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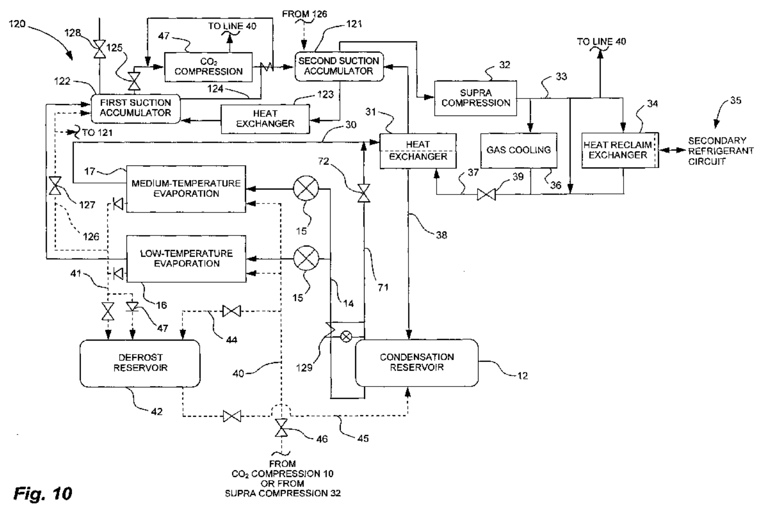

Fig. 10

(57) Abstract: A CO_2 refrigeration system comprises a refrigeration circuit in which circulates CO_2 refrigerant between a compression stage in which the CO_2 refrigerant is compressed. A condensation stage is provided in which the CO_2 refrigerant releases heat and is accumulated in a condensation reservoir. An evaporation stage is provided in which the CO_2 refrigerant is expanded to a gaseous state to absorb heat from a fluid for refrigeration, with at least a portion of CO_2 refrigerant exiting the evaporation stage being directed to a supra-compression circuit comprising a supra-compression stage in which the portion of CO_2 refrigerant is compressed. A heat exchanger is provided by which the compressed CO_2 refrigerant is in a heat-exchange relation with a secondary-refrigerant circuit, such that the compressed CO_2 refrigerant releases heat to a secondary refrigerant used for heating purposes. Pressure-regulating means control a pressure of the compressed CO_2 refrigerant being returned to the condensation stage.

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CO_2 REFRIGERATION SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

This patent application claims priority on United States Patent Applications No. 61/107,689, filed on October 23, 2008, No. 61/166,884, filed on April 6, 2009, and No. 61/184,021, filed on June 4, 2009.

FIELD OF THE APPLICATION

The present application relates to refrigeration systems, and more particularly to refrigeration systems using CO_2 refrigerant.

BACKGROUND OF THE ART

With the growing concern for global warming, the use of chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) as refrigerant has been identified as having a negative impact on the environment. These chemicals have non-negligible ozone-depletion potential and/or global-warming potential.

As alternatives to CFCs and HCFCs, ammonia, hydrocarbons and CO_2 are used as refrigerants. Although ammonia and hydrocarbons have negligible ozone-depletion potential and global-warming potential as does CO_2, these refrigerants are highly flammable and therefore represent a risk to local safety. On the other hand, CO_2 is environmentally benign and locally safe.

SUMMARY OF THE APPLICATION

It is therefore an aim of the present disclosure to provide a CO_2 refrigeration system that addresses issues associated with the prior art.

Therefore, in accordance with a first embodiment of the present application, there is provided a CO_2 refrigeration system comprising a refrigeration circuit in which circulates CO_2 refrigerant between a compression stage in which the CO_2 refrigerant is compressed, a condensation stage in which the CO_2 refrigerant releases heat and is accumulated in a condensation reservoir, and an evaporation stage in which the CO_2 refrigerant is expanded to a gaseous state to absorb heat from a fluid for refrigeration, with at least a portion of CO_2 refrigerant exiting the evaporation stage being directed to a supra-compression circuit comprising a supra-compression stage in which the portion of CO_2 refrigerant is compressed, a heat exchanger by which the compressed CO_2 refrigerant is in a heat-exchange relation with a secondary-refrigerant circuit, such that the compressed CO_2 refrigerant releases heat to a secondary refrigerant used for heating purposes, and pressure-regulating means to control a pressure of the compressed CO_2 refrigerant being returned to the condensation stage.

Further in accordance with the first embodiment, a defrost circuit has a line directing CO_2 refrigerant from the compression stage, through a refrigeration coil of an evaporator of the evaporation stage to defrost the refrigeration coil, to then return the CO_2 refrigerant to the refrigeration circuit.

Still further in accordance with the first embodiment, the CO_2 refrigerant having defrosted the refrigeration coil is subsequently directed to a defrost reservoir, the defrost circuit further comprising a flushing circuit to transfer accumulated liquid CO_2 refrigerant from said defrost reservoir to said condensation reservoir.

Still further in accordance with the first embodiment, a suction accumulator is provided between a discharge of the compression stage and a suction of the supra compression stage, to separate liquid and gaseous portions from the CO_2 refrigerant such that gaseous CO_2 refrigerant is fed to the supra compression stage.

Still further in accordance with the first embodiment, the suction accumulator receives the portion of the CO_2 refrigerant exiting the evaporation stage to then feed said portion of the CO_2 refrigerant to the supra-compression stage.

Still further in accordance with the first embodiment, an other suction accumulator is provided upstream of the compression stage to separate liquid and gaseous portions from the CO_2 refrigerant such that gaseous CO_2 refrigerant is fed to the compression stage.

Still further in accordance with the first embodiment, the other suction accumulator receives an other portion of the CO_2 refrigerant exiting the evaporation stage to then feed said other portion of the CO_2 refrigerant to the compression stage.

Still further in accordance with the first embodiment, a return line is provided between the suction accumulators to direct liquid CO_2 refrigerant to the suction accumulator upstream of the compression stage.

Still further in accordance with the first embodiment, the other suction accumulator receives an other portion of the CO_2 refrigerant exiting the evaporation stage to then feed said other portion of the CO_2 refrigerant to the compression stage.

Still further in accordance with the first embodiment, the heat-exchanger line is in heat exchange with a discharge line of the compression stage.

Still further in accordance with the first embodiment, a gaseous line extends from the condensation reservoir to the suction accumulator to direct gaseous CO_2 refrigerant from the condensation reservoir to the suction accumulator.

Still further in accordance with the first embodiment, heat-exchanger means is provided in the gaseous line for the gaseous CO_2 refrigerant to cool liquid CO_2 refrigerant fed to the expansion stage.

Still further in accordance with the first embodiment, an independent refrigerant circuit is in heat-exchange relation with a discharge of the compression stage to cool the CO_2 refrigerant subsequently reaching the condensation reservoir.

Still further in accordance with the first embodiment, a pressure-relief system is provided for the evaporators of the evaporation stage, the pressure relief system exhausting defrost CO_2 refrigerant from any one of the refrigeration coils when a pressure of refrigerant in the refrigeration coil reaching a given threshold.

Still further in accordance with the first embodiment, the pressure-relief system exhausts defrost CO_2 refrigerant from any one of the refrigeration coils when a pressure of refrigerant in the refrigeration coil reaching a given threshold, the pressure-relief system directing excess-pressure defrost CO_2 refrigerant to any one of the suction accumulators.

Still further in accordance with the first embodiment, a pressure-relief valve is provided for the one of the suction accumulators receiving the excess-pressure defrost CO_2 refrigerant.

Still further in accordance with the first embodiment, electric coils are provided for each evaporator of the evaporation stage to defrost the evaporators.

Still further in accordance with the first embodiment, the supra-compression stage compresses the CO_2 refrigerant to a transcritical state.

In accordance with a second embodiment of the present application, there is provided a method for relieving CO_2 refrigerant pressure from evaporators during a defrost cycle, comprising: providing a pressure-relief valve for each evaporator line, the pressure relief-valve opening at a pressure threshold; feeding CO_2 refrigerant to at least one evaporator in the evaporator line to defrost the evaporator; exhausting the evaporator from the CO_2 refrigerant with the pressure-relief valve when the CO_2 refrigerant pressure is above the pressure threshold; and directing the exhausted CO_2 refrigerant to an accumulator in a refrigeration cycle.

In accordance with a third embodiment of the present application, there is provided a method for feeding vaporized CO_2 refrigerant and oil to a compressor, comprising: collecting a mixture of liquid CO_2 refrigerant and oil from an accumulator; vaporizing the mixture of CO_2 refrigerant and oil by heating the mixture; and feeding the feeding vaporized CO_2 refrigerant and oil to a compressor.

Further in accordance with the third embodiment, vaporizing the mixture of CO_2 refrigerant and oil comprises heating the mixture by heat-exchange exposure to a discharge of the compressor.

Still further in accordance with the third embodiment, collecting a mixture of liquid CO_2 refrigerant and oil from an accumulator comprises collecting the mixture from the same accumulator feeding a compression stage with gaseous CO_2 refrigerant.

BRIEF DESCRIPTION OF DRAWINGS

Fig. 1 is a block diagram of a CO_2 refrigeration system in accordance with an embodiment of the present application;

Fig. 2 is a block diagram of the CO_2 refrigeration system of Fig. 1, with an example of operating pressures for a cold climate application;

Fig. 3 is a block diagram of the CO_2 refrigeration system of Fig. 1, with an example of operating pressures for a warm climate application; and

Fig. 4 is a schematic view of a line used with the CO_2 refrigeration system, in accordance with another embodiment of the present application.

Fig. 5 is a block diagram of a CO_2 refrigeration system in accordance with another embodiment,

Fig. 6 is a schematic view of a line configuration for a refrigeration unit, in accordance with yet another embodiment of the present application;

Fig. 7 is a block diagram of a CO_2 refrigeration system in accordance with another embodiment, with dedicated compression for defrost;

Fig. 8 is a block diagram of a CO_2 refrigeration system in accordance with another embodiment, e.g., for a skating rink application;

Fig. 9 is a block diagram of a CO_2 refrigeration system in accordance with another embodiment, with a supra-compression providing defrost;

Fig. 10 is a block diagram of a CO_2 refrigeration system in accordance with another embodiment, with cascaded compression;

Fig. 11 is a block diagram of a CO_2 refrigeration system in accordance with another embodiment, with suction accumulation upstream of a supra-compression stage;

Fig. 12 is a block diagram of a CO_2 refrigeration system in accordance with another embodiment, with a heat-exchanger for defrost refrigerant; and

Fig. 13 is a schematic view of a desiccant system in accordance with another embodiment of the present application.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to Fig. 1, a CO_2 refrigeration system in accordance with an embodiment is illustrated at 1. The CO_2 refrigeration system 1 has a CO_2 refrigeration circuit comprising a CO_2 compression stage 10. CO_2 refrigerant is compressed in the compression stage 10, and is subsequently directed via line 11 to a condensation reservoir 12, or to a heat-reclaim stage 13.

The condensation reservoir 12 accumulates CO_2 refrigerant in a liquid and gaseous state, and is in a heat-exchange relation with a condensation circuit that absorbs heat from the CO_2 refrigerant. The condensation circuit is described in further detail hereinafter. Moreover, a transcritical circuit and a defrost circuit may supply CO_2 refrigerant to the condensation reservoir 12, as is described in further detail hereinafter.

