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HOT GAS DEFROST USING MEDIUM TEMPERATURE DISCHARGE GAS

Abstract

A refrigeration system includes evaporators, one or more medium temperature compressors, and a three-way valve positioned downstream from the one or more medium temperature compressors. The three-way valve receives the compressed refrigerant from the medium temperature compressors and directs flow of the received compressed refrigerant to (i) a gas cooler and/or (ii) one or more of the evaporators based on an operation mode of the evaporators. A controller determines that operation of a first evaporator in a defrost mode is indicated and causes the first evaporator to operate in the defrost mode by adjusting the three-way valve to direct a portion of the received compressed refrigerant to the first evaporator.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION [0001] The application is a continuation of U.S. patent application Ser. No. 17/844,651 filed Jun. 20, 2022, entitled "HOT GAS DEFROST USING MEDIUM TEMPERATURE DISCHARGE GAS," which is incorporated herein by reference.

TECHNICAL FIELD
[0002] This disclosure relates generally to refrigeration systems. More particularly, in certain embodiments, this disclosure relates to hot gas defrost using medium temperature discharge gas.
BACKGROUND
[0003] Refrigeration systems are used to regulate environmental conditions within an enclosed space. Refrigeration systems are used for a variety of applications, such as in supermarkets and warehouses, to cool stored items. For example, refrigeration systems may provide cooling operations for refrigerators and freezers.
SUMMARY OF THE DISCLOSURE
[0004] During operation of refrigeration systems, ice may build up on evaporators. These evaporators need to be defrosted to remove ice buildup and prevent loss of performance. Previous evaporator defrost processes are limited in terms of their efficiency and effectiveness. For example, using previous technology, defrost processes may take a relatively long time and consume a relatively large amount of energy. In some cases, previous technology may be incapable of providing adequate defrosting, for instance, in cases where a relatively large number of evaporators need to be defrosted in a multiple-evaporator refrigeration system.
[0005] This disclosure provides technical solutions to the problems of previous technology, including those described above. For example, a refrigeration system is described that facilitates improved evaporator defrost using medium temperature discharge gas from one or more compressors located downstream of a medium temperature portion of the refrigeration system. While one or a portion of the evaporators of the refrigeration system are operating in a normal refrigeration mode, other evaporator(s) can be operated in a defrost mode using the hot gas produced by the refrigeration process. When defrost operations are complete, evaporators may be operated in a transition mode that protects the system from sudden increases in pressure before the system is returned to normal refrigeration mode operation. Embodiments of this disclosure may provide improved defrost operations to evaporators of refrigeration systems, such as CO.sub.2 refrigeration systems. Certain embodiments may include none, some, or all of the above technical advantages. One or more other technical advantages may be readily apparent to one skilled in the art from the figures, descriptions, and claims included herein.
[0006] In an embodiment, a refrigeration system includes a plurality of evaporators configured to transfer heat from a space to a refrigerant, one or more medium temperature compressors configured to compress the refrigerant, and a three-way valve positioned downstream from the one or more medium temperature compressors. The three-way valve receives the compressed refrigerant from the one or more medium temperature compressors and is operable to direct flow of the received compressed refrigerant to one or both of (i) a gas cooler and (ii) one or more of the evaporators of the plurality of evaporators based on an operation mode of the plurality of evaporators. A controller is communicatively coupled to the three-way valve. The controller determines that operation of a first evaporator of the plurality of evaporators in a defrost mode is

