality of ejectors is greater than zero in each of the plurality of stages.

[0018] In one or more embodiments according to the disclosure, the plurality of stages include at least a first stage, a second stage, and a third stage. During the first stage, the opening percentage of the plurality of ejectors excluding the first ejector equals zero. During the second stage, the opening percentage of the plurality of ejectors excluding the first ejector and a second ejector equals zero. During the third stage, the opening percentage of the plurality of ejectors excluding the first ejector, the second ejector, and a third ejector equals zero.

[0019] In one or more embodiments according to the disclosure, the set of predefined conditions include the following:

- (a) the opening percentages of the plurality of ejectors increase within a stage;
- (b) when switching between the plurality of stages of each of the plurality of maps, the opening percentages of the plurality of ejectors are adjusted to keep the flow rate of the refrigerant fluid constant;
- (c) when switching between the plurality of stages of each of the plurality of maps, the opening percentages of the plurality of ejectors are greater than zero; and
- (d) a flow rate of the refrigerant fluid through the secondary low pressure input port of each of the plurality of ejectors is greater than zero.

[0020] In one or more embodiments according to the disclosure, each of the plurality of ejectors include a primary high pressure input port, a secondary low pressure input port, and an output port.

[0021] In one or more embodiments according to the disclosure, each of the plurality of ejectors are controllable variable ejectors connected in a parallel configuration.

[0022] In one or more embodiments according to the disclosure, the plurality of ejectors have at least one of different capacities and equal capacities.

[0023] In one or more embodiments according to the disclosure, the ejector refrigeration circuit includes a high pressure ejector circuit and a refrigerating evaporator flow path. The high pressure ejector circuit includes, in a direction of flow of a circulating refrigerant, the heat rejecting heat exchanger having an inlet side and an outlet side, the plurality of ejectors, a receiver, and at least one compressor. Each of the plurality of ejectors have the primary high pressure input port, the secondary low pressure input port, and the output port, such that the

primary high pressure input port is in fluid communication with the outlet side of the heat rejecting heat exchanger. The receiver includes an inlet, a liquid outlet, and a gas outlet. The inlet is in fluid communication with the output port of each of the plurality of ejectors. The at least one compressor includes an inlet side and an outlet side. The inlet side of the at least one compressor is in fluid communication with the gas outlet of the receiver and the outlet side of the at least one compressor is in fluid communication with the inlet side of the heat rejecting heat exchanger. The refrigerating evaporator flow path includes, in the direction of flow of the circulating refrigerant, a liquid pump, at least one refrigeration expansion device, and at least one refrigeration evaporator. The liquid pump includes an inlet side and an outlet side such that the inlet side is in fluid communication with the liquid outlet of the receiver. The at least one refrigeration expansion device includes an inlet side and an outlet side. The inlet side of the at least one refrigeration expansion device is in fluid communication with the outlet side of the liquid pump. The at least one refrigeration evaporator includes an inlet side and an outlet side. The inlet side is in fluid communication with the outlet side of the at least one refrigeration expansion device and the outlet side is in fluid communication with the secondary low pressure input port of each of the plurality of ejectors.

[0024] In one or more embodiments according to the disclosure, the liquid pump comprises a bypass-line including a switchable bypass valve allowing refrigerant to selectively bypass the liquid pump by opening the switchable bypass valve.

[0025] To further clarify the advantages and features of the methods, systems, and apparatuses, a more particular description of the methods, systems, and apparatuses will be rendered by reference to specific embodiments thereof, which are illustrated in the appended drawings. It is appreciated that these drawings depict only typical embodiments of the disclosure and are therefore not to be considered limiting of its scope. The disclosure will be described and explained with additional specificity and detail with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] These and other features, aspects, and advantages of the disclosure will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

FIG. 1A exemplarily illustrates a schematic view of a system for controlling a plurality of ejectors in an ejector refrigeration circuit;

FIG. 1B exemplarily illustrates a schematic sectional view of a controllable ejector as shown in **FIG. 1A**;

FIG. 2 exemplarily illustrates a schematic view of a plurality of maps generated by a controller of the system shown in **FIG. 1A**; and

FIG. 3 exemplarily illustrates a flowchart depicting a method for controlling the plurality of ejectors in the ejector refrigeration circuit.

[0027] Further, skilled artisans will appreciate that elements in the drawings are illustrated for simplicity and may not have necessarily been drawn to scale. For example, the flow charts illustrate the method in terms of the most prominent steps involved to help to improve understanding of aspects of the disclosure. Furthermore, in terms of the construction of the device, one or more components of the device may have been represented in the drawings by conventional symbols, and the drawings may show only those specific details that are pertinent to understanding the embodiments of the disclosure so as not to obscure the drawings with details that will be readily apparent to those of ordinary skill in the art having the benefit of the description herein.

DETAILED DESCRIPTION

[0028] For the purpose of promoting an understanding of the principles of the disclosure, reference will now be made to the various embodiments and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the disclosure is thereby intended, such alterations and further modifications in the illustrated system, and such further applications of the principles of the disclosure as illustrated therein being contemplated as would normally occur to one skilled in the art to which the disclosure relates.

[0029] It will be understood by those skilled in the art that the foregoing general description and the following detailed description are explanatory of the disclosure and are not intended to be restrictive thereof.

[0030] Reference throughout this specification to "an aspect", "another aspect" or similar language means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the disclosure. Thus, appearances of the phrase "in an embodiment", "in another embodiment", "some embodiments", "one or more embodiments" and similar language throughout this specification may, but do not necessarily, all refer to the same embodiment.

[0031] The terms "comprises", "comprising", or any other variations thereof, are intended to cover a non-exclusive inclusion, such that a process or method that comprises a list of steps does not include only those steps but may include other steps not expressly listed or inherent to such process or method. Similarly, one or more devices or sub-systems or elements or structures or components proceeded by "comprises... a" does not,

without more constraints, preclude the existence of other devices or other sub-systems or other elements or other structures or other components or additional devices or additional sub-systems or additional elements or additional structures or additional components.

[0032] Embodiments of the disclosure will be described below in detail with reference to the accompanying drawings.