The heat-reclaim stage 13 is provided to absorb heat from the CO_2 refrigerant exiting from the compression stage 10. The heat-reclaim stage 13 may take various forms, such as that of a heat exchanger by which the CO_2 refrigerant is in heat exchange with an alcohol-based refrigerant circulating in a closed loop. As another example, the heat-reclaim stage 13 features coils by which the CO_2 refrigerant releases heat to a water tank.

Line 14 directs CO_2 refrigerant from the condensation reservoir 12 to an evaporation stage via expansion valves 15. As is shown in Fig. 1, the CO_2 refrigerant is supplied in a liquid state by the condensation reservoir 12 into line 14. The expansion valves 15 control the pressure of the CO_2 refrigerant, which is then fed to either low-temperature evaporation stage 16 or medium-temperature evaporation stage 17. Both the evaporation stages 16 and 17 feature evaporators associated with refrigerated enclosures, such as closed or opened refrigerators, freezers or the like. It is pointed out that the expansion valves 15 may be part of a refrigeration pack in the mechanical room, as opposed to being at the refrigeration cabinets. As a result, flexible lines (e.g., plastic non-rigid lines) could extend from the expansion valves 15 to diffuser upstream of the coils of the evaporation stages 16 and 17. The valves 15 may be at the refrigeration cabinets, at the refrigeration pack in a mechanical room, or any other suitable location.

CO_2 refrigerant exiting the low-temperature evaporation stage 16 is directed to the CO_2 compression stage 10 via line 18 to complete a refrigeration cycle. A heat exchanger 19 is provided in the line 18, and ensures that the CO_2 refrigerant is fed to the compression stage 10 in a gaseous state. Other components, such as a liquid accumulator, may be used as an alternative to the heat exchanger 19. As described hereinafter, the heat exchanger 19 may be associated with a condensation circuit.

CO_2 refrigerant exiting the medium-temperature evaporation stage 17 is directed to the transcritical circuit as is described hereinafter.

A condensation circuit has a heat exchanger 20. The heat exchanger 20 is in fluid communication with the condensation reservoir 12, so as to receive CO_2 refrigerant in a gaseous state. The condensation circuit is closed and comprises a condensation refrigerant that also circulates in the heat exchanger 20 so as to absorb heat from the CO_2 refrigerant.

In the condensation circuit, the condensation refrigerant circulates between the heat exchanger 20 in which the condensation refrigerant absorbs heat, a compression stage 21 in which the condensation refrigerant is compressed, and a condensation stage 22 in which the condensation refrigerant releases heat.

The compression stage 21 may use Turbocor™ compressors. In an example, the condensation stage 22 features heat reclaiming (e.g., using a heat exchanger with a heat-transfer fluid) in parallel or in series with other components of the condensation stage 22, so as to reclaim heat from the CO_2 refrigerant. Although not shown, the condensation circuit may be used in conjunction with the heat exchanger 19, so as to absorb heat from the CO_2 refrigerant being directed to the compression stage 10. In this case, the condensation refrigerant is in a heat-exchange relation with the CO_2 refrigerant.

It is pointed out that the condensation circuit may be used with more than one CO_2 refrigeration circuit. In such a case, the condensation circuit features a plurality of heat exchangers 20, for instance with one for each of the CO_2 refrigeration circuits.

Examples of the condensation refrigerant are refrigerants such as R-404 and R-507, amongst numerous examples. It is observed that the condensation circuit may be confined to its own casing as illustrated in Fig. 1. Moreover, considering that the condensation circuit is preferably limited to absorbing heat from stages on a refrigeration pack (e.g., condensation reservoir 12, suction header in line 18), the condensation circuit does not contain a large volume of refrigerant when compared to the CO_2 refrigeration circuit, of a secondary refrigerant circuit defined hereinafter.

The transcritical circuit (i.e., supra-compression circuit) is provided to compress the CO_2 refrigerant exiting from the medium-temperature evaporation stage 17 to a transcritical state, for heating purposes, or supra-compressed state. In both compression states, the CO_2 refrigerant is pressurized in view of maintaining the condensation reservoir 12 at a high enough pressure to allow vaporized CO_2 refrigerant to be circulated in the evaporation stages 16 and 17, as opposed to liquid CO_2 refrigerant.

A line 30 relates the medium-temperature evaporation stage 17 to a heat exchanger 31 and subsequently to a supra-compression stage 32. The heat exchanger 31 is provided to vaporize the CO_2 refrigerant fed to the transcritical compression stage 32. The supra-compression stage 32 features one or more compressors (e.g., Bock™, Dorin™), that compress the CO_2 refrigerant to a supra-compressed or transcritical state.

In the transcritical state, the CO_2 refrigerant is used to heat a secondary refrigerant via heat-reclaim exchanger 34. In the heat-reclaim exchanger 34, the CO_2 refrigerant is in a heat-exchange relation with the secondary refrigerant circulating in the secondary refrigerant circuit 35. The secondary refrigerant is preferably an environmentally-sound refrigerant, such as water or glycol, that is used as a heat-transfer fluid. Because of the transcritical state of the CO_2 refrigerant, the secondary refrigerant circulating in the circuit 35 reaches a high temperature. Accordingly, due to the high temperature of the secondary refrigerant, lines of smaller diameter may be used for the secondary refrigerant circuit 35. It is pointed out that the secondary refrigerant circuit 35 is the largest of the circuits of the refrigeration system 1 in terms of quantity of refrigerant. Therefore, the compression of the CO_2 refrigerant into a transcritical state by the transcritical circuit allows the lines of the secondary refrigerant circuit 35 to be reduced in terms of diameter.

A gas cooling stage 36 is provided in the transcritical circuit. The gas cooling stage 36 absorbs excess heat from the CO_2 refrigerant in the transcritical state, in view of re-injecting the CO_2 refrigerant in the condensation reservoir 12. Although it is illustrated in a parallel relation with the heat-reclaim exchanger 34, the gas cooling stage 36 may be in series therewith, or in any other suitable arrangement. Although not shown, appropriate valves are provided so as to control the amount of CO_2 refrigerant directed to the gas cooling stage 36, in view of the heat demand from the heat-reclaim exchanger 34.

In warmer climates in which the demand for heat is smaller, the CO_2 refrigerant is compressed to a supra-compressed state, namely at a high enough pressure to allow the expansion of the CO_2 refrigerant at the exit of the condensation reservoir 12, so as to reduce the amount of CO_2 refrigerant circulating in the refrigeration circuit. A by-pass line is provided to illustrate that the heat-reclaim exchanger 24 and the gas cooling stage 36 are optional for warmer climates.

The gas cooling stage 36 may feature a fan blowing a gas refrigerant on coils. The speed of the fan may be controlled as a function of the heat demand of the heat reclaim exchanger 34. For an increased speed of the fan, there results an increase in the temperature differential at opposite ends of the gas cooling stage 36.

Lines 37 and 38 return the CO_2 refrigerant to the condensation reservoir 12, and thus to the refrigeration circuit. The line 37 feeds the heat exchanger 31 such that the CO_2 refrigerant exiting the stages 34 and 36 release heat to the CO_2 refrigerant fed to the supra-compression stage 32. Accordingly, the CO_2 refrigerant fed to the supra-compression stage 32 is in a gaseous state.

In the case of transcritical compression, a CO_2 transcritical pressure-regulating valve 39 is provided to maintain appropriate pressures at the stages

34 and 36, and in the condensation reservoir 12. The CO_2 transcritical pressure-regulating valve 39 is for instance a Danfoss™ valve. Any other suitable pressure-control device may be used as an alternative to the valve 39, such as any type of valve or loop.

The condensation circuit and the supra-compression circuit allow the condensation reservoir 12 to store refrigerant at a relatively medium pressure. Accordingly, no pump may be required to induce the flow of refrigerant from the condensation reservoir 12 to the evaporation stages 16 and 17. As CO_2 refrigerant is vaporized downstream of the expansion valves 15, the amount of CO_2 refrigerant in the refrigeration circuit is reduced, especially if the expansion valves 15 are in the refrigeration pack.

It is considered to operate the supra-compression circuit (i.e., supra compression 32) with higher operating pressure. CO_2 refrigerant has a suitable efficiency at a higher pressure. More specifically, more heat can be extracted when the pressure is higher.

The refrigeration system 1 may be provided with a refrigerant defrost system. In Fig. 1, a portion of the CO_2 refrigerant exiting from the compression stage 10 is directed to the evaporation stages 16 and 17. Although not shown, appropriate valves and pressure-reducing devices are provided to stop the flow of cooling CO_2 refrigerant in the evaporators in view of the defrost. The defrost CO_2 refrigerant releases heat to defrost any frost build-up on the evaporators of the evaporation stages 16 and/or 17.

Although not shown, other compression configurations may be used to supply defrost refrigerant to the evaporators, such as dedicated compressors, cascaded compressors of the like.

Line 41 directs the defrost CO_2 refrigerant having released heat to the defrost reservoir 42. The defrost reservoir 42 accumulates the defrost CO_2 refrigerant, and features a line 43 with a control valve (e.g., exhaust valve, check valve), so as to allow gaseous CO_2 refrigerant to be sucked back into the CO_2 refrigeration circuit by the CO_2 compression stage 10. The defrost reservoir 42 is an option, as the evaporation stages 16 and 17 may direct the refrigerant to other reservoirs or accumulators of any other refrigeration system presenter herein.

A flush of the defrost reservoir 42 may be performed periodically, so as to empty the defrost reservoir 42. Accordingly, lines 44 and 45, with appropriate valves, allow the flush of the liquid CO_2 refrigerant from the defrost reservoir 42 to the condensation reservoir 12.

A pressure-reducing valve 46 may be provided in the line 40 or line 11 to regulate a pressure of the defrost CO_2 refrigerant fed to the evaporation stage 16 and/or 17 for defrost. Valves, such as check valve 47, are as relief valves for the evaporation stages 16 and 17. For instance, in case of a power shortage, the CO_2 refrigerant in the evaporators may increase in pressure. Accordingly, the check valves 47 open at a threshold pressure to allow the CO_2 refrigerant to reach the defrost reservoir 42.

Considering that the compressors of the CO_2 compression stage 10 or of the compression stage 21 are low-consumption compressors, these compressors may be operated during a power outage to maintain suitable refrigerating conditions in the evaporation stages 16 and 17. The compressors of the compression stage 21 may also be Turbocor™ compressors.

As an alternative to the defrost circuit, the evaporators of the evaporation stages 16 and 17 may be equipped with electric coils for the electric defrost of the evaporators.

In an embodiment, the casing enclosing the condensation circuit may also comprise an air-conditioning unit 50. Accordingly, the roof-top equipment associated with the refrigeration system 1 is provided in a single casing, thereby facilitating the installation thereof. Moreover, it is considered to unite as many components of the refrigeration system 1 in a single refrigeration pack. For instance, the compressors of the CO_2 compression stage 10, the condensation reservoir 12, the expansion valves 15, and optionally the compressors from the supra-compression stage 32, as well as the defrost reservoir 42 may all be provided in a same pack, with most of the lines joining these components. The installation is therefore simplified by such a configuration.

In order to illustrate the operating pressures of the CO_2 refrigeration system 1 in cold and warm climates, Figs. 2 and 3 are respectively provided with pressure values. It is pointed out that all values are just an illustration, whereby pressure values could be higher or lower. Fig. 2 shows operating pressures for the CO_2 refrigeration system 1 as used in cold climates (e.g., winter conditions in colder regions), with a demand for heat by the secondary refrigerant circuit 35. Fig. 3 shows operating pressures for the CO_2 refrigeration system as used in warm climates (e.g., summer conditions, warmer regions).