indicated and, after determining that operation of the first evaporator in the defrost mode is indicated, causes the first evaporator to operate in the defrost mode by adjusting the three-way valve to direct a portion of the received compressed refrigerant to the first evaporator.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0007] For a more complete understanding of the present disclosure, reference is now made to the following description, taken in conjunction with the accompanying drawings, in which:
[0008] FIG. **1** is a diagram of an example refrigeration system of this disclosure configured to operate evaporators in a refrigeration mode;
[0009] FIG. **2** is a diagram of the example refrigeration system of FIG. **1** configured to operate an evaporator in a defrost mode;
[0010] FIG. **3** is a diagram of an example refrigeration system of this disclosure configured to operate the evaporator in a transition mode; and
[0011] FIG. **4** is a flowchart of an example method of operating the refrigeration system of FIGS. **1-3** to provide improved evaporator defrost.
DETAILED DESCRIPTION
[0012] Embodiments of the present disclosure and its advantages are best understood by referring to FIGS. **1-4** of the drawings, like numerals being used for like and corresponding parts of the various drawings.
[0013] As described above, prior to this disclosure, defrost operations of refrigeration systems suffered from certain inefficiencies and drawbacks. The refrigeration system of this disclosure provides improvements in defrost performance and energy efficiency. The refrigeration system of this disclosure may be a CO.sub.2 refrigeration system. CO.sub.2 refrigeration systems may differ from conventional refrigeration systems in that these systems circulate refrigerant that may become a supercritical fluid (i.e., where distinct liquid and gas phases are not present) above the critical point. As an example, the critical point for carbon dioxide (CO.sub.2) is 31° C. and 73.8 MPa, and above this point, CO.sub.2 becomes a homogenous mixture of vapor and liquid that is called a supercritical fluid. This unique characteristic of transcritical refrigerants is associated with certain operational differences between transcritical and conventional refrigeration systems. For example, transcritical refrigerants are typically associated with discharge temperatures that are higher than their critical temperatures and discharge pressures that are higher than their critical pressures. When a transcritical refrigerant is at or above its critical temperature and/or pressure, the refrigerant may become a “supercritical fluid”—a homogenous mixture of gas and liquid. Supercritical fluid does not undergo phase change process (vapor to liquid) in a gas cooler as occurs in a condenser of a conventional refrigeration system circulating traditional refrigerant. Rather, supercritical fluid cools down to a lower temperature in the gas cooler. Stated differently, the gas cooler in a CO.sub.2 transcritical refrigeration system may receive and cool supercritical fluid, and the transcritical refrigerant undergoes a partial state change from gas to liquid as it is discharged from an expansion valve.
Refrigeration System
[0014] FIGS. **1-3** illustrate an example refrigeration system **100** configured for improved defrost operation. The refrigeration system **100** shown in FIG. **1** is configured to operate evaporators **116**, **128** in a refrigeration mode, such that the evaporators **116**, **128** provide cooling to a corresponding space, such as a freezer and deep freeze, respectively (not shown for clarity and conciseness). FIG. **2** illustrates the example refrigeration system **100** when configured for operation of evaporator **128** in a defrost mode, such that evaporator **128** is defrosted and evaporator **116** still provides cooling to a space. When at least one of the evaporators **116**, **128** is operated in the defrost mode, refrigerant

from one or more medium-temperature (MT) compressors **102** is provided to the evaporators **116**, **128** to facilitate defrosting of the evaporators **116**, **128**. The refrigerant removes ice buildup from coils of the evaporator(s) **116**, **128**. The evaporators **116**, **128** may be configured to operate at relatively high pressures of refrigerant provided from the MT compressor(s) **102** (e.g., at about 120 bar). FIG. **3** illustrates the example refrigeration system **100** when configured for operation of evaporator **128** in a transition mode, such that a portion of the hot gas used to defrost the evaporator **128** is provided back towards the MT compressor(s) **102** via valve **130**. The transition mode operation helps prevent excessively high pressures in the evaporator **128** before it is returned to the refrigeration mode operation shown in FIG. **1**.

[0015] Refrigeration system **100** includes one or more MT compressors **102**, refrigerant conduit subsystem **104**, three-way valve **106**, gas cooler **108**, flash tank **112**, one or more MT evaporators **116** and corresponding valves **114**, **118**, **120**, **122**, **124**, one or more low-temperature (LT) evaporators **128** and corresponding valves **126**, **130**, **132**, **134**, **136**, one or more LT compressors **138**, a valve **140**, a flash-gas bypass valve **142**, and controller **150**. In some embodiments, refrigeration system **100** is a transcritical refrigeration system that circulates a transcritical refrigerant such as CO.sub.2.

[0016] The MT compressor(s) **102** are configured to compress refrigerant discharged from the MT evaporator(s) **116** operating in refrigeration mode (as shown in each of FIGS. **1-3**) and provide supplemental compression to refrigerant discharged from any of the LT evaporators **128** that are operating in refrigeration mode (as shown in FIG. **1**). Refrigeration system **100** may include any suitable number of MT compressors **102**. MT compressor(s) **102** may vary by design and/or by capacity. For example, some compressor designs may be more energy efficient than other compressor designs, and some MT compressors **102** may have modular capacity (e.g., a capability to vary capacity). The controller **150** is in communication with the MT compressors **102** and controls their operation.

[0017] Refrigerant conduit subsystem **104** facilitates the movement of refrigerant (e.g., CO.sub.2) through a refrigeration cycle such that the refrigerant flows in the refrigeration mode as illustrated by the arrows in FIG. **1**. The refrigerant conduit subsystem **104** includes conduit, tubing, and the like that facilitates the movement of refrigerant between components of the refrigeration system **100**.