[0033] FIG. 1 exemplarily illustrates a schematic view of a system 100 for controlling a plurality of ejectors 101 in an ejector refrigeration circuit according to one or more embodiments of the disclosure.

[0034] In an exemplary embodiment according to the disclosure, the ejector refrigeration circuit includes a high pressure ejector circuit including, in the direction of flow of a circulating refrigerant, a heat rejecting heat exchanger 105, the plurality of ejectors 101, a receiver 106, and at least one compressor 107. The ejector refrigeration circuit also includes a refrigerating evaporator flow path including, in the direction of flow of the circulating refrigerant, a liquid pump 108, at least one refrigeration expansion device 109, and at least one refrigeration evaporator 110.

[0035] The heat rejecting heat exchanger 105 includes an inlet side 105a and an outlet side 105b. The heat rejecting heat exchanger 105 may also be interchangeably referred to as a gas cooler unit or a condenser. The heat rejecting heat exchanger 105 is configured for transferring heat from the refrigerant to the environment thereby reducing the superheat of the refrigerant. In an embodiment, the heat rejecting heat exchanger 105 may include one or more fans for blowing air through the heat rejecting heat exchanger 105 to enhance the transfer of heat from the refrigerant to the environment. The type and number of the fans used may be adjusted based on the type of the condenser used, etc. The cooled refrigerant leaving the heat rejecting heat exchanger 105 at the outlet side 105b is delivered via a high pressure input line and an optional service valve to a primary high pressure input port 101a of the plurality of ejectors 101.

[0036] The plurality of ejectors 101 is adapted to expand the refrigerant to a reduced medium pressure level. Each of the plurality of ejectors 101 includes the primary high pressure input port 101a, a secondary low pressure input port 101b, and an output port 101c. The primary high pressure input port 101a is in fluid communication with the outlet side 105b of the heat rejecting heat exchanger 105. The expanded refrigerant leaves the ejectors 101 through a respective ejector output port 101c and is delivered to an inlet 106a of the receiver 106. Moreover, the receiver 106 includes a liquid outlet 106b and a gas outlet 106c, and the inlet 106a is in fluid communication with the output port 101c of each of the plurality of ejectors 101. Within the receiver 106, the refrigerant is separated by means of gravity into a liquid portion collecting at a bottom part of the receiver 106 and a gas phase portion collecting in an upper part of the receiver 106. The gas phase portion of the refrigerant

leaves the receiver 106 through the gas outlet 106c provided at the upper part of the receiver 106 and is delivered to the inlet side 107a of the at least one compressor 107 completing the refrigerant cycle of the high pressure ejector circuit.

[0037] The at least one compressor 107 includes the inlet side 107a and an outlet side 107b. The inlet side 107a of the at least one compressor 107 is in fluid communication with the gas outlet 106c of the receiver 106 and the outlet side 107b of the at least one compressor 107 is in fluid communication with the inlet side 105a of the heat rejecting heat exchanger 105.

[0038] The liquid pump 108 includes an inlet side 108a and an outlet side 108b. The inlet side 108a is in fluid communication with the liquid outlet 106b of the receiver 106. In an embodiment, the liquid pump 108 may be located below the receiver 106. Arranging the liquid pump 108 below the receiver 106 allows using the forces of gravity for supplying the liquid refrigerant from the receiver 106 to the inlet side 108a of the liquid pump 108. The liquid pump 108 also includes a bypass-line including a switchable bypass valve 111 allowing refrigerant to selectively bypass the liquid pump 108 by opening the switchable bypass valve 111. In an embodiment, separate liquid pumps 108 and (optional) bypass-lines may be provided allowing to adjust the pressure of the liquid refrigerant independently.

[0039] The at least one refrigeration expansion device 109 includes an inlet side 109a and an outlet side 109b. The inlet side 109a of the at least one refrigeration expansion device 109 is in fluid communication with the outlet side 108b of the liquid pump 108. The at least one refrigeration evaporator 110 includes an inlet side 110a and an outlet side 110b. The inlet side 110a is in fluid communication with the outlet side 109b of the at least one refrigeration expansion device 109 and the outlet side 110b is in fluid communication with the secondary low pressure input port 101b of each of the plurality of ejectors 101.

[0040] The system 100 includes a controller 104 coupled to each of the plurality of ejectors 101 having the primary high pressure input port 101a, the secondary low pressure input port 101b, and the output port 101c. In an embodiment, each of the plurality of ejectors 101 are controllable variable ejectors 101 as disclosed in the detailed description of FIG. 1B. Hereinafter, the "ejector 101" may interchangeably be referred to as the "controllable variable ejector 101". Moreover, the plurality of ejectors 101 may be connected in parallel to each other or in a parallel configuration.

[0041] The plurality of ejectors 101 may have different capacities or may all be of the same capacity. In another embodiment, a first group of ejectors 101 from the plurality of ejectors 101 may have equal capacities and a second group of ejectors 101 from the plurality of ejectors 101 may have equal capacities such that the capacities of the second group are greater than the first group of ejectors 101. In yet another embodiment, the first group

of ejectors 101 from the plurality of ejectors 101 may have equal capacities and the second group of ejectors 101 from the plurality of ejectors 101 may have equal capacities such that the capacities of the first group are greater than the second group of ejectors 101.

[0042] If the plurality of ejectors 101 used are controllable variable ejectors 101, the plurality of ejectors 101 may have opening percentages that are adjustable by actuating a needle 126, shown in FIG. 1B, of the plurality of ejectors 101 by the controller 104. As used herein, the term "opening percentage" is defined and described in detail in the detailed description of FIG. 1B. Alternatively, each of the plurality of ejectors 101 used may be controllable variable ejectors 101 with a flow valve 112 upstream of the secondary low pressure input port 101b. In an embodiment, the controller 104 is adapted to open the flow valve 112 to permit refrigerant flow and adapted to close the flow valve 112 to prevent refrigerant flow. In such an implementation, the controller 104 actuates the flow valve 112 between an ON and OFF position to permit or prevent a refrigerant flow towards the secondary low pressure input port 101b of the respective ejector 101.