Although not fully illustrated, numerous valves are provided to control the operation of the CO_2 refrigeration system 1 as described above. Moreover, a controller ensures that the various stages of the refrigeration system 1 operate as described, for instance by having a plurality of sensors places throughout the refrigeration system 1.

Referring to Fig. 3, there is illustrated a safety valve circuit 55 so as to ensure that the refrigerant pressure in the coils of the evaporation stages 16 and 17 does not exceed a given maximum value (e.g., 410 Psi), which may result in damages to the coils. The safety valve circuits 55 extends from the evaporation stages 16 and 17 (e.g., lines at the exit of the coils) to the defrost reservoir 42. A safety valve 56 is provided in the circuit, and operates by monitoring the pressure in the coils and opening as a result of the pressure reaching the maximum value. The defrost reservoir 42 then absorbs the excess pressure by receiving the refrigerant. The defrost reservoir 42 subsequently discharges the refrigerant using the lines described previously.

Referring to Fig. 4, a line that may be used in the CO_2 refrigeration system 1 is illustrated at 60. The line 60 is a flexible hose adapted to support the relatively high pressures associated with CO_2 refrigerant. One suitable example of flexible hose is the "Transfer Oil" hydraulic hose by Gomax™. The hose 60 is rodded into a conduit of sleeves 61 of an insulating material, such as urethane, positioned end to end to cover the length of hose 60. A plurality of hoses 60 may be used with a single sleeve 61, provided the inner diameter of the sleeve 61 is large enough to receive the hoses 60. Therefore, by the use of flexible hoses, the installation of the lines is simplified. Previous lines required welding operation to join tubes of metallic material.

Referring to Fig. 5, an alternative embodiment of the CO_2 refrigeration system 1 of Figs. 1-3 is illustrated at 70. The CO_2 refrigeration systems 1 and 70 have numerous common stages and lines, whereby like elements will bear like reference numerals. One difference between the CO_2 refrigeration systems 1 and

70 is the absence of a condensation circuit such as the one having the heat exchanger 20 in Figs. 1-3. Rather, the CO_2 refrigerant in the condensation reservoir 12 is cooled by the transcritical circuit (i.e., supra-compression circuit) featuring the heat exchanger 31.

Therefore, a line 71 extends from the condensation reservoir 12 and directs CO_2 refrigerant to the hot side of the heat exchanger 31, which heat exchanger 31 is optional and is used to vaporize the CO_2 refrigerant if necessary. The line 71 may be collecting gas CO_2 refrigerant at a top of the condensation reservoir 12 to direct the CO_2 refrigerant to the heat exchanger 31. A pressure-reducing valve 72 is provided in line 71 to ensure that the CO_2 refrigerant reaches the heat exchanger 31 at a suitable pressure. The CO_2 refrigerant goes through the supra-compression circuit in the manner described previously, so as to lose heat, and return to the condensation reservoir 12 primarily in a liquid state.

It is pointed out that the configuration of the CO_2 refrigeration system 70 of Fig. 5 is such that a single refrigerant, namely CO_2 refrigerant, is used therein.

Referring to Fig. 6, an alternative line configuration is shown at 80, which line configuration is typically used to supply refrigerant to large refrigeration units (e.g., in freezer rooms). Line 81, typically a large diameter line, diverges into a plurality of smaller lines, from an expansion valve 82. Each smaller line may have a valve 83, and each feeds an own smaller refrigeration unit 84. As a result, some of the units 84 may be turned off, so as to meet more precisely the cool demand of an enclosure.

Referring to Fig. 7, yet another embodiment of a CO_2 refrigeration system is illustrated at 90. The CO_2 refrigeration systems 1 and 90 have numerous common stages and lines, whereby like elements will bear like reference numerals. One difference between the CO_2 refrigeration systems 1 and 90 is the presence of at least one dedicated compressor 10′ to compress defrost refrigerant. The discharge of the dedicated compressor 10′ goes at least partially to the defrost circuit, whereas the discharge of the other compressors 10 is directed to the refrigeration circuit. A line and valve (not shown) may be used to direct some excess refrigerant from the dedicated compressor 10′ to the refrigeration circuit. The CO_2 dedicated compressor 10′ may also be used to flush the defrost reservoir 42.

As an alternative, defrost could be made by directing refrigerant from the supra-compression circuit, into the defrost circuit, using an appropriate pressure-reducing valve.

Referring to Fig. 8, yet another embodiment of a CO_2 refrigeration system is illustrated at 100. The CO_2 refrigeration systems 70 (Fig. 5) and 90 have numerous common stages and lines, whereby like elements will bear like reference numerals. The CO_2 refrigeration system 100 is well suited for applications requiring low-temperature cooling, such as ice-skating rinks and industrial freezer applications.

The CO_2 refrigeration system 100 may be configured to operate without the CO_2 compression stages, due to the heat removal capacity of the supra-compression circuit. In such a configuration, a pump may circulate the refrigerant in the refrigeration circuit, from the condensation reservoir 12 to the low-temperature evaporation 16. In the ice-skating rink applications, the various heat absorbing components (e.g., the heat reclaim stage 13, the heat reclaim exchanger 34) may be used to melt zamboni residue in an ice dump.. It is preferred not to use the supra-compression circuit when the CO_2 refrigeration system

100 is operated in warmer countries. The CO_2 refrigeration system 100 is more efficient with CO_2 compression in such climates.

Considering the nature of the refrigerant, plastic tubing or non-rigid lines may be used as an alternative to the rigid metallic lines previously used, between the mechanical room and the stages of the systems, such as the condensation stage 12 and the evaporation stages 16 and 17. One known type of pipes that can be used is Halcor Cusmart pipes, and features a non-rigid copper core with a plastic insulation sleeve about the core. Such configurations are cost-efficient in that no weld joints are required to interconnect pipes, as is the case for rigid metallic lines. Gutters, for instance having a trapezoid cross-section, may be used as a guide for lines.

Referring to Fig. 9, yet another embodiment of a CO_2 refrigeration system is illustrated at 110. The CO_2 refrigeration systems 1 and 110 have numerous common stages and lines, whereby like elements will bear like reference numerals. One difference between the CO_2 refrigeration systems 1 and 110 is line 111 directing CO_2 refrigerant from the supra-compression stage 32 to the evaporator stages 16 and 17 for defrost. Accordingly, the CO_2 refrigerant fed to the evaporation stage 16/17 is at a relatively high pressure - valve 114 may be provided to lower the pressure of the CO_2 refrigerant to an appropriate level (e.g., 500 Psi). The defrost refrigerant is then directed to the defrost reservoir 42. A valve 112 is provided to control the amount of defrost refrigerant from the reservoir 42 reintegrating the refrigeration cycle. Moreover, in order to maintain a suitable compression ratio in view of the operating pressure of the condensation reservoir 12, a pressure-reducing valve 113 is provided in the line 11, so as to reduce the pressure of the CO_2 refrigerant feeding the condensation reservoir 12.

Moreover, the refrigeration system 110 has a line 115 (with appropriate valves) selectively directing refrigerant from the supra-compression stage 32 to the defrost reservoir 42, to flush the reservoir 42 when required. It is pointed out that the heat exchangers 19 and 31 are optional, as is the condensation circuit featuring the compression stage 21.

Referring to Fig. 10, yet another embodiment of a CO_2 refrigeration system is illustrated at 120. The CO_2 refrigeration systems 70 and 120 have numerous common stages and lines, whereby like elements will bear like reference numerals. The CO_2 refrigeration system 120 has a cascaded arrangement for the two stages of CO_2 compression, namely compression stage 10 and supra-compression stage 32. More specifically, the refrigerant discharge from the compression stage 10 is fed to a suction accumulator 121, and CO_2 refrigerant in a gas state is sucked from a top of the accumulator 121 by the supra-compression stage 32.

The suction accumulator 121 also receives CO_2 refrigerant from the evaporation stage 17, optionally via heat exchanger 31. Gas CO_2 refrigerant from the condensation reservoir 12 may also be directed to the suction accumulator 121. The liquid CO_2 refrigerant from the suction accumulator 121 may be directed to the compression stage 10.

In order to maintain suitable conditions for the refrigerant at the inlet of the compression stage, a first suction accumulator 122 is provided downstream of the compression stage 10, which suction accumulator 122 receives CO_2 refrigerant from the suction accumulator 121 through a line (e.g., capillary) having a heat exchanger 123 for heat exchange with a discharge of the supracompression stage 32, or with a discharge of the compression stage 10. Moreover, liquid refrigerant from the suction accumulator 122 may be heated by line 124, in heat exchange with the discharge of the compression stage 10 or with supracompression stage 32, or simply by using an electric heater. The line 124 may then direct the vaporized refrigerant to the suction of the compression stage 10. In an embodiment, the line 124 collects liquid CO_2 refrigerant and oil at a bottom of the suction accumulator 122. Accordingly, the vaporized refrigerant has an oil content when fed to the compressors of the compression stage 10. The oil is then recuperated for instance in the suction accumulator 121. A similar loop may be performed to feed a mixture of CO_2 refrigerant and oil to the supra-compression stage 32.

In the embodiment in which the line 124 directs vaporized refrigerant to the suction of the compression stage 10, a valve 125 is provided in that case to maintain a pressure differential between the suction accumulator 122 and the suction of the compression stage 10, to allow the flow of refrigerant from line 124 into CO_2 compression stage 10. It is considered to use other components than suction accumulator 121, suction accumulator 122, line 124 and heat exchanger 123 to vaporize the refrigerant, such as a heating element, an air conditioning system, a heat exchanger and the like. It is also considered that CO_2 refrigerant leaving suction accumulator 121 and suction accumulator 122 be directed elsewhere in the CO_2 refrigeration system.

The cascaded compressor configuration of Fig. 10 is well suited to preserve the oil in the compression stage 10. More specifically, oil accumulating in the suction accumulator 121 is returned to the suction accumulator 122 via the line of heat-exchanger 123. The oil may then be sucked with refrigerant by the compression stage 10. Accordingly, the oil cycles between stages 10, 121 and 122. A similar cycle may be used for feeding an oil and refrigerant mixture to the supra-compression stage 32.

The defrost of the evaporation stages 16 and 17 may be performed at low pressure so as to avoid damaging the evaporator coils. Accordingly, the refrigeration cycle 120 may be retrofitted to existing evaporator coils, considering the relatively low defrost pressures. The defrost CO_2 refrigerant may be fed by the compression stage 10, or by the supra compression stage 32, with valve 46 controlling the pressure.

In order to protect the evaporator coils from high defrost pressures, a set of lines 126 extends from the evaporator coils to any reservoir or accumulator of the refrigeration system 120. For instance, the lines 126 are connected to one of the accumulators 121 and 122 while being separated by a valve 127. The valve 127 opens if the pressure in the evaporator coils is above a given threshold. Accordingly, if the defrost pressure in the evaporator coils is too high, the defrost CO_2 refrigerant is discharged to one of the accumulators 121 and 122, whereby the CO_2 refrigerant stays in the refrigeration system 120. As another safety measure, a pressure-relief valve system 128 is provided on the appropriate accumulators, such as 122 as shown but alternatively on the accumulator 121 or on the condensation reservoir 12.