[0018] Three-way valve **106** is generally a motorized or otherwise electronically controllable three-way valve. Three-way valve **106** receives compressed refrigerant from the MT compressor(s) **102** and is adjustable to control the direction of this refrigerant towards the gas cooler **108** to be used to provide refrigeration and/or toward the MT and/or LT evaporators **116**, **128** to provide defrost. The controller **150** is in communication with three-way valve **106** and controls its operation.

[0019] Gas cooler **108** is generally operable to receive refrigerant (e.g., from three-way valve **106**) and apply a cooling stage to the received refrigerant. In some embodiments, gas cooler **108** is a heat exchanger comprising cooler tubes configured to circulate the received refrigerant and coils through which ambient air is forced. Inside gas cooler **108**, the coils may absorb heat from the refrigerant, thereby cooling the refrigerant.

[0020] Flash tank **112** is configured to receive mixed-state refrigerant and separate the received refrigerant into flash gas and liquid refrigerant. Flash tank **112** may include one or more tanks operable to hold refrigerant at least temporarily. Typically, the flash gas collects near the top of flash tank **112**, and the liquid refrigerant is collected in the bottom of flash tank **112**. A valve **110** may be disposed at or near an inlet of the flash tank **112** to reduce pressure of refrigerant received by the flash tank **112**. When both evaporators **116** and **128** are operated in refrigeration mode (see FIG. **1**), the liquid refrigerant flows from flash tank **112** and provides cooling to the MT evaporator **116** and LT evaporator **128**. When evaporator **128** is operated in defrost mode (see FIG. **2**), hot gas refrigerant provided to defrost evaporator **128** is provided to flash tank **112**. Valve **140** may be a pressure-regulating valve that adjusts the pressure of refrigerant provided to the flash tank **112** as appropriate to facilitate refrigerant flow as illustrated in FIG. **2**.

[0021] When operated in refrigeration mode (see FIG. **1**), the MT evaporator **116** receives cooled liquid refrigerant from the flash tank **112** and uses the cooled refrigerant to provide cooling. As an example, the evaporator **116** may be part of a refrigerated case and/or cooler for storing items that must be kept at particular temperatures. The refrigeration system **100** may include any appropriate number of MT evaporators **116** with the same or a similar configuration to that shown for the example MT evaporator **116** shown in FIGS. **1-3**.

[0022] Each of the one or more MT evaporators **116** has corresponding valves **114**, **118**, **120**, **122**, **124** to facilitate operation of the MT evaporator **116** in a refrigeration mode, a defrost mode, and a transition mode. Valve **114** may be an expansion valve. Expansion valve **114** may be configured to receive liquid refrigerant from flash tank **112** and reduce the pressure of the received refrigerant. In some embodiments, this reduction in pressure causes some of the refrigerant to vaporize. Valve **118** may be a motorized orifice valve. Valve **118** at least partially opens when the MT evaporator **116** is operated in a transition mode to direct refrigerant back toward the MT compressor(s) **102**, as described in greater detail below. Valves **120**, **122**, **124** may be any appropriate motorized or electronically controllable valves, such as motorized ball valves, solenoid valves, and/or the like. The controller **150** is in communication with valves **114**, **118**, **120**, **122**, **124** and controls their operation.

[0023] When the MT evaporator **116** is operated in the refrigeration mode illustrated in FIGS. **1-3**, the first valve **114** upstream of the evaporator **116** is open and the second valve **120** downstream of the evaporator **116** is open. The third valve **124** and fourth valve **122** are both closed. The transition-mode valve **118** is also closed. In this configuration, the liquid refrigerant from flash tank **112** flows through expansion valve **114**, where the pressure of the refrigerant is decreased, before it reaches the evaporator **116**. Expansion valve **114** may be configured to achieve a refrigerant temperature into the evaporator **116** at a predefined temperature for a given application (e.g., about −6° C.). Refrigerant from the MT evaporator **116** that is operating in refrigeration mode is provided to the one or more MT compressors **102**.