[0043] As used herein, the "controller 104" may be configured to control the at least one compressor 107, the liquid pump 108, the flow valves 112, and/or the plurality of ejectors 101 if at least one ejector 101 of the plurality of ejectors 101 are variable. The controller 104 is adapted to control the plurality of ejectors 101 based on a plurality of generated maps that are described in detail in the detailed description of FIG. 2 for enhancing the Coefficient of Performance (COP) of the ejector refrigeration circuit as efficiently as possible. In an embodiment, the controller 104 may refer to a single controller 104 or may be construed to encompass one or a combination of microprocessors, suitable logic, circuits, printed circuit boards (PCB), audio interfaces, visual interfaces, haptic interfaces, or the like. The controller 104 may include, but is not limited to, a microcontroller, a Reduced Instruction Set Computing (RISC) processor, an Application-Specific Integrated Circuit (ASIC) processor, a Complex Instruction Set Computing (CISC) processor, a central processing unit (CPU), a graphics processing unit (GPU), a state machine, and/or other processing units or circuits.

[0044] The controller 104 may also include suitable logic, circuits, interfaces, and/or code that may be configured to execute a set of instructions stored in a memory unit. In an exemplary implementation of the memory unit according to the disclosure, the memory unit may include, but is not limited to, Electrically Erasable Programmable Read-only Memory (EEPROM), Random Access Memory (RAM), Read Only Memory (ROM), Hard Disk Drive (HDD), Flash memory, Solid-State Drive (SSD), and/or CPU cache memory.

[0045] The controller 104 may also include a communication unit adapted to communicate with a computing device via a communication network. The communication unit may be configured of, for example, a telematic

transceiver (DCM), a mayday battery, a GPS, a data communication module ASSY, a telephone microphone ASSY, and a telephone antenna ASSY. The communication network may include, but is not limited to, a Wide Area Network (WAN), a cellular network, such as a 3G, 4G, or 5G network, an Internet-based mobile ad hoc networks (IMANET), etc. The communication network may also include wired media such as a wired network or direct-wired connection, and wireless media such as acoustic, radio frequency (RF), microwave, infrared (IR) and other wireless media. In an embodiment, the computing device may be implemented as a portion of a small-form factor portable (or mobile) electronic device such as a cell phone, a personal data assistant (PDA), a personal media player device, a wireless web-watch device, a personal headset device, an application specific device, or a hybrid device that include any of the above functions.

[0046] In an exemplary embodiment, the controller 104 may receive power from a suitably coupled power source (not shown). For example, a battery or a power source may be electrically coupled to supply electrical power to the controller 104. In an embodiment, the power source may be, for example, a battery, such as a rechargeable battery or a non-rechargeable battery. Examples of suitable batteries include, for example, a lithium battery (such as a lithium-ion battery), a nickel battery (such as a nickel-cadmium battery), and an alkaline battery.

[0047] FIG. 1B exemplarily illustrates a schematic sectional view of the controllable variable ejector 101 as it may be employed in the exemplary embodiment shown in FIG. 1A. Each of the plurality of ejectors 101 includes the primary high pressure input port 101a, the secondary low pressure input port 101b, and the output port 101c. The ejector 101 is formed by a motive nozzle 113 nested within an outer member 114. The primary high pressure input port 101a forms the inlet to the motive nozzle 113. The outlet of the outer member 114 provides the output port 101c of the ejector 101. A primary refrigerant flow 115 enters the primary high pressure input port 101a and then passes into a convergent section 116 of the motive nozzle 113. The primary refrigerant flow 115 then passes through a throat section 117 and a divergent expansion section 118 to an outlet 119 of the motive nozzle 113. The motive nozzle 113 accelerates the primary refrigerant flow 115 and decreases the pressure of the primary refrigerant flow 115. The secondary low pressure input port 101b forms an inlet of the outer member 114. The pressure reduction caused to the primary flow by the motive nozzle 113 draws a secondary flow 120 into the outer member 114. The outer member 114 includes a mixer having a convergent section 121 and an elongate throat or mixing section 122. The outer member 114 also has a divergent section or diffuser 123 downstream of the elongate throat or mixing section 122. The outlet 119 of the motive nozzle 113 is positioned within the convergent section 121. As the primary refrigerant flow 115 exits the outlet 119, the primary refrigerant flow 115 begins to mix

with the secondary flow 120 with further mixing occurring through the elongated throat or mixing section 122 which provides a mixing zone. Thus, respective primary and secondary flow paths respectively extend from the primary high pressure input port 101a and the secondary low pressure input port 101b to the output port 101c, merging at the exit.

[0048] In operation, the primary refrigerant flow 115 may be supercritical upon entering the controllable variable ejector 101 and subcritical upon exiting the motive nozzle 113. The secondary flow 120 may be gaseous or a mixture of gas with a smaller amount of liquid upon entering the secondary low pressure input port 101b. The resulting combined flow 124 is a liquid/vapor mixture and decelerates and recovers pressure in the diffuser 123 while remaining a mixture.

[0049] The controllability of the controllable variable ejector 101 is provided by a needle valve 125 having a needle 126 and an actuator 127. The actuator 127 is adapted to move a tip portion 128 of the needle 126 into and out of the throat section 117 of the motive nozzle 113 to modulate the primary refrigerant flow 115 through the motive nozzle 113 and, in turn, the controllable variable ejector 101 overall. In an embodiment, each of the plurality of ejectors 101 may have throat sections 117 having different diameters. Alternatively, each of the plurality of ejectors 101 may have throat sections 117 having equal diameters. As used throughout this document, the term "opening percentage" refers to the percentage of opening of the throat section 117. When the tip portion 128 of the needle 126 moves into the throat section 117, the opening percentage reduces to zero percent. Similarly, when the tip portion 128 moves completely out of the throat section 117, the opening percentage increases to 100 percent. Therefore, by actuating the tip portion of the needle 126 into and out of the throat section 117 of the motive nozzle 113, the opening percentage of the throat section 117 is controlled to range between 0-100 percent, such that the opening percentage of zero percent restricts the primary refrigerant flow 115 completely and the opening percentage of 100 percent allows the primary refrigerant flow 115 completely.