For instance, the method for relieving CO_2 refrigerant pressure from evaporators during a defrost cycle comprises providing a pressure-relief valve for each evaporator line, the pressure relief-valve opening at a pressure threshold. CO_2 refrigerant is then fed to evaporators in the evaporator line to defrost the evaporator. The evaporators are exhausted from the CO_2 refrigerant with the pressure-relief valve when the CO_2

refrigerant pressure is above the pressure threshold; and directing the exhausted CO_2 refrigerant to an accumulator in a refrigeration cycle.

In specific conditions, it may be required to cool the CO_2 refrigerant fed to the evaporation stages 16 and/or 17 during the refrigeration cycle. Accordingly, a heat-exchanger system 129, for instance with an expansion valve, may direct refrigerant from the line 71 and feed same to the heat-exchanger system 129, to cool the CO_2 refrigerant fed to the evaporation stages 16 and/or 17.

The valve 39 is controlled (e.g., modulated) to maximize the heat reclaim via the heat reclaim exchanger 34. When the heat demand is high (e.g., during Winter in colder climates), the valve 39 may maintain a high refrigerant pressure downstream of the compression stage 32, to ensure the heat reclaim exchanger 34 extracts as much heat as possible from the CO_2 refrigerant. The amount of refrigerant sent to the gas cooling stage 36 is controlled simultaneously.

Referring to Fig. 11, yet another embodiment of a CO_2 refrigeration system is illustrated at 130. The CO_2 refrigeration systems 1 and 130 have numerous common stages and lines, whereby like elements will bear like reference numerals. The CO_2 refrigeration system 130 is particularly well suited for hot climate applications. In the CO_2 refrigeration system 130, the discharge of the compression stage 10 is directed to the heat exchanger 20 prior to reaching the condensation reservoir 12, for relatively low pressure condensation. Alternatively, the refrigerant exiting the heat exchanger 20 may be directed to the suction accumulator 133, thereby bypassing the condensation reservoir 12. A gaseous portion of the CO_2 refrigerant in the condensation reservoir 12 is directed via line 131 and pressure-reducing valve 132 into the heat exchanger 31 to reach the suction accumulator 133. The CO_2 refrigerant passing through the heat exchanger 31 absorbs heat from the CO_2 refrigerant exiting the supra-compression circuit via line 134. A line 135 relates a top of the suction accumulator 133 to the supra-compression stage 32, to feed gaseous CO_2 refrigerant to the compressors. Liquid CO_2 refrigerant may be directed to another suction accumulator 136, at the suction of the compression stage 10, in similar fashion to the CO_2 refrigeration system 120 of Fig. 10 (with appropriate heat exchange with the discharge of stage 10 if necessary). The supra-compression circuit is typically used to reclaim heat, while the evaporation stages 16 and 17 are part of a HVAC unit, amongst other possibilities.

Referring to Fig. 12, yet another embodiment of a CO_2 refrigeration system is illustrated at 140. The CO_2 refrigeration systems 1 and 140 have numerous common stages and lines, whereby like elements will bear like reference numerals. The CO_2 refrigeration system 140 has a heat exchanger 141 collecting defrost CO_2 refrigerant at the outlet of the evaporators 16/17, to vaporize the defrost CO_2 refrigerant and return same into the refrigeration cycle, namely to feed the suction of the compression stage 10 via line 142 or the supra-compression stage 32 via line 143. The heat exchanger 141 allows heat exchange between the defrost CO_2 refrigerant and the CO_2 refrigerant exiting the supra-compression stage 32 via lines 144, and may also be any other heat source (e.g. electric heater, heat reclaim, air-conditioning unit, or the like).

An air-conditioning unit 145 may be in fluid communication with the defrost reservoir 42 so as to use the defrost CO_2 refrigerant accumulated therein for air-conditioning purposes. The discharge of the air-conditioning unit 145 may be returned to the suction of the supra-compression stage 32, amongst other possibilities. In the various refrigerant systems described above, it is pointed out that the defrost refrigerant may be fed to the evaporators of stages 16 and 17 from either direction (as opposed to being fed in a direction opposed to that of refrigerant in the refrigeration cycle). Moreover, it is considered to provide the valves controlling the flow of defrost refrigerant to the evaporators 16 and 17 in the refrigeration pack, and have a plurality of lines for each single valve.

Referring to Fig. 13, a desiccant system is generally shown at 150. The desiccant system 150 may be used with any of the refrigeration systems described above, or with other refrigeration systems, to dry air being entered into a building for ventilating or refrigerating purposes. The desiccant system 150 is a closed circuit in which circulates a desiccant fluid.

The system 150 has a dryer 151, upon which exterior air flows when entering the building. The dryer 151 is a structural device upon which the desiccant fluid is sprayed. For instance, the dryer 151 may provide a honeycomb body. The desiccant fluid sprayed on the dryer 151 is in a suitable cooled state to absorb humidity from the warm exterior air entering the building. The desiccant fluid reaches a substantially liquid state after the absorption of humidity, and drips into pan 152 (or any oter collector).

By way of a line and pump, the desiccant fluid passes through a heating exchanger 153 to be heated. Although not shown, the heating exchanger 153 may be connected to one of the above-referred refrigeration circuits, so as to provide the necessary energy to heat the desiccant fluid. Alternatively, the heating exchanger 153 may have an electric coil or the like.

The desiccant fluid, in a heated state, is then sprayed onto a humidifier 154. The humidifier 154 is similar to the dryer 151 in construction, but releases water to the exterior air. The desiccant fluid is heated as a function of the exterior temperature, for the desiccant fluid to release the previously-absorbed water to the air. The liquid desiccant is then collected in another pan 155 (or the like).

By way of a line and pump, the desiccant fluid passes through a cooling exchanger 156 to be cooled. Although not shown, the cooling exchanger 156 may be connected to one of the above-referred refrigeration circuits, so as to provide the necessary energy to cool the desiccant fluid. The desiccant fluid is cooled as a function of the exterior temperature, for the desiccant to absorb water from the outdoor air entering the building. Once it is cooled, the desiccant fluid is directed to the dryer 151.

CLAIMS:

1. A CO_2 refrigeration system comprising a refrigeration circuit in which circulates CO_2 refrigerant between a compression stage in which the CO_2 refrigerant is compressed, a condensation stage in which the CO_2 refrigerant releases heat and is accumulated in a condensation reservoir, and an evaporation stage in which the CO_2 refrigerant is expanded to a gaseous state to absorb heat from a fluid for refrigeration, with at least a portion of CO_2 refrigerant exiting the evaporation stage being directed to a supra-compression circuit comprising a supra-compression stage in which the portion of CO_2 refrigerant is compressed, a heat exchanger by which the compressed CO_2 refrigerant is in a heat-exchange relation with a secondary-refrigerant circuit, such that the compressed CO_2 refrigerant releases heat to a secondary refrigerant used for heating purposes, and pressure-regulating means to control a pressure of the compressed CO_2 refrigerant being returned to the condensation stage.

2. The CO_2 refrigeration system according to claim 1, further comprising a defrost circuit having a line directing CO_2 refrigerant from the compression stage, through a refrigeration coil of an evaporator of the evaporation stage to defrost the refrigeration coil, to then return the CO_2 refrigerant to the refrigeration circuit.

3. The CO_2 refrigeration system according to claim 2, wherein the CO_2 refrigerant having defrosted the refrigeration coil is subsequently directed to a defrost reservoir, the defrost circuit further comprising a flushing circuit to transfer accumulated

liquid CO_2 refrigerant from said defrost reservoir to said condensation reservoir.

4. The CO_2 refrigeration system according to any one of claims 1 to 3, further comprising a suction accumulator between a discharge of the compression stage and a suction of the supra compression stage, to separate liquid and gaseous portions from the CO_2 refrigerant such that gaseous CO_2 refrigerant is fed to the supra compression stage.

5. The CO_2 refrigeration system according to claim 4, wherein the suction accumulator receives the portion of the CO_2 refrigerant exiting the evaporation stage to then feed said portion of the CO_2 refrigerant to the supra-compression stage.

6. The CO_2 refrigeration system according to claim 5, further comprising an other suction accumulator upstream of the compression stage to separate liquid and gaseous portions from the CO_2 refrigerant such that gaseous CO_2 refrigerant is fed to the compression stage.

7. The CO_2 refrigeration system according to claim 6, wherein the other suction accumulator receives an other portion of the CO_2 refrigerant exiting the evaporation stage to then feed said other portion of the CO_2 refrigerant to the compression stage.

8. The CO_2 refrigeration system according to any one of claims 6 and 7, further comprising a return line between the suction accumulators to direct liquid CO_2 refrigerant to the suction accumulator upstream of the compression stage.

9. The CO_2 refrigeration system according to claim 1, further comprising a suction accumulator upstream of the compression stage to separate liquid and gaseous portions from the CO_2 refrigerant such that gaseous CO_2 refrigerant is fed to the compression stage, a heat-exchanger line collecting liquid CO_2 refrigerant and oil in the suction accumulator and vaporizing the CO_2 refrigerant to a gaseous state, to then direct the CO_2 refrigerant and oil in the gaseous state to the compression stage.

10. The CO_2 refrigeration system according to claim 9, wherein the other suction accumulator receives an other portion of the CO_2 refrigerant exiting the evaporation stage to then feed said other portion of the CO_2 refrigerant to the compression stage.

11. The CO_2 refrigeration system according to claim 9, wherein the heat-exchanger line is in heat exchange with a discharge line of the compression stage.

12. The CO_2 refrigeration system according to any one of claims 4 to 8, further comprising a gaseous line extending from the condensation reservoir to the suction accumulator to direct gaseous CO_2 refrigerant from the condensation reservoir to the suction accumulator.

13. The CO_2 refrigeration system according to claim 12, further comprising heat-exchanger means in the gaseous line for the gaseous CO_2 refrigerant to cool liquid CO_2 refrigerant fed to the expansion stage.

14. The CO_2 refrigeration system according to any one of claims 1 to 13, further comprising an independent refrigerant circuit in heat-exchange relation with a discharge of the compression stage to cool the CO_2

refrigerant subsequently reaching the condensation reservoir.

15. The CO_2 refrigeration system according to claim 2, further comprising a pressure-relief system for the evaporators of the evaporation stage, the pressure relief system exhausting defrost CO_2 refrigerant from any one of the refrigeration coils when a pressure of refrigerant in the refrigeration coil reaching a given threshold.

16. The CO_2 refrigeration system according to any one of claims 4 to 8 when dependent on claim 2, further comprising a pressure-relief system for the evaporators of the evaporation stage, the pressure-relief system exhausting defrost CO_2 refrigerant from any one of the refrigeration coils when a pressure of refrigerant in the refrigeration coil reaching a given threshold, the pressure-relief system directing excess-pressure defrost CO_2 refrigerant to any one of the suction accumulators.

17. The CO_2 refrigeration system according to claim 16, further comprising a pressure-relief valve for the one of the suction accumulators receiving the excess-pressure defrost CO_2 refrigerant.

18. The CO_2 refrigeration system according to claim 1, wherein electric coils are provided for each evaporator of the evaporation stage to defrost the evaporators.

19. The CO_2 refrigeration system according to any one of claims 1 to 18, wherein the supra-compression stage compresses the CO_2 refrigerant to a transcritical state.