[0024] When the MT evaporator **116** is operated in the defrost mode (not shown for conciseness), the three-way valve **106** is adjusted such that at least a portion of compressed refrigerant from the MT compressor(s) **102** is directed towards the MT evaporator **116**. The first valve **114** upstream of the evaporator **116** is closed, and the second valve **120** downstream of the evaporator **116** is closed. Third valve **124** and fourth valve **122** are opened to allow flow of compressed refrigerant from the three-way valve **106** toward the MT evaporator **116**. The transition-mode valve **118** is closed. In this configuration, heated refrigerant from MT compressor(s) **102** flows through the evaporator **116** and defrosts the evaporator **116**. Refrigerant exiting the evaporator **116** flows through the opened valve **124** and to optional pressure-regulating valve **140**. Pressure-regulating valve **140**, if present, adjusts the pressure of the refrigerant (i.e., decreases or increases pressure of the refrigerant) before it flows back into the flash tank **112**.

[0025] Once defrost mode operation is complete, the controller **150** may end defrost mode operation and start transition mode operation by at least partially opening valve **118**. In some embodiments, the controller **150** may cause defrost mode to end after a predefined period of time included in the instructions **158** and/or schedule **162**. In some embodiments, the controller **150** may cause defrost mode operation to end after predefined conditions indicated in the instructions **158** are reached (e.g., after a temperature and/or pressure **160** measured by sensor **144** reaches a threshold **164**).

[0026] When the MT evaporator **116** is operated in the transition mode (not shown for conciseness), the three-way valve **106** is adjusted such that compressed refrigerant from the MT compressor(s) **102** is no longer provided to the MT evaporator **116**. The first valve **114** upstream of the evaporator **116** is closed, and the second valve **120** downstream of the evaporator **116** is closed. Third valve **124** and fourth valve **122** are also closed to stop the flow of compressed refrigerant from the three-way valve **106** toward the MT evaporator **116**. The transition-mode valve **118** is opened to allow a controlled flow of refrigerant toward the MT compressor(s) **102**. In this configuration, heated refrigerant from the evaporator **116** flows back to the MT compressor(s) **102** at a relatively slow rate determined by the radius of the orifice valve **118**. Transition mode operation may continue at least until a pressure of the evaporator **116** is below a threshold value **164**. For example, a sensor **144** may measure a pressure and/or temperature **160** of the evaporator **116** that is compared to a threshold **164** in order to end transition mode operation. When transition mode operation is complete, the evaporator **116** returns to refrigeration mode operation.

[0027] The LT evaporator **128** is generally similar to the MT evaporator **116** but is configured to operate at lower temperatures (e.g., for deep freezing applications near about −30° C. or the like). When operated in refrigeration mode (see FIG. **1**), the LT evaporator **128** receives cooled liquid refrigerant from the flash tank **112** and uses the cooled refrigerant to provide cooling. As an example, the evaporator **128** may be part of a deep freezer for relatively long-term storage of perishable items that must be kept at particular temperatures. For clarity and conciseness, the components of a single LT evaporator **128** are illustrated. The refrigeration system **100** may include any appropriate number of LT evaporators **128** with corresponding valves **126**, **130**, **132**, **134**, **136**.

[0028] The LT evaporator **128** includes valves **126**, **130**, **132**, **134**, **136** to facilitate operation of the LT evaporator **128** in a refrigeration mode (see FIG. **1**), a defrost mode (see FIG. **2**), and a transition mode (see FIG. **3**). Valve **126** may be an expansion valve that is the same as or similar to valve **114**, described above. Expansion valve **126** may be configured to receive liquid refrigerant from flash tank **112** and reduce the pressure of the received refrigerant. In some embodiments, this reduction in pressure causes some of the refrigerant to vaporize. Valve **130** may be a motorized orifice valve that is the same as or similar to valve **118**, described above. Valve **130** at least partially opens when the LT evaporator **128** is operated in a transition mode to provide refrigerant back towards the MT compressor(s) **102** via LT compressor(s) **138** (see FIG. **3**). Valves **132**, **134**, **136** may be any appropriate motorized or electronically controllable valves, such as motorized ball valves, solenoid valves, and/or the like (e.g., the same as or similar to valve **120**, **122**, **124**, described above). The controller **150** is in communication with valves **126**, **130**, **132**, **134**, **136** and controls their operation.

[0029] When the LT evaporator **128** is operated in the refrigeration mode illustrated in FIG. **1**, the first valve **126** upstream of the evaporator **128** is open and the second valve **132** downstream of the evaporator **128** is open. The third valve **136** and fourth valve **134** are both closed. The transition-mode valve **130** is also closed. In this configuration, the liquid refrigerant from flash tank **112** flows through expansion valve **126**, where the pressure of the refrigerant is decreased, before it reaches the evaporator **128**. Expansion valve **126** may be configured to achieve a refrigerant temperature into the evaporator **128** at a predefined temperature for a given application (e.g., about −30° C.). Refrigerant from the LT evaporator **128** that is operating in refrigeration mode is provided to the one or more LT compressors **138**.