[0050] In an embodiment, the actuators 127 may be an electric actuator, for example, a solenoid or the like. The controller 104 disclosed in the detailed description of **FIG. 1A** may be coupled to the actuator 127 and other controllable components of the controllable variable ejector 101 using hardwired or wireless communication paths. The controller 104 may store a mathematical model to estimate the suction and motive flow rate. As such, the controller 104 may extract signals from sensors such as temperature sensors, pressure sensors, and the like to determine one or more parameters for use in the mathematical model. For example, the controller uses a motive Pressure, a motive temperature, a diameter of an Ejector needle opening, a diffuser Pressure, a Suction Pressure, etc. to estimate the suction flow rates and motive flow rates dynamically during operation.

[0051] **FIG. 2** exemplarily illustrates a schematic view of the plurality of maps 200, 200A, 200B, 200C generated by the controller 104 of the system 100 shown in **FIG. 1A**. The controller 104 is coupled to each of the plurality of ejectors 101 of the system 100. As an example, the controller 104 is shown to generate the maps 200, 200A, 200B, and 200C based on a set of predefined conditions.

[0052] Each of the maps 200, 200A, 200B, 200C include a plurality of stages 201, 202, 203. For example, in the first stage 201, only the first ejector 101' is open. In the second stage 202, the first ejector 101' and the second ejector 101" are open. In the third stage 203, the first ejector 101', the second ejector 101", and the third ejector 101''' are open. The number of stages 201, 202, 203 may be the same as the number of ejectors 101. As shown in **FIG. 2**, in the illustrated embodiment, three stages 201, 202, 203 are depicted with respect to three ejectors 101', 101", 101'''. It may be appreciated that the number of ejectors 101 may be two, three, more than three, or in extreme cases only one. As such, the number of stages may also include two stages, three stages or, in extreme cases, a single stage. Therefore, the number of stages is equal to the number of ejectors.

[0053] In an embodiment, the set of predefined conditions may be a set of constraints that include at least the following:

- (A) the opening percentages of the plurality of ejectors 101 increase within a stage. This means the opening percentages of the plurality of ejectors 101 cannot decrease within a stage.
- (b) When switching between the plurality of stages 201, 202, 203 of each of the plurality of maps 200, 200A, 200B, 200C, the opening percentages of the plurality of ejectors 101 are adjusted to keep the flow rate of the refrigerant fluid constant. This means the cumulative refrigerant fluid exiting the plurality of ejectors 101 may be kept constant irrespective of the number of ejectors 101 being closed or opened.
- (c) When switching between the plurality of stages 201, 202, 203 of each of the plurality of maps 200, 200A, 200B, 200C, the opening percentages of the plurality of ejectors 101 are greater than zero. This means once an ejector 101 from the plurality of ejectors 101 is opened during any stage, the same ejector 101 cannot be closed in any subsequent stage; and
- (d) A flow rate of the refrigerant fluid through the secondary low pressure input port 101b of each of the plurality of ejectors 101 is greater than zero.

[0054] In an embodiment, each of the plurality of maps 200, 200A, 200B, 200C are associated with a corresponding temperature of the heat rejecting heat exchanger 105. For example, the map 200 is generated for a temperature of 277.1K of the heat rejecting heat exchanger 105, the map 200A is generated for a temperature of

289.1K of the heat rejecting heat exchanger 105, the map 200B is generated for a temperature of 301.1K of the heat rejecting heat exchanger 105, the map 200C is generated for a temperature of 313.1K of the heat rejecting heat exchanger 105, and so on. Each of the plurality of maps 200, 200A, 200B, 200C indicates a rate of change of the flow rate of the refrigerant fluid through each of the plurality of ejectors 101 based on a change in the opening percentage of each of the plurality of ejectors 101 during the corresponding temperature of the heat rejecting heat exchanger 105.

[0055] Each of the plurality of maps 200, 200A, 200B, 200C comprises the plurality of stages 201, 202, 203. During the first stage 201, the opening percentage of only the first ejector 101' is greater than zero. This means the first ejector 101' is open while the second ejector 101" and the third ejector 101''' remain closed. During the second stage 202, the opening percentage of the plurality of ejectors 101 excluding the first ejector 101' and the second ejector 101" equals zero. This means the first ejector 101' and the second ejector 101" are open while the third ejector 101''' remains closed. Similarly, during the third stage 203, the opening percentage of the plurality of ejectors 101 excluding the first ejector 101', the second ejector 101", and the third ejector 101''' equals zero. This means the first ejector 101', the second ejector 101", and the third ejector 101''' are open while any remaining ejectors are closed. Therefore, in each of the maps 200, 200a, 200b, 200c the opening percentage of at least the first ejector 101' from the plurality of ejectors 101 is greater than zero in each of the plurality of stages 201, 202, 203.

[0056] As an example, when the temperature of the heat rejecting heat exchanger 105 reaches 289.1K, the controller 104 identifies the first map 200A from the plurality of maps 200, 200A, 200B, 200C. The controller 104 also receives an input signal from the first ejector 101' indicative of a flow rate of a refrigerant fluid through the first ejector 101'. The controller 104 adjusts the opening percentages of the plurality of ejectors 101 based on the identified first map 200A.

[0057] FIG. 3 exemplarily illustrates a flowchart indicating a method 300 for controlling the plurality of ejectors 101 in the ejector refrigeration circuit. While the steps of FIG. 3 are shown and described in a particular sequence, the steps may occur in variations to the sequence in accordance with various embodiments of the disclosure. Further, the details related to various steps of FIG. 3, which are already covered in the description related to FIGS. 1A-2 are not discussed again in detail here for the sake of brevity. The method 300 for controlling the plurality of ejectors in an ejector refrigeration circuit, is disclosed.

[0058] At Step 301, the controller 104 generates the plurality of maps 200, 200A, 200B, 200C as shown in FIG. 2 based on the set of predefined conditions. Each of the plurality of maps 200, 200A, 200B, 200C, is associated with a corresponding temperature of the heat rejecting

heat exchanger 105. The generation of the plurality of maps 200, 200A, 200B, 200C for different temperatures of the heat rejecting heat exchanger 105 ensures the optimization of the ejector control over the entire working range of the heat rejecting heat exchanger 105.