20. A method for relieving CO_2 refrigerant pressure from evaporators during a defrost cycle, comprising:

providing a pressure-relief valve for each evaporator line, the pressure relief-valve opening at a pressure threshold;

feeding CO_2 refrigerant to at least one evaporator in the evaporator line to defrost the evaporator;

exhausting the evaporator from the CO_2 refrigerant with the pressure-relief valve when the CO_2 refrigerant pressure is above the pressure threshold; and

directing the exhausted CO_2 refrigerant to an accumulator in a refrigeration cycle.

21. A method for feeding vaporized CO_2 refrigerant and oil to a compressor, comprising:

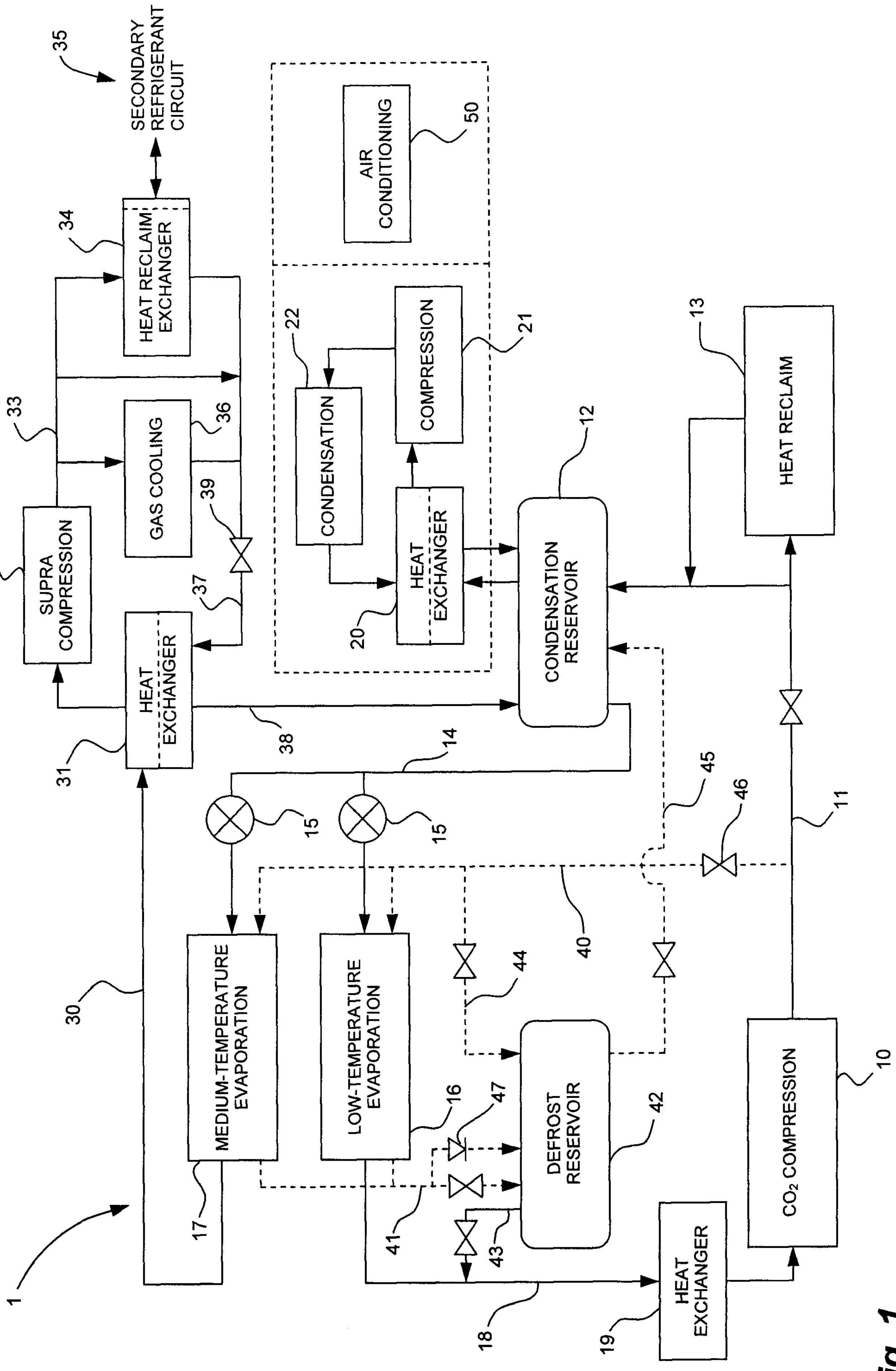
collecting a mixture of liquid CO_2 refrigerant and oil from an accumulator;

vaporizing the mixture of CO_2 refrigerant and oil by heating the mixture; and

feeding the feeding vaporized CO_2 refrigerant and oil to a compressor.

22. The method according to claim 21, wherein vaporizing the mixture of CO_2 refrigerant and oil comprises heating the mixture by heat-exchange exposure to a discharge of the compressor.

23. The method according to any one of claims 21 and 22, wherein collecting a mixture of liquid CO_2 refrigerant and oil from an accumulator comprises collecting the mixture from the same accumulator feeding a compression stage with gaseous CO_2 refrigerant.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35
AIR CONDITIONING
50
HEAT RECLAIM EXCHANGER
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COMPRESSION
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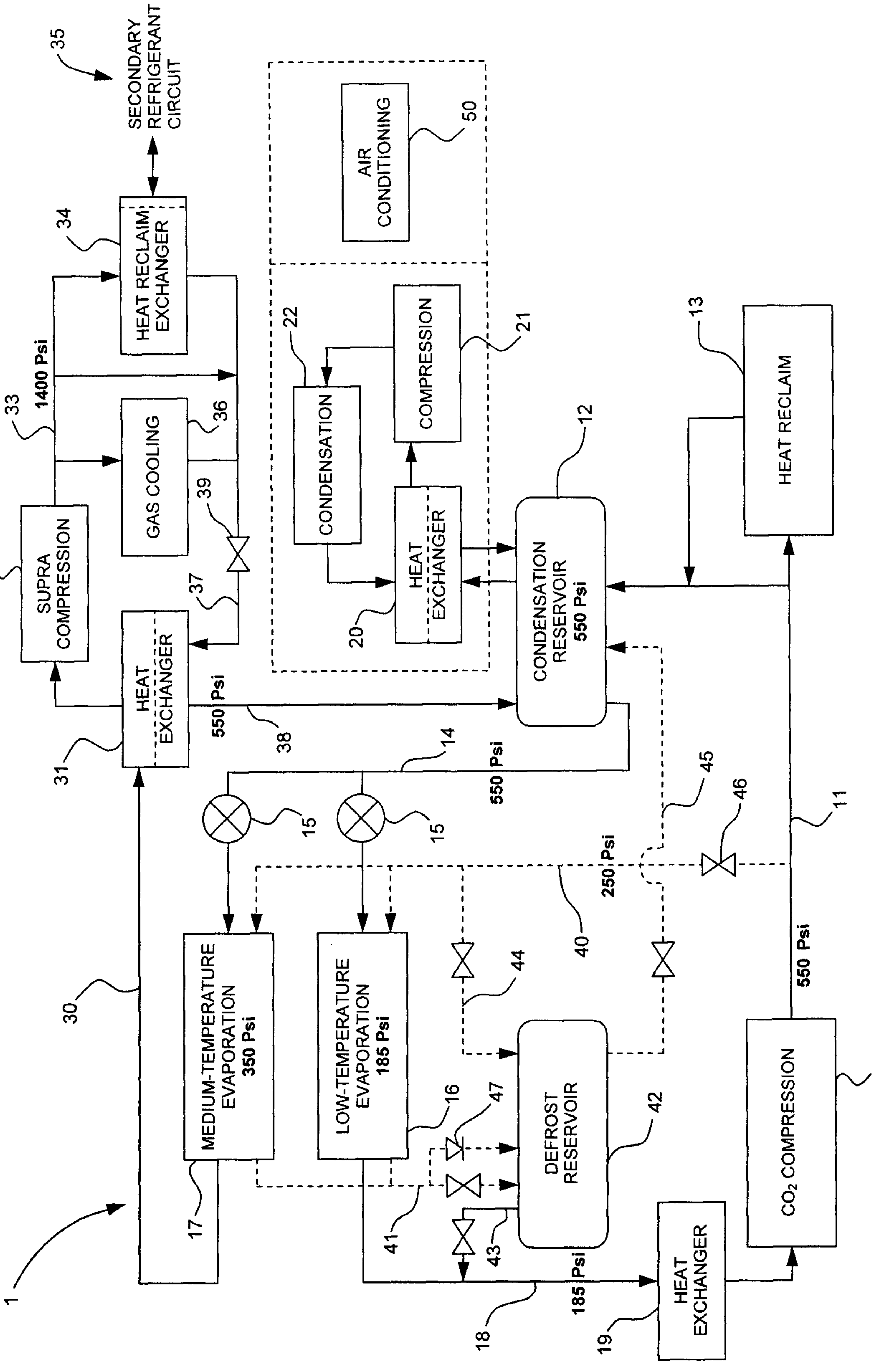
22
CONDENSATION
33
GAS COOLING
36
HEAT EXCHANGER
20
13
HEAT RECLAIM
12
CONDENSATION RESERVOIR
39
32
SUPRA COMPRESSION
37
HEAT EXCHANGER
31
38
14
45
46
15
15
11
40
MEDIUM-TEMPERATURE EVAPORATION
LOW-TEMPERATURE EVAPORATION
30
44
16
47
DEFROST RESERVOIR
42
CO2 COMPRESSION
10
17
41
43
HEAT EXCHANGER
19
18
1