[0030] When the LT evaporator **128** is operated in the defrost mode of FIG. **2**, the three-way valve **106** is adjusted such that at least a portion of compressed refrigerant from the MT compressor(s) **102** is directed towards the LT evaporator **128**. The first valve **126** upstream of the evaporator **128** is closed, and the second valve **132** downstream of the evaporator **128** is closed. Third valve **136** and fourth valve **134** are opened to allow flow of compressed refrigerant from the three-way valve **106** toward the LT evaporator **128**. The transition-mode valve **130** is closed. In this configuration, heated refrigerant from MT compressor(s) **102** flows through the evaporator **128** and defrosts the evaporator **128**. Refrigerant exiting the evaporator **128** flows through the opened valve **136** and to optional pressure-regulating valve **140**, described above.

[0031] Once defrost mode operation is complete, the controller **150** may end defrost mode operation and start transition mode operation by at least partially opening valve **130**, as shown in the example of FIG. **3**. In some embodiments, the controller **150** may cause defrost mode to end after a predefined period of time included in the instructions **158** and/or schedule **162**. In some embodiments, the controller **150** may cause defrost mode operation to end after predefined conditions indicated in the instructions **158** are reached (e.g., after a temperature and/or pressure **160** measured by sensor **146** reaches a threshold **164**).

[0032] When the LT evaporator **128** is operated in the transition mode of FIG. **3**, the three-way valve **106** is adjusted such that compressed refrigerant from the MT compressor(s) **102** is no longer directed towards the LT evaporator **128**. The first valve **126** upstream of the evaporator **128** is closed, and the second valve **132** downstream of the evaporator **128** is closed. Third valve **136** and fourth valve **134** are also closed to stop the flow of compressed refrigerant from the three-way valve **106** toward the LT evaporator **128**. The transition-mode valve **130** is opened to allow a controlled flow of refrigerant toward the LT compressor(s) **138** and subsequently to MT compressor(s) **102**. In this configuration, heated refrigerant from the evaporator **128** flows to the LT compressor(s) **138** at a relatively slow rate determined by the radius of the orifice valve **130**. Transition mode operation may continue at least until a pressure of the evaporator **128** is below a threshold value **164**. For example, a sensor **146** may measure a pressure and/or temperature **160** of the evaporator **128** that is compared to a threshold **164** in order to end transition mode operation. When transition mode operation is complete, the evaporator **128** returns to refrigeration mode operation.

[0033] The temperature and/or pressure sensors **144**, **146** may be disposed on, in, or near the corresponding evaporators **116**, **128** or refrigerant conduit connected to the evaporators **116**, **128**. In addition to being used to determine when transition mode operation can be ended, information from sensors **144**, **146** may assist in determining when operation in defrost mode is appropriate or should be ended. For example, if the temperature and/or pressure **160** measured by sensors **144**, **146** indicates potential freezing of the MT evaporator **116** and/or LT evaporator **128**, defrost mode operation may be indicated. In some cases, defrost mode operation is determined to be indicated based on a schedule **162** (e.g., defrost mode operation may be performed at certain predefined time intervals or at certain times).

[0034] Valves **114**, **118**, **120**, **122**, and **124** for the MT evaporator **116** and valves **126**, **130**, **132**, **134**, and **136** for the LT evaporator **128** may be in communication with controller **150**, and the controller **150** may provide instructions for adjusting these valves **114**, **118**, **120**, **122**, **124**, **126**, **130**, **132**, **134**, **136** to open or closed positions to achieve the configurations described above for refrigeration mode operation, defrost mode operation, and transition mode operation. For example, instructions **158** implemented by the processor **152** of the controller **150** may determine that operation of the MT evaporator **116** and/or the LT evaporator **128** in a defrost mode is indicated. For example, instructions **158** stored by the controller **150** may indicate that defrost mode operation is needed on a certain schedule **162** or at a certain time. As another example, a temperature and/or pressure **160** of the evaporators **116**, **128** may indicate that defrost mode operation is needed (e.g., because the temperature and/or pressure **160** indicates that expected cooling performance or efficiency is not being obtained).

[0035] Flash gas bypass valve **142** may be located in refrigerant conduit of the conduit subsystem **104** connecting the flash tank **112** to the MT compressor(s) **102** and configured to open and close to permit or restrict the flow of flash gas discharged from flash tank **112**. In some embodiments, controller **150** controls the opening and closing of flash gas bypass valve **142**. As depicted in FIGS. **1-3**, closing flash gas bypass valve **142** may restrict flash gas from flowing to MT compressor(s) **102** and opening flash gas bypass valve **142** may permit flow of flash gas to MT compressor(s) **102**.