[0059] At Step 303, the controller 104 identifies a first map 200A from the plurality of maps 200, 200A, 200B, 200C associated with the first temperature of the heat rejecting heat exchanger 105 and the input signal from the first ejector 101' indicative of the flow rate of the refrigerant fluid through the first ejector 101'. This feature advantageously allows the ejector control to be adjusted based on changes in the first temperature of the heat rejecting heat exchanger 105. This means any fluctuation or variation in the first temperature will not adversely affect the ejector control of the system 100.

[0060] At Step 305, the controller 104 adjusts the opening percentages of the plurality of ejectors 101 based on the identified first map 200A.

[0061] The system 100, disclosed herein, ensures the overall machine behavior is more robust by minimizing the number of ON/OFF switches. This is because the set of predefined conditions includes the constraint that the ejector 101' opened in the first stage 201 cannot be closed in subsequent stages 202 or 203. Moreover, within a stage, the opening percentage of the ejectors 101 always increase thereby enhancing the overall coefficient of performance (COP).

[0062] While specific language has been used to describe the subject matter, any limitations arising on account thereto, are not intended. As would be apparent to a person in the art, various working modifications may be made to the method in order to implement the inventive concept as taught herein. The drawings and the foregoing description give examples of embodiments. Those skilled in the art will appreciate that one or more of the described elements may well be combined into a single functional element. Alternatively, certain elements may be split into multiple functional elements. Elements from one embodiment may be added to another embodiment.

Claims

1. A system (100) for controlling a plurality of ejectors (101) in an ejector refrigeration circuit, the system comprising:

a plurality of ejectors (101), each of the plurality of ejectors having a primary high pressure input port (101a), a secondary low pressure input port (101b), and an output port (101c); and
a controller (104) coupled to each of the plurality of ejectors, the controller adapted to:

generate a plurality of maps (200, 200A, 200B, 200C) based on a set of predefined conditions, each of the plurality of maps

- being associated with a corresponding temperature of a heat rejecting heat exchanger (105);
 identify a first map (200A) from the plurality of maps associated with a first temperature of the heat rejecting heat exchanger and an input signal indicative of a flow rate of a refrigerant fluid through a first ejector (101'); and
 adjust opening percentages of the plurality of ejectors based on the identified first map.
2. The system of claim 1, wherein each of the plurality of maps (200, 200A, 200B, 200C) indicates a rate of change of the flow rate of the refrigerant fluid through each of the plurality of ejectors (101) based on a change in the opening percentage of each of the plurality of ejectors during the corresponding temperature of the heat rejecting heat exchanger (105).
3. The system of claims 1 or 2, wherein each of the plurality of maps (200, 200A, 200B, 200C) comprises a plurality of stages (201, 202, 203) and the opening percentage of at least the first ejector (101') from the plurality of ejectors (101) is greater than zero in each of the plurality of stages,
 optionally wherein the plurality of stages comprises at least:
- a first stage (201), wherein the opening percentage of the plurality of ejectors excluding the first ejector equals zero;
 a second stage (202), wherein the opening percentage of the plurality of ejectors excluding the first ejector and a second ejector (101'') equals zero; and
 a third stage (203), wherein the opening percentage of the plurality of ejectors excluding the first ejector, the second ejector, and a third ejector (101''') equals zero.
4. The system according to any of the preceding claims, wherein the set of predefined conditions comprise:
- the opening percentages of the plurality of ejectors (101) increase within a stage;
 when switching between the plurality of stages (201, 202, 203) of each of the plurality of maps (200, 200A, 200B, 200C), the opening percentages of the plurality of ejectors are adjusted to keep the flow rate of the refrigerant fluid constant;
 when switching between the plurality of stages of each of the plurality of maps, the opening percentages of the plurality of ejectors are greater than zero; and
 a flow rate of the refrigerant fluid through the
- secondary low pressure input port (101b) of each of the plurality of ejectors is greater than zero.
5. The system according to any of the preceding claims, wherein the plurality of ejectors (101) are controllable variable ejectors connected in a parallel configuration.
6. The system according to any of the preceding claims, wherein the plurality of ejectors (101) have at least one of different capacities and equal capacities.
7. The system according to any of the preceding claims, wherein the ejector refrigeration circuit comprises:
- a high pressure ejector circuit comprising in a direction of flow of a circulating refrigerant:
- the heat rejecting heat exchanger (105) having an inlet side (105a) and an outlet side (105b);
 the plurality of ejectors (101), each of the plurality of ejectors having the primary high pressure input port (101a), the secondary low pressure input port (101b), and the output port (101c), wherein the primary high pressure input port is in fluid communication with the outlet side of the heat rejecting heat exchanger;
 a receiver (106), having an inlet (106a), a liquid outlet (106b), and a gas outlet (106c), the inlet in fluid communication with the output port of each of the plurality of ejectors;
 at least one compressor (107) having an inlet side (107a) and an outlet side (107b), the inlet side of the at least one compressor in fluid communication with the gas outlet of the receiver and the outlet side of the at least one compressor in fluid communication with the inlet side of the heat
- rejecting heat exchanger; and
 a refrigerating evaporator flow path comprising in the direction of flow of the circulating refrigerant:
- a liquid pump (108) having an inlet side (108a) and an outlet side (108b), the inlet side in fluid communication with the liquid outlet of the receiver;
 at least one refrigeration expansion device (109) having an inlet side (109a) and an outlet side (109b), the inlet side of the at least one refrigeration expansion device in

fluid communication with the outlet side of the liquid pump; and
 at least one refrigeration evaporator (110) having an inlet side (110a) and an outlet side (110b), the inlet side in fluid communication with the outlet side of the at least one refrigeration expansion device and the outlet side in fluid communication with the secondary low pressure input port of each of the

plurality of ejectors,
 optionally wherein the liquid pump (108) comprises a bypass-line having a switchable bypass valve (111) for allowing refrigerant to selectively bypass the liquid pump by opening the switchable bypass valve.