Fig. 1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SUPRA COMPRESSION
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39
37
HEAT EXCHANGER
31
550 Psi
38
AIR CONDITIONING
50
COMPRESSION
21
CONDENSATION
22
HEAT EXCHANGER
20
CONDENSATION RESERVOIR 550 Psi
12
HEAT RECLAIM
13
14
550 Psi
15
15
45
46
11
250 Psi
40
MEDIUM-TEMPERATURE EVAPORATION 350 Psi
LOW-TEMPERATURE EVAPORATION 185 Psi
44
30
DEFROST RESERVOIR
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16
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HEAT EXCHANGER
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CO_2 COMPRESSION
10
550 Psi
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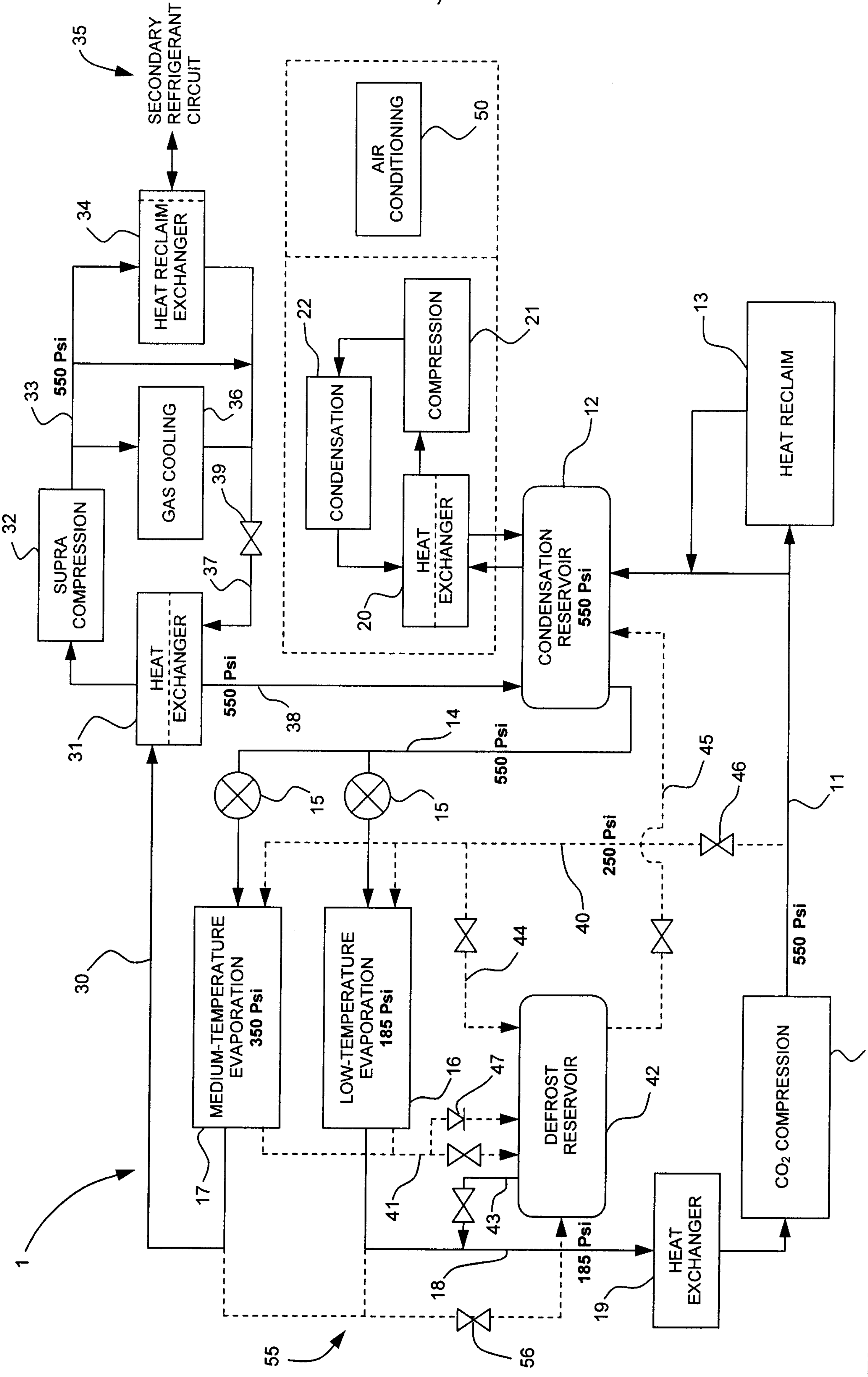
Fig. 2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HEAT RECLAIM EXCHANGER
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GAS COOLING
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SUPRA COMPRESSION
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37
HEAT EXCHANGER
31
550 Psi
38
AIR CONDITIONING
50
COMPRESSION
21
22
CONDENSATION
HEAT EXCHANGER
20
CONDENSATION RESERVOIR
550 Psi
12
HEAT RECLAIM
13
14
550 Psi
15
15
45
46
11
250 Psi
40
44
30
MEDIUM-TEMPERATURE EVAPORATION
350 Psi
LOW-TEMPERATURE EVAPORATION
185 Psi
550 Psi
DEFROST RESERVOIR
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CO₂ COMPRESSION
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16
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17
41
43
185 Psi
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HEAT EXCHANGER
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1
55
56

Fig. 3

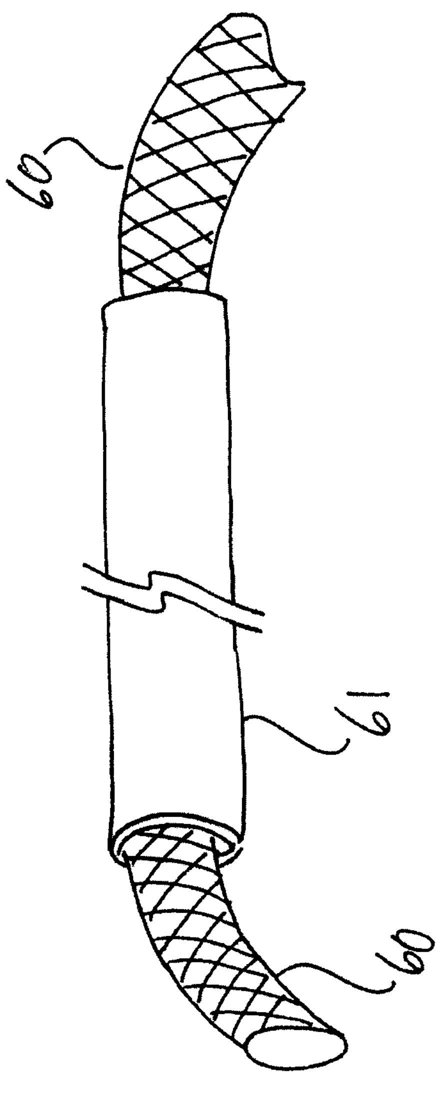
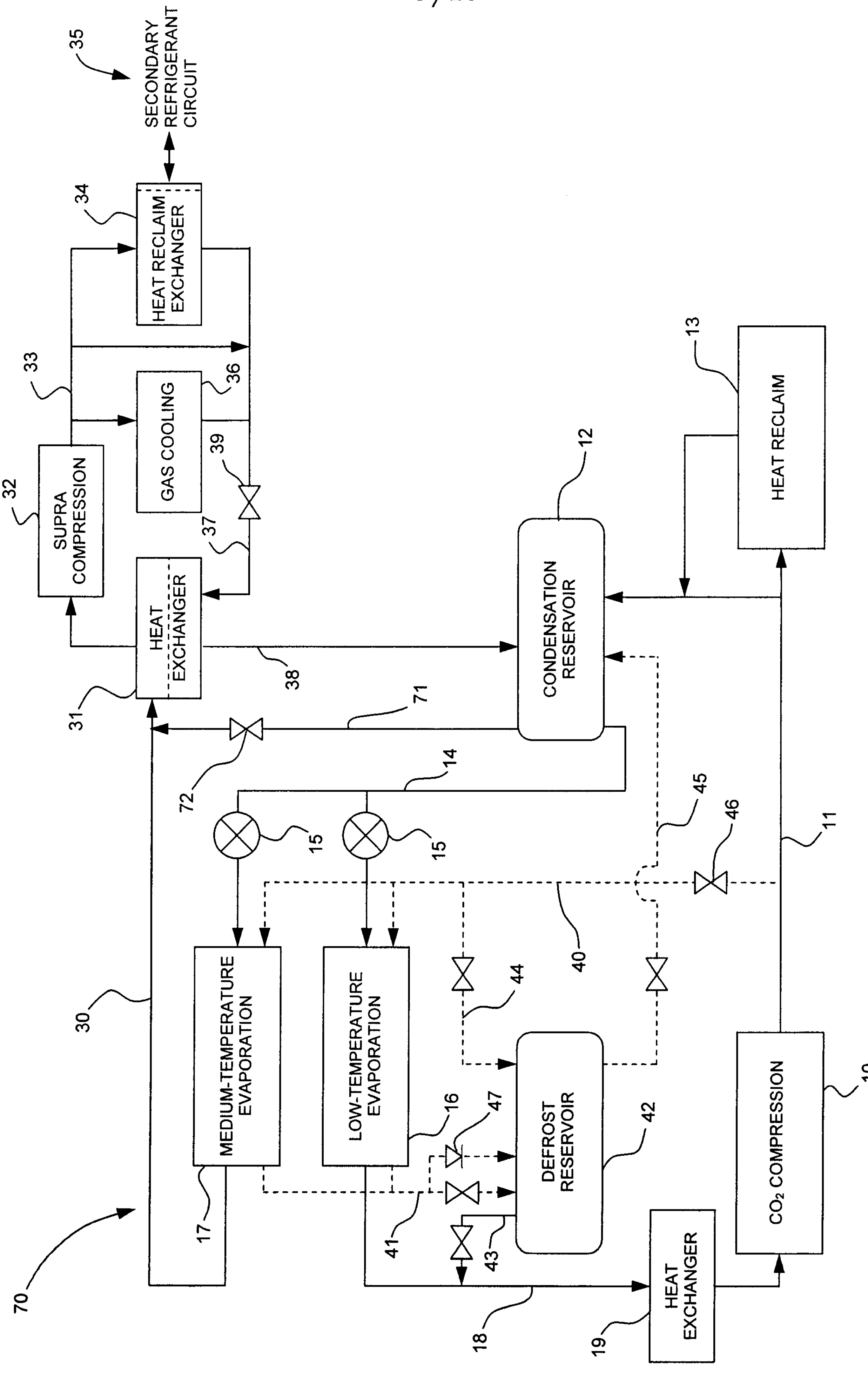


Fig. 4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EXCHANGER
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SUPRA
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32
37
HEAT
EXCHANGER
31
38
71
72
CONDENSATION
RESERVOIR
12
HEAT RECLAIM
13
14
15
15
45
46
11
40
MEDIUM-TEMPERATURE
EVAPORATION
LOW-TEMPERATURE
EVAPORATION
44
30
DEFROST
RESERVOIR
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16
47
17
41
43
CO$_2$ COMPRESSION
10
HEAT
EXCHANGER
19
18
70