[0036] As described above, controller **150** is in communication with at least three-way valve **106**; valves **114**, **118**, **120**, **122**, and **124** of the MT evaporator **116**; valves **126**, **130**, **132**, **134**, and **136** of the LT evaporator **128**; and compressors **102**, **138**. The controller **150** adjusts operation of components of the refrigeration system **100** to operate the evaporators **116**, **128** in refrigeration mode, defrost mode, or transition mode as described herein. The controller **150** includes a processor **152**, memory **154**, and input/output (I/O) interface **156**. The processor **152** includes one or more processors operably coupled to the memory **154**. The processor **152** is any electronic circuitry including, but not limited to, state machines, one or more central processing unit (CPU) chips, logic units, cores (e.g., a multi-core processor), field-programmable gate array (FPGAs), application specific integrated circuits (ASICs), or digital signal processors (DSPs) that communicatively couples to memory **154** and controls the operation of refrigeration system **100**.

[0037] The processor **152** may be a programmable logic device, a microcontroller, a microprocessor, or any suitable combination of the preceding. The processor **152** is communicatively coupled to and in signal communication with the memory **154**. The one or more processors are configured to process data and may be implemented in hardware or software. For example, the processor **152** may be 8-bit, 16-bit, 32-bit, 64-bit or of any other suitable architecture. The processor **152** may include an arithmetic logic unit (ALU) for performing arithmetic and logic operations, processor registers that supply operands to the ALU and store the results of ALU operations, and a control unit that fetches instructions from memory **154** and executes them by directing the coordinated operations of the ALU, registers, and other components. The processor **152** may include other hardware and software that operates to process information, control the refrigeration system **100**, and perform any of the functions described herein (e.g., with respect to FIGS. **1-4**). The processor **152** is not limited to a single processing device and may encompass multiple processing devices. Similarly, the controller **150** is not limited to a single controller but may encompass multiple controllers.

[0038] The memory **154** includes one or more disks, tape drives, or solid-state drives, and may be used as an over-flow data storage device, to store programs when such programs are selected for execution, and to store instructions **158** and data that are read during program execution. The memory **154** may be volatile or non-volatile and may include ROM, RAM, ternary content-addressable memory (TCAM), dynamic random-access memory (DRAM), and static random-access memory (SRAM). The memory **154** is operable (or configured) to store information used by the controller **150** and/or any other logic and/or instructions for performing the function described in this disclosure.

[0039] The I/O interface **156** is configured to communicate data and signals with other devices. For example, the I/O interface **156** may be configured to communicate electrical signals with components of the refrigeration system **100** including valves **106**, **114**, **118**, **120**, **122**, **124**, **126**, **130**, **132**, **134**, **136**, **140**, **142**; sensors **144**, **146**; and compressors **102**, **138**. The I/O interface **156** may be configured to communicate with other devices and systems. The I/O interface **156** may provide and/or receive, for example, compressor speed signals, compressor on/off signals, valve open/close signals, temperature signals, pressure signals, temperature setpoints, environmental conditions, and an operating mode status for the refrigeration system **100** and send electrical signals to the components of the refrigeration system **100**. The I/O interface **156** may include ports or terminals for establishing signal communications between the controller **150** and other devices. The I/O interface **156** may be configured to enable wired and/or wireless communications.

[0040] Although this disclosure describes and depicts refrigeration system **100** including certain components, this disclosure recognizes that refrigeration system **100** may include any suitable components. As an example, refrigeration system **100** may include one or more additional sensors configured to detect temperature and/or pressure information.

[0041] In an example operation of the refrigeration system **100**, the refrigeration system **100** is initially operating with both evaporators **116**, **128** in the refrigeration mode, as illustrated in FIG. **1**. In this mode, first valve **126** and second valve **132** of LT evaporator **128** are open, and third valve **136** and fourth valve **134** are closed. The transition-mode valve **130** is also closed.

[0042] At some point during operation of the refrigeration system **100**, the controller **150** determines that defrost mode operation is needed for the LT evaporator **128**. For example, the LT evaporator **128** may be scheduled for defrost at the time that has just been reached. After determining that the defrost mode operation is indicated, the controller **150** causes the LT evaporator **128** to be configured according to FIG. **2**. In other words, the controller **150** causes the three-way valve **106** to allow a portion of refrigerant from the MT compressor(s) **102** to flow towards the LT evaporator **128**. First valve **126** and second valve **132** are closed, and third valve **136** and fourth valve **134** are opened. The transition-mode valve **130** remains closed.