8. A method for controlling a plurality of ejectors (101) in an ejector refrigeration circuit, the method comprising:

generating, via a controller (104), a plurality of maps (200, 200A, 200B, 200C) based on a set of predefined conditions, each of the plurality of maps associated with a corresponding temperature of a heat rejecting heat exchanger (105);
 identifying, via the controller, a first map (200A) from the plurality of maps associated with a first temperature of the heat rejecting heat exchanger and an input signal indicative of a flow rate of a refrigerant fluid through a first ejector (101');
 and
 adjusting, via the controller, opening percentages of the plurality of ejectors based on the identified first map.

9. The method of claim 8, wherein each of the plurality of maps (200, 200A, 200B, 200C) indicates a rate of change of the flow rate of the refrigerant fluid through each of the plurality of ejectors (101) based on a change in the opening percentage of each of the plurality of ejectors during the corresponding temperature of the heat rejecting heat exchanger (105).

10. The method of claims 8 or 9, wherein each of the plurality of maps (200, 200A, 200B, 200C) comprises a plurality of stages (201, 202, 203) and the opening percentage of at least the first ejector (101') from the plurality of ejectors (101) is greater than zero in each of the plurality of stages,
 optionally wherein the plurality of stages comprises at least:

a first stage (201), wherein the opening percentage of the plurality of ejectors excluding the first ejector equals zero;
 a second stage (202), wherein the opening percentage of the plurality of ejectors excluding the

first ejector and a second ejector (101'') equals zero; and
 a third stage (203), wherein the opening percentage of the plurality of ejectors excluding the first ejector, the second ejector, and a third ejector (101''') equals zero.

11. The method according to any of claims 8-10, wherein the set of predefined conditions comprise:

the opening percentages of the plurality of ejectors (101) increase within a stage;
 when switching between the plurality of stages (201, 202, 203) of each of the plurality of maps (200, 200A, 200B, 200C), the opening percentages of the plurality of ejectors are adjusted to keep the flow rate of the refrigerant fluid constant;
 when switching between the plurality of stages of each of the plurality of maps, the opening percentages of the plurality of ejectors are greater than zero; and
 a flow rate of the refrigerant fluid through a secondary low pressure input port (101b) of each of the plurality of ejectors is greater than zero.

12. The method according to any of claims 8-11, wherein each of the plurality of ejectors (101) comprise a primary high pressure input port (101a), a secondary low pressure input port (101b), and an output port (101c).

13. The method of claims 8-12, wherein each of the plurality of ejectors (101) are controllable variable ejectors connected in a parallel configuration.

14. The method of claims 8-13, wherein the plurality of ejectors (101) have at least one of different capacities and equal capacities.

15. The method of claims 8-14, wherein the ejector refrigeration circuit comprises:

a high pressure ejector circuit comprising in the direction of flow of a circulating refrigerant:

the heat rejecting heat exchanger (105) having an inlet side (105a) and an outlet side (105b);
 the plurality of ejectors (101), each of the plurality of ejectors having the primary high pressure input port (101a), the secondary low pressure input port (101b), and the output port (101c), wherein the primary high pressure input port is in fluid communication with the outlet side of the heat rejecting heat exchanger;

a receiver (106), having an inlet (106a), a liquid outlet (106b), and a gas outlet (106c), the inlet in fluid communication with the output port of each of the plurality of ejectors;

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at least one compressor (107) having an inlet side (107a) and an outlet side (107b), the inlet side of the at least one compressor in fluid communication with the gas outlet of the receiver and the outlet side of the at least one compressor in fluid communication with the inlet side of the heat

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rejecting heat exchanger; and

a refrigerating evaporator flow path comprising in the direction of flow of the circulating refrigerant:

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a liquid pump (108) having an inlet side (108a) and an outlet side (108b), the inlet side in fluid communication with the liquid outlet of the receiver;

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at least one refrigeration expansion device (109) having an inlet side (109a) and an outlet side (109b), the inlet side of the at least one refrigeration expansion device in fluid communication with the outlet side of the liquid pump; and

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at least one refrigeration evaporator (110) having an inlet side (110a) and an outlet side (110b), the inlet side in fluid communication with the outlet side of the at least one refrigeration expansion device and the outlet side in fluid communication with the secondary low pressure input port of each of the

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plurality of ejectors,

optionally wherein the liquid pump (108) comprises a bypass-line including a switchable bypass valve (111) allowing refrigerant to selectively bypass the liquid pump by opening the switchable bypass valve.