Fig. 5

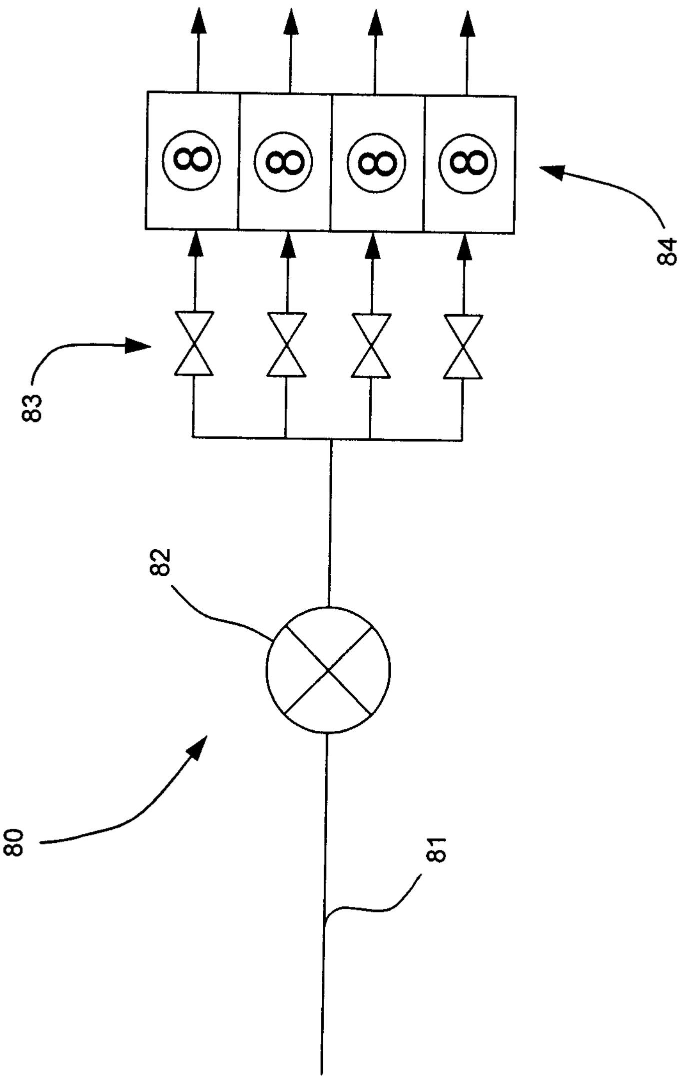
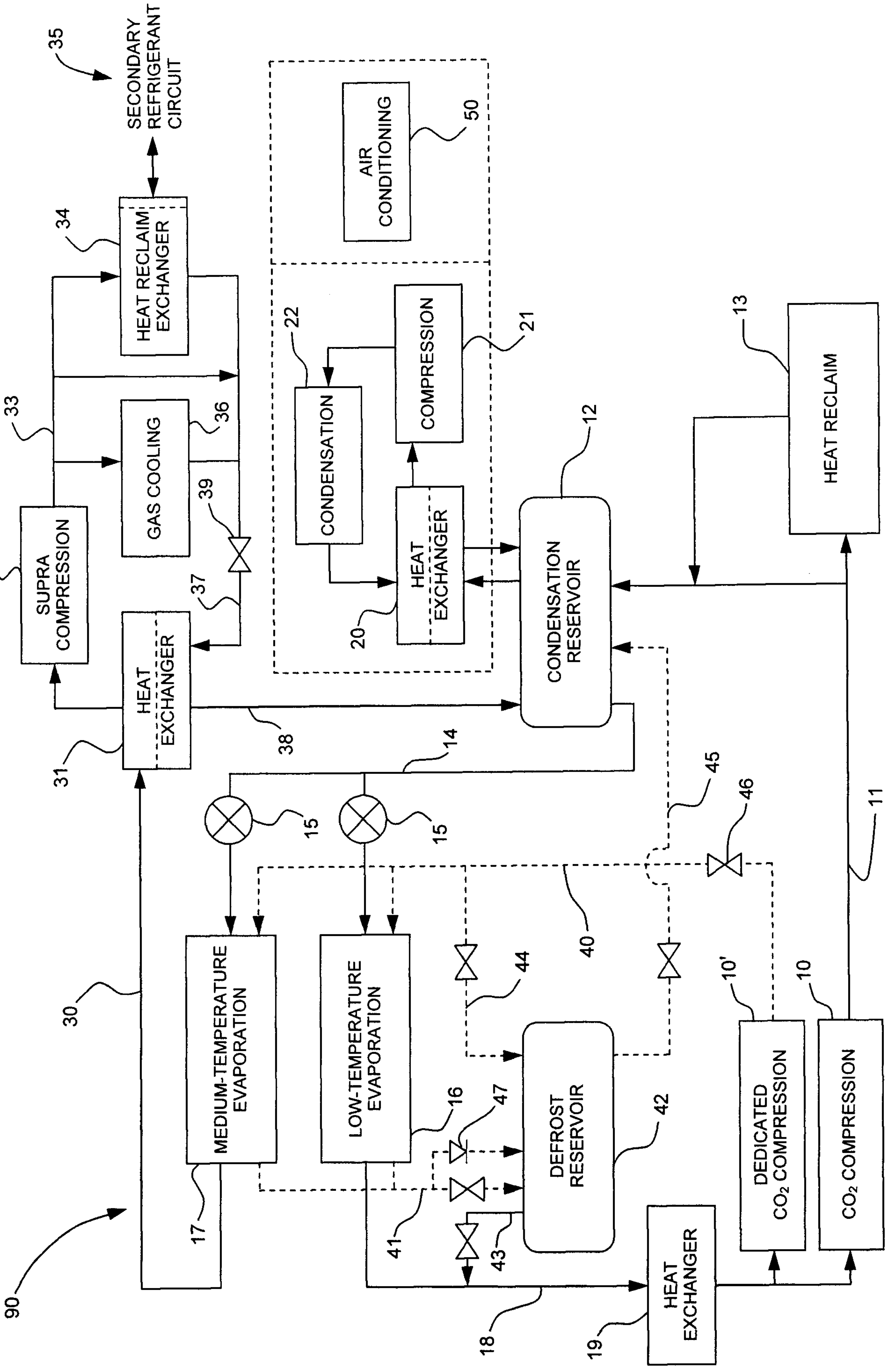


Fig. 6


SECONDARY REFRIGERANT CIRCUIT
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AIR CONDITIONING
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GAS COOLING
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SUPRA COMPRESSION
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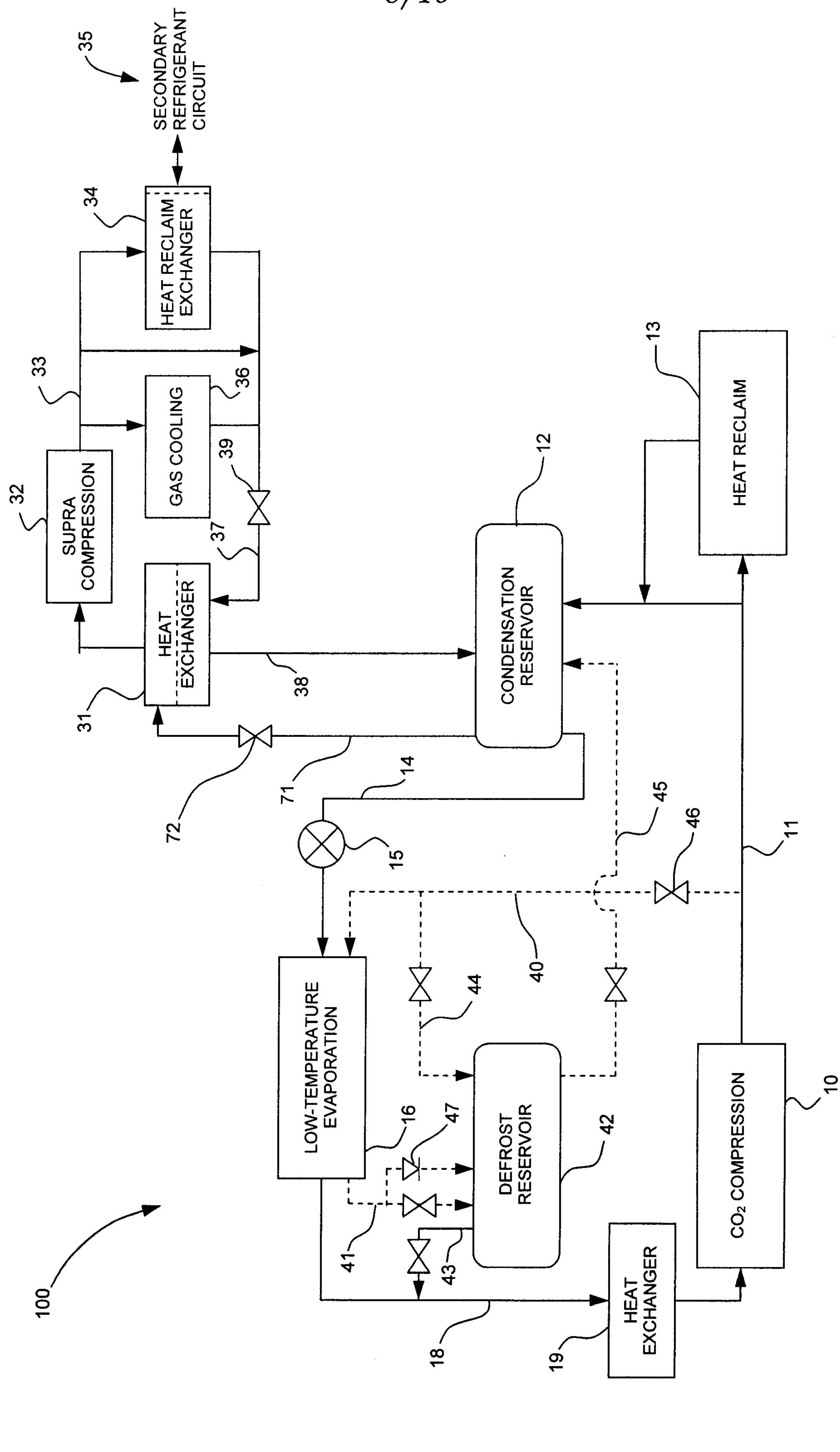
37
HEAT EXCHANGER
31
38
CONDENSATION
22
COMPRESSION
21
HEAT EXCHANGER
20
CONDENSATION RESERVOIR
12
HEAT RECLAIM
13
14
15
15
45
46
11
40
MEDIUM-TEMPERATURE EVAPORATION
LOW-TEMPERATURE EVAPORATION
44
30
16
47
DEFROST RESERVOIR
42
17
41
43
90
18
HEAT EXCHANGER
19
DEDICATED CO_2 COMPRESSION
10'
CO_2 COMPRESSION
10

Fig. 7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HEAT RECLAIM EXCHANGER
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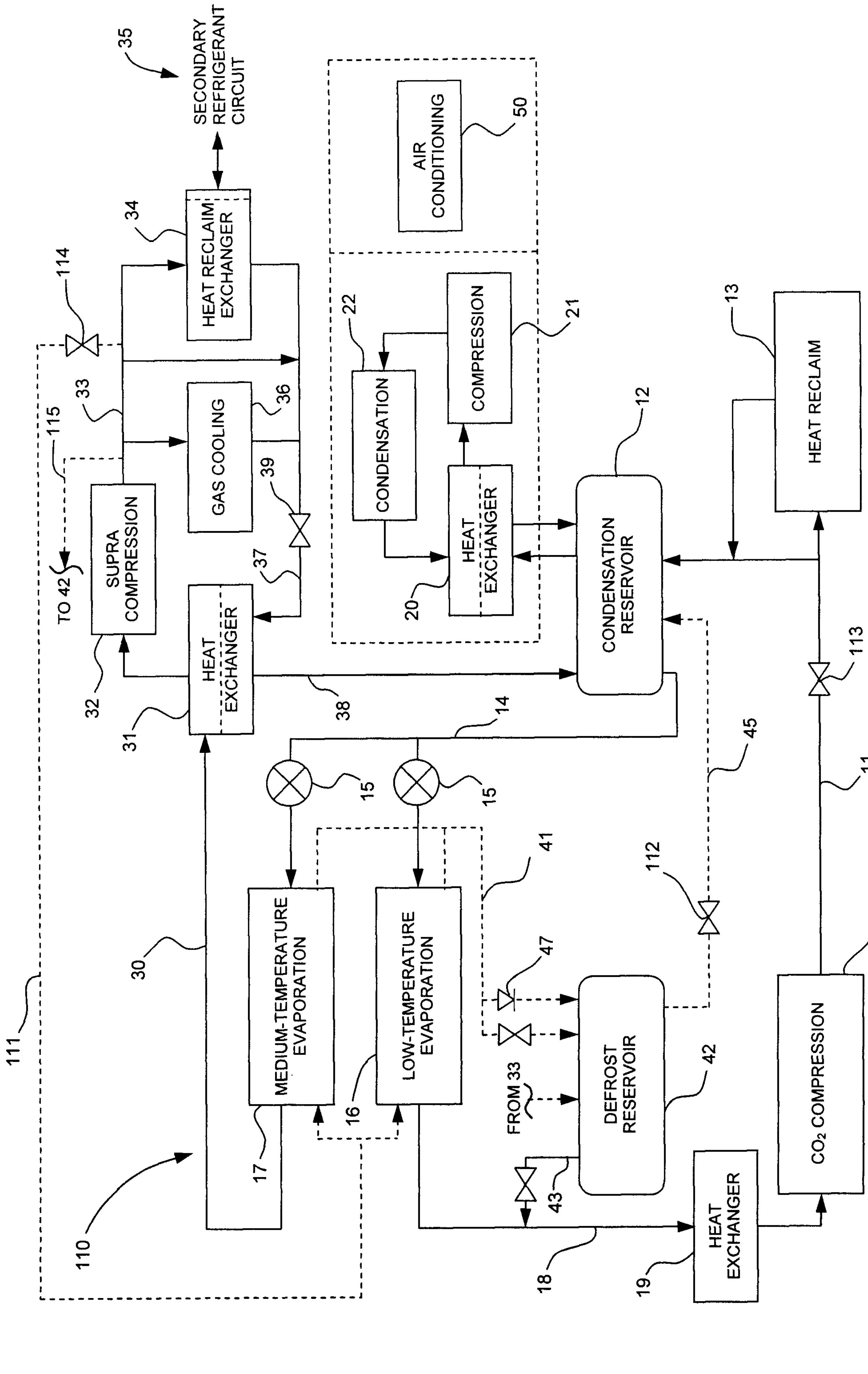
33
GAS COOLING
36
SUPRA COMPRESSION
32
39
37
HEAT EXCHANGER
31
38
CONDENSATION RESERVOIR
12
HEAT RECLAIM
13
72
71
14
15
45
46
11
40
LOW-TEMPERATURE EVAPORATION
44
DEFROST RESERVOIR
42
16
47
41
43
CO2 COMPRESSION
10
HEAT EXCHANGER
19
18
100