[0043] Once defrost of the LT evaporator **128** is complete (e.g., because defrost mode operation has been performed for a predefined period of time and/or a threshold pressure and/or temperature **160** of the LT evaporator **128** has been reached), the controller **150** causes the LT evaporator **128** to operate in the transition mode as illustrated in FIG. **3**. In other words, the controller **150** causes third valve **136** and fourth valve **134** to close and opens, at least partially, transition-mode valve **130**. Once transition mode operation is complete (e.g., once temperature and/or pressure **160** of the LT evaporator **128** is less than a threshold value **164**), the controller **150** causes the evaporator **128** to return to operation in the refrigeration mode, as shown in FIG. **1** and described above.

Example Method of Operation

[0044] FIG. **4** illustrates an example method **400** of operating the refrigeration system **100** described above with respect to FIGS. **1-3**. The method **400** may be implemented using the processor **152**, memory **154**, and I/O interface **156** of the controller **150** of FIGS. **1-3**. The method **400** may begin at operation **402** where the controller **150** initially operates the evaporator **116**, **128** in the refrigeration mode. At operation **404**, the controller **150** determines whether defrost mode is indicated for any of the evaporators **116**, **128**. For example, the controller **150** may determine whether the instructions **158** and/or schedule **162** indicate that a defrost cycle is needed for one of the evaporators **116**, **128**. As another example, the controller **150** may determine whether a temperature and/or pressure **160** measured at an evaporator **116**, **128** indicates decreased performance (e.g., if a target or threshold value **164** of temperature and/or pressure **160** is not being reached). This behavior may indicate that a defrost mode operation is indicated. If defrost mode is not indicated, the controller **150** proceeds to operation **402** and continues to operate the evaporators **116**, **128** in the refrigeration mode. If defrost mode operation is indicated, the controller **150** proceeds to operation **406**.

[0045] At operation **406**, the controller **150** causes the evaporator **116**, **128** determined at operation **404** to be operated in the defrost mode. For instance, if defrost of the LT evaporator **128** is needed, the controller **150** may cause the three-way valve **106** to allow a portion of refrigerant from the MT compressor(s) **102** to flow towards the LT evaporator **128**. First valve **126** and second valve **132** are closed, and third valve **136** and fourth valve **134** are opened. The transition-mode valve **130** remains closed. This achieves the defrost mode configuration of evaporator **128** illustrated in FIG. **2**.

[0046] At operation **408**, the controller **150** determines whether defrost mode operation of the evaporator **128** is complete. For example, the controller **150** may determine whether defrost mode operation has been performed for a predefined period of time indicated by schedule **162** and/or if a threshold value **164** is reached for a pressure and/or temperature **160** of the LT evaporator **128**. If defrost mode operation is not complete, the controller continues to operate in the defrost mode at operation **406**. Once defrost mode operation is complete, the controller **150** proceeds to operation **410**

[0047] At operation **410**, the controller **150** causes the evaporator **128** to operate in the transition mode. For example, the controller **150** may cause third valve **136** and fourth valve **134** to close and may open, at least partially, transition-mode valve **130**.

[0048] At operation **412**, the controller determines whether the transition mode operation is complete. For example, the controller **150** may determine whether a temperature and/or pressure **160** of the LT evaporator **128** is less than a threshold value **164** (e.g., of 20 bar). If transition mode operation is not complete, the controller **150** continues to operate the evaporator **128** in the transition mode. However, if transition mode operation is complete, the controller **150** returns to operation **402** and operates the evaporator **128** in the refrigeration mode.

[0049] Modifications, additions, or omissions may be made to method **400** depicted in FIG. **4**. Method **400** may include more, fewer, or other operations. For example, operations may be performed in parallel or in any suitable order. While at times discussed as controller **150**, refrigeration system **100**, or components thereof performing the operations, any suitable refrigeration system or components of the refrigeration system may perform one or more operations of the method **400**.

[0050] While several embodiments have been provided in the present disclosure, it should be understood that the disclosed systems and methods might be embodied in many other specific forms without departing from the spirit or scope of the present disclosure. The present examples are to be considered as illustrative and not restrictive, and the intention is not to be limited to the details given herein. For example, the various elements or components may be combined or integrated in another system or certain features may be omitted, or not implemented.