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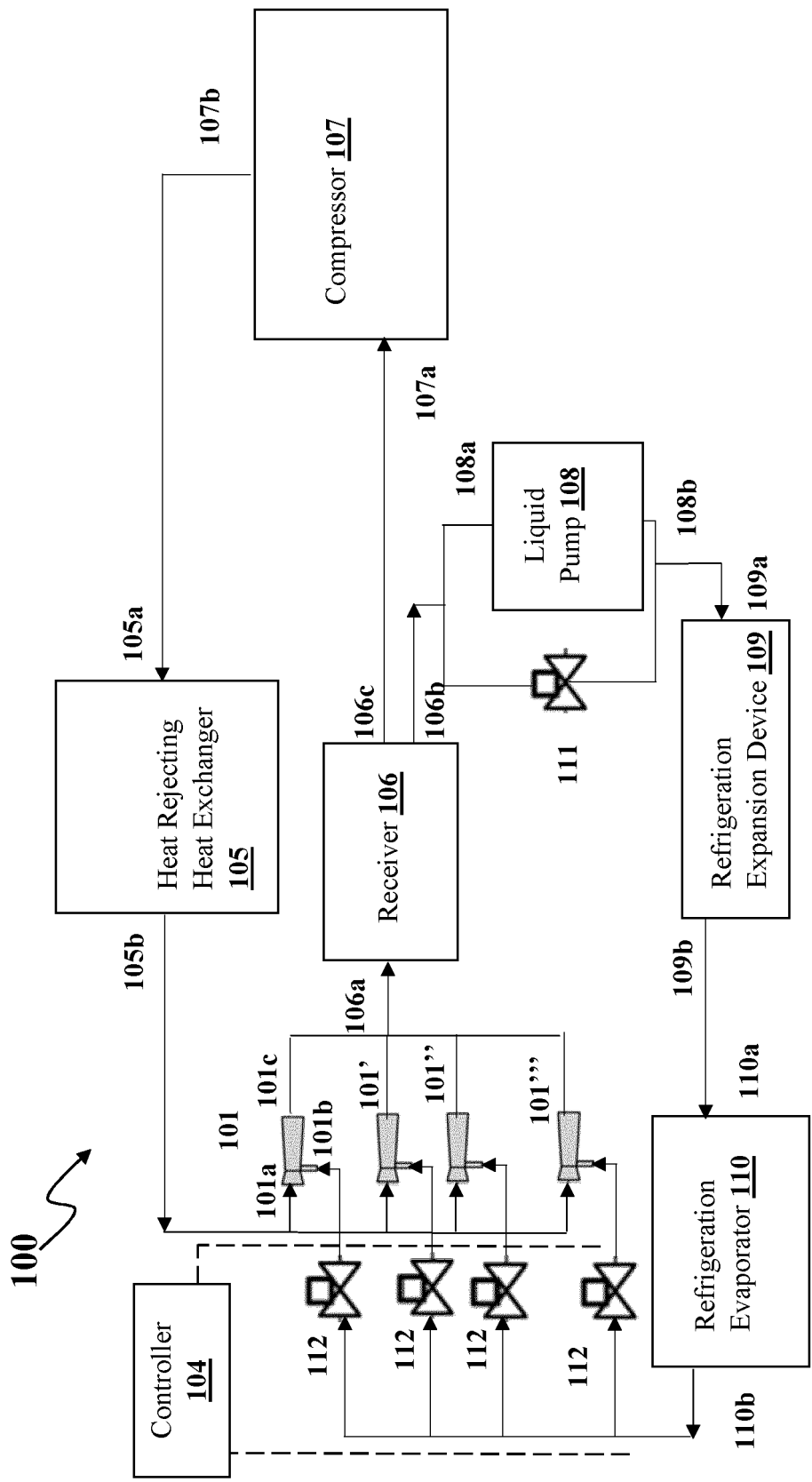