[0051] In addition, techniques, systems, subsystems, and methods described and illustrated in the various embodiments as discrete or separate may be combined or integrated with other systems, modules, techniques, or methods without departing from the scope of the present disclosure. Other items shown or discussed as coupled or directly coupled or communicating with each other may be indirectly coupled or communicating through some interface, device, or intermediate component whether electrically, mechanically, or otherwise. Other examples of changes, substitutions, and alterations are ascertainable by one skilled in the art and could be made without departing from the spirit and scope disclosed herein.

[0052] To aid the Patent Office, and any readers of any patent issued on this application in interpreting the claims appended hereto, applicants note that they do not intend any of the appended claims to invoke 35 U.S.C. § 112 (f) as it exists on the date of filing hereof unless the words “means for” or “step for” are explicitly used in the particular claim.

Claims

1. A refrigeration system, comprising: a plurality of evaporators configured to transfer heat from a space to a refrigerant; one or more medium temperature compressors configured to compress the refrigerant; a three-way valve positioned downstream from the one or more medium temperature compressors, the three-way valve configured to receive the compressed refrigerant from the one or more medium temperature compressors, wherein the three-way valve is operable to direct flow of the received compressed refrigerant to one or both of a gas cooler and one or more of the evaporators of the plurality of evaporators based on an operation mode of the plurality of evaporators; and a controller communicatively coupled to the three-way valve, wherein the controller is configured to: determine that operation of a first evaporator of the plurality of evaporators in a defrost mode is indicated; after determining that operation of the first evaporator in the defrost mode is indicated, cause the first evaporator to operate in the defrost mode by adjusting the three-way valve to direct a portion of the received compressed refrigerant to the first evaporator; determine that defrost mode operation of the first evaporator is complete; after determining that defrost mode operation of the first evaporator is complete, cause the first evaporator to operate in a transition mode, wherein during operation in the transition mode at least a portion of the compressed refrigerant provided to the first evaporator is provided back toward the one or more medium temperature compressors; and during operation of the first evaporator in the transition mode: determine a pressure associated with the first evaporator; determine that the pressure is less than a threshold value; and after determining that the pressure is less than the threshold value, cause the first evaporator to operate in a refrigeration mode.

2. The refrigeration system of claim 1, further comprising: the gas cooler configured to receive refrigerant and facilitate heat transfer from the received refrigerant, thereby cooling the refrigerant; and a flash tank located downstream from the gas cooler and configured to receive the refrigerant cooled by the gas cooler and store at least a portion of the received refrigerant.

3. The refrigeration system of claim 2, further comprising: a first valve located upstream from the first evaporator in refrigerant conduit coupling a liquid outlet of the flash tank to the first evaporator, wherein, when the first evaporator is operating in a refrigeration mode, the first valve is open; and a second valve located downstream from the first evaporator in refrigerant conduit allowing flow of refrigerant towards the one or more medium temperature compressors, wherein, when the first evaporator is operating in the refrigeration mode, the second valve is open; and the controller is further configured to cause the first evaporator to operate in the defrost mode by causing the first valve to close and causing the second valve to close.

4. The refrigeration system of claim 3, further comprising: a third valve located upstream from the first evaporator in refrigerant conduit coupling an inlet of the flash tank to the first evaporator, wherein, when the first evaporator is operating in a refrigeration mode, the third valve is closed; and a fourth valve located downstream from the first evaporator in refrigerant conduit allowing flow of refrigerant from the one or more medium temperature compressors to the first evaporator, wherein, when the first evaporator is operating in the refrigeration mode, the fourth valve is closed; wherein the controller is further configured to cause the first evaporator to operate in the defrost mode by causing the third valve to open and causing the fourth valve to open.

5. The refrigeration system of claim 4, wherein the controller is further configured to, during operation of the first evaporator in the transition mode: determine a pressure associated with the first evaporator; determine that the pressure is less than a threshold value; and after determining that the pressure is less than the threshold value, cause the first evaporator to operate in a refrigeration mode.

6. The refrigeration system of claim 1, wherein, while the first evaporator is caused to operate in the defrost mode, a second evaporator of the plurality of evaporators is caused to operate in a refrigeration mode.

7. The refrigeration system of claim 1, wherein the controller is further configured to: at least partially open a third valve located upstream from the first evaporator in refrigerant conduit coupling an inlet of the flash tank to the first evaporator; and at least partially open a fourth valve located downstream from the first evaporator in refrigerant conduit allowing flow of refrigerant from the one or more medium temperature compressors to the first evaporator.