FIG. 1A

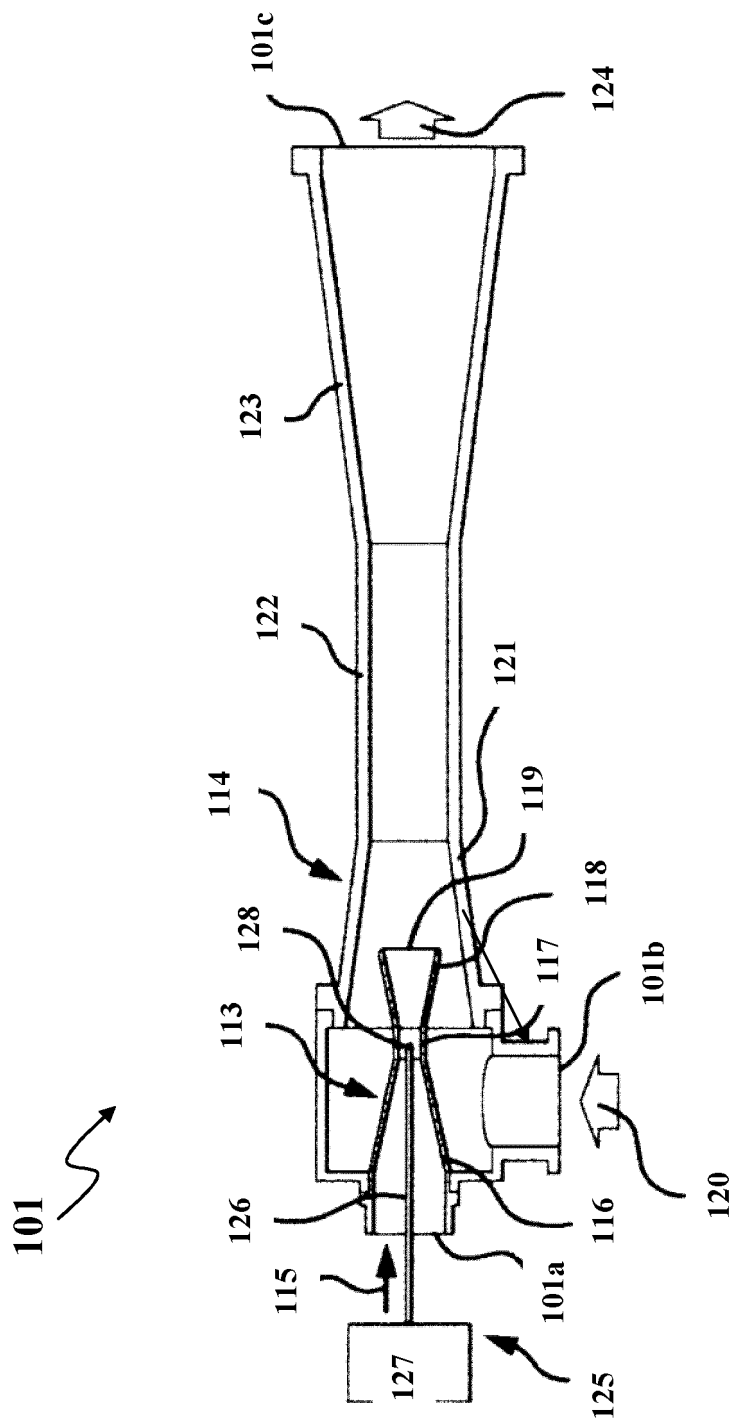


FIG. 1B

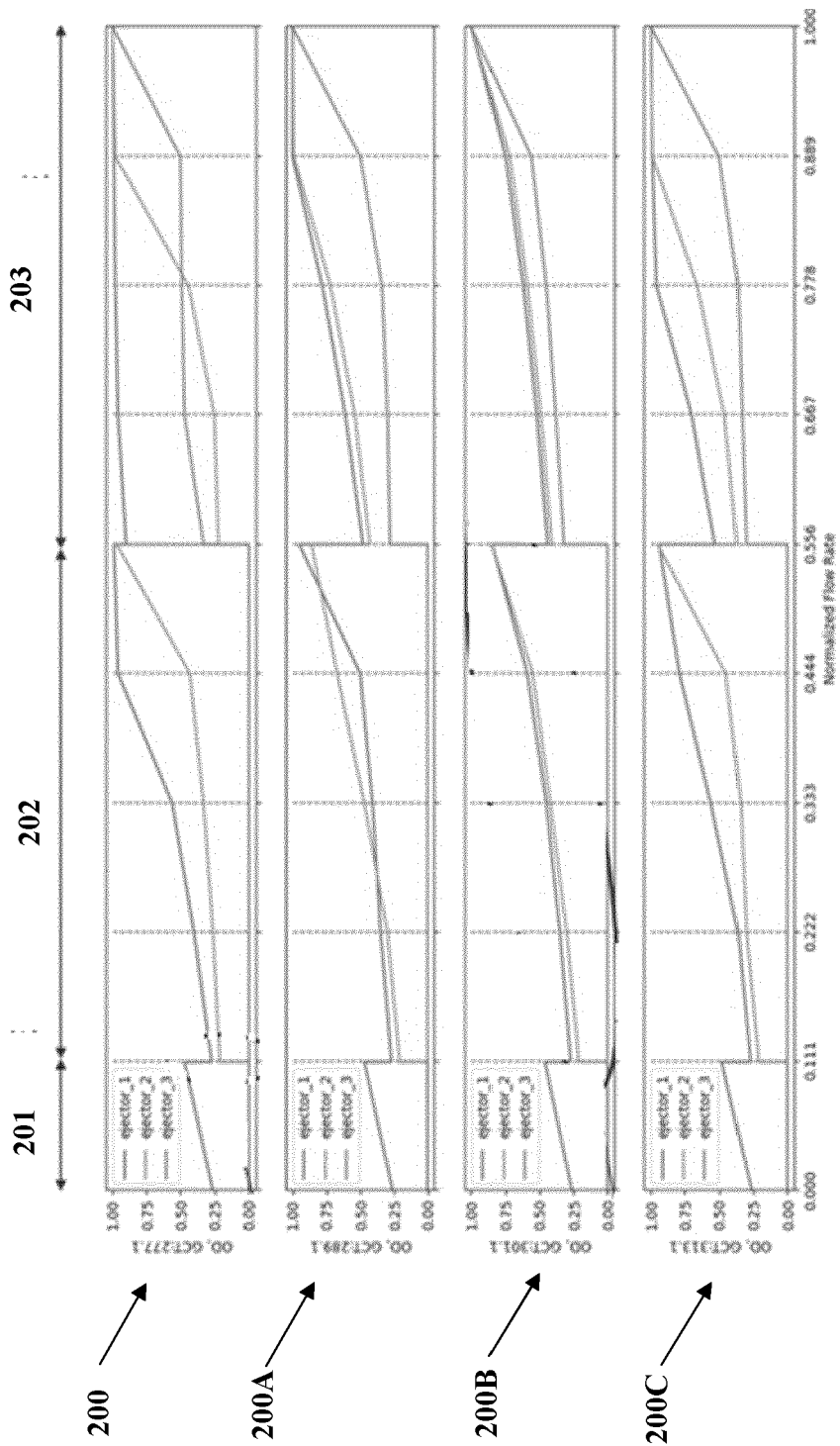


FIG. 2

300

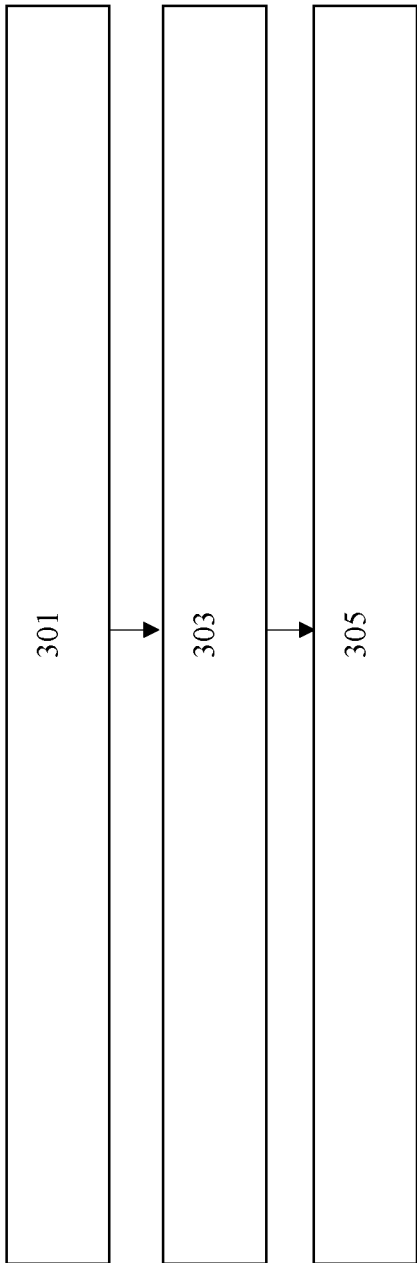


FIG. 3



EUROPEAN SEARCH REPORT

Application Number

EP 24 19 3293

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	JP 2010 151424 A (DAIKIN IND LTD) 8 July 2010 (2010-07-08) * paragraphs [0075] - [0093]; figures 6-8 *	1-15	INV. F25B49/02
A	US 2021/348810 A1 (HELLMANN SASCHA [DE]) 11 November 2021 (2021-11-11) * paragraphs [0060] - [0080]; figure 1 * -----	1-15	
			TECHNICAL FIELDS SEARCHED (IPC)
			F25B
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
Munich		3 December 2024	Weisser, Meinrad
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ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 24 19 3293

5

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
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 2010151424 A	08-07-2010	NONE	

US 2021348810 A1	11-11-2021	CN 113623887 A	09-11-2021
		EP 3907443 A1	10-11-2021
		US 2021348810 A1	11-11-2021

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