Fig. 8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HEAT RECLAIM EXCHANGER
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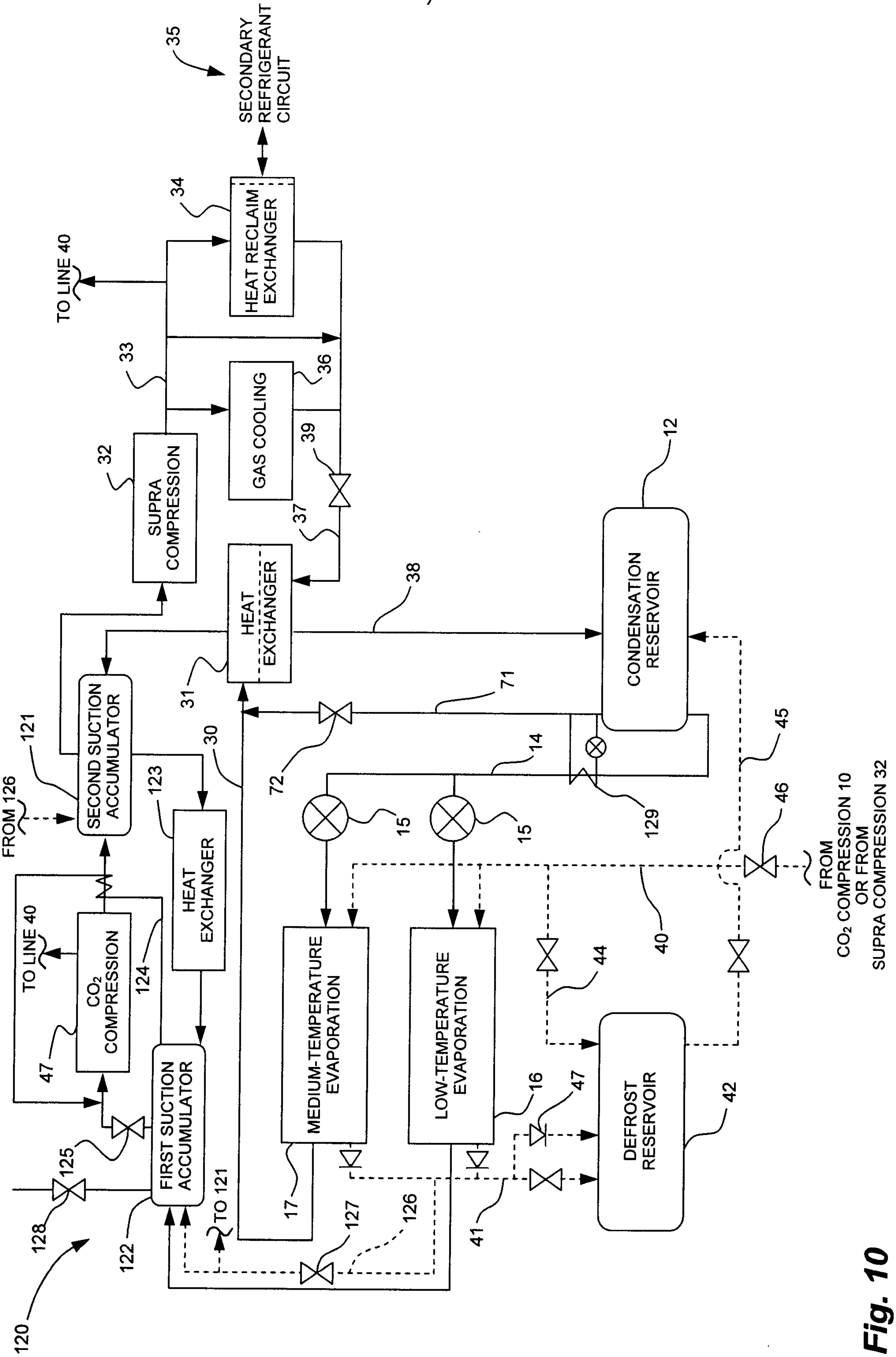
GAS COOLING
115
39
SUPRA COMPRESSION
TO 42
37
HEAT EXCHANGER
32
31
38
30
111
MEDIUM-TEMPERATURE EVAPORATION
17
110
LOW-TEMPERATURE EVAPORATION
16
15
15
14
41
47
FROM 33
43
18
AIR CONDITIONING
50
22
COMPRESSION
21
CONDENSATION
HEAT EXCHANGER
20
12
CONDENSATION RESERVOIR
45
112
DEFROST RESERVOIR
42
HEAT EXCHANGER
19
13
HEAT RECLAIM
113
11
10
CO_2 COMPRESSION

Fig. 9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SECONDARY REFRIGERANT CIRCUIT
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HEAT RECLAIM EXCHANGER
TO LINE 40
33
36
GAS COOLING
39
32
SUPRA COMPRESSION
37
HEAT EXCHANGER
38
31
12
CONDENSATION RESERVOIR
71
72
30
14
129
45
46
FROM CO₂ COMPRESSION 10 OR FROM SUPRA COMPRESSION 32
121
SECOND SUCTION ACCUMULATOR
FROM 126
123
HEAT EXCHANGER
15
15
MEDIUM-TEMPERATURE EVAPORATION
LOW-TEMPERATURE EVAPORATION
40
44
TO LINE 40
CO₂ COMPRESSION
124
47
DEFROST RESERVOIR
42
16
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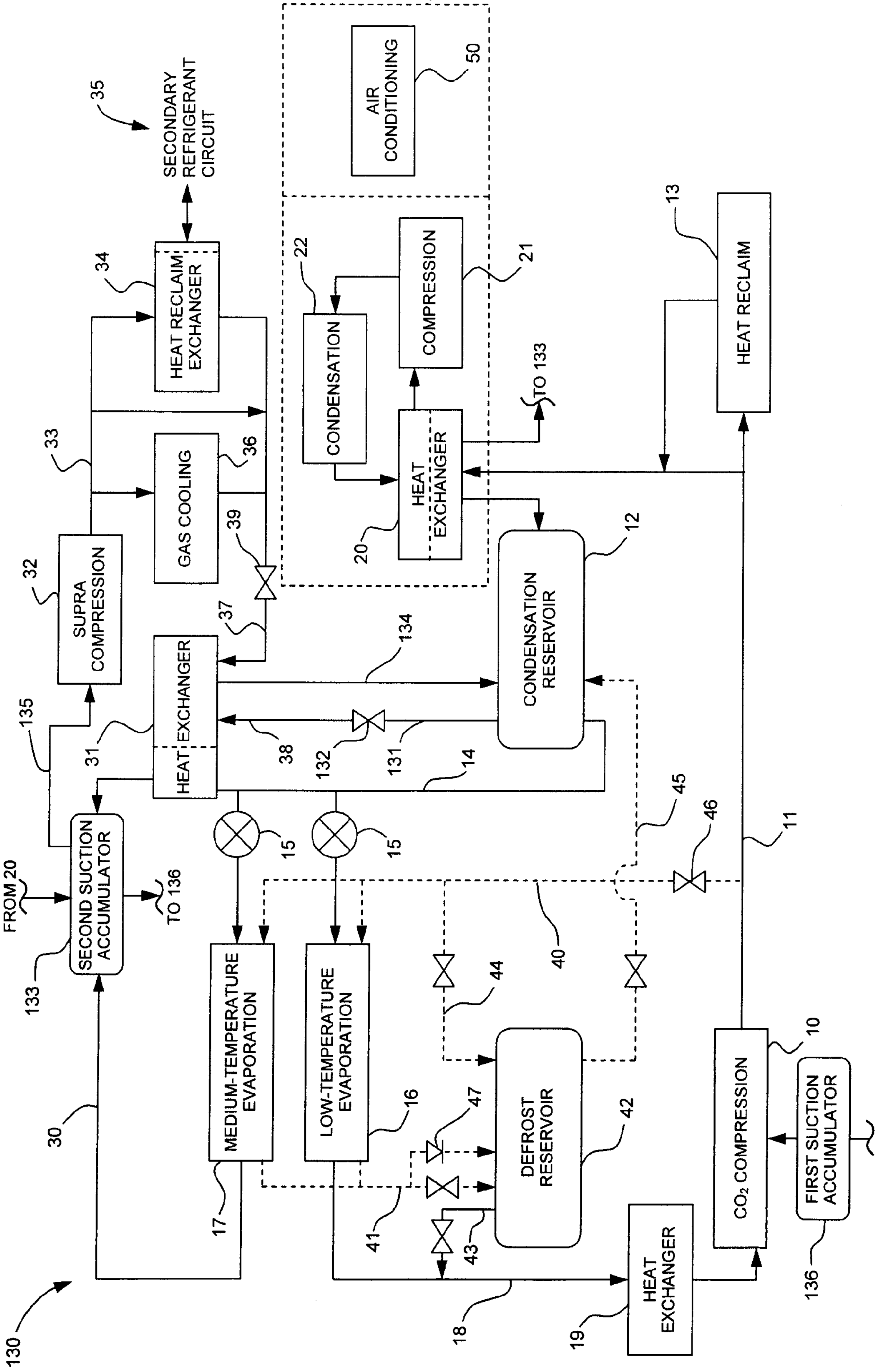
FIRST SUCTION ACCUMULATOR
125
128
122
TO 121
17
127
126
41
120

Fig. 10

11/13


SECONDARY REFRIGERANT CIRCUIT
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AIR CONDITIONING
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HEAT RECLAIM EXCHANGER
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COMPRESSION
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CONDENSATION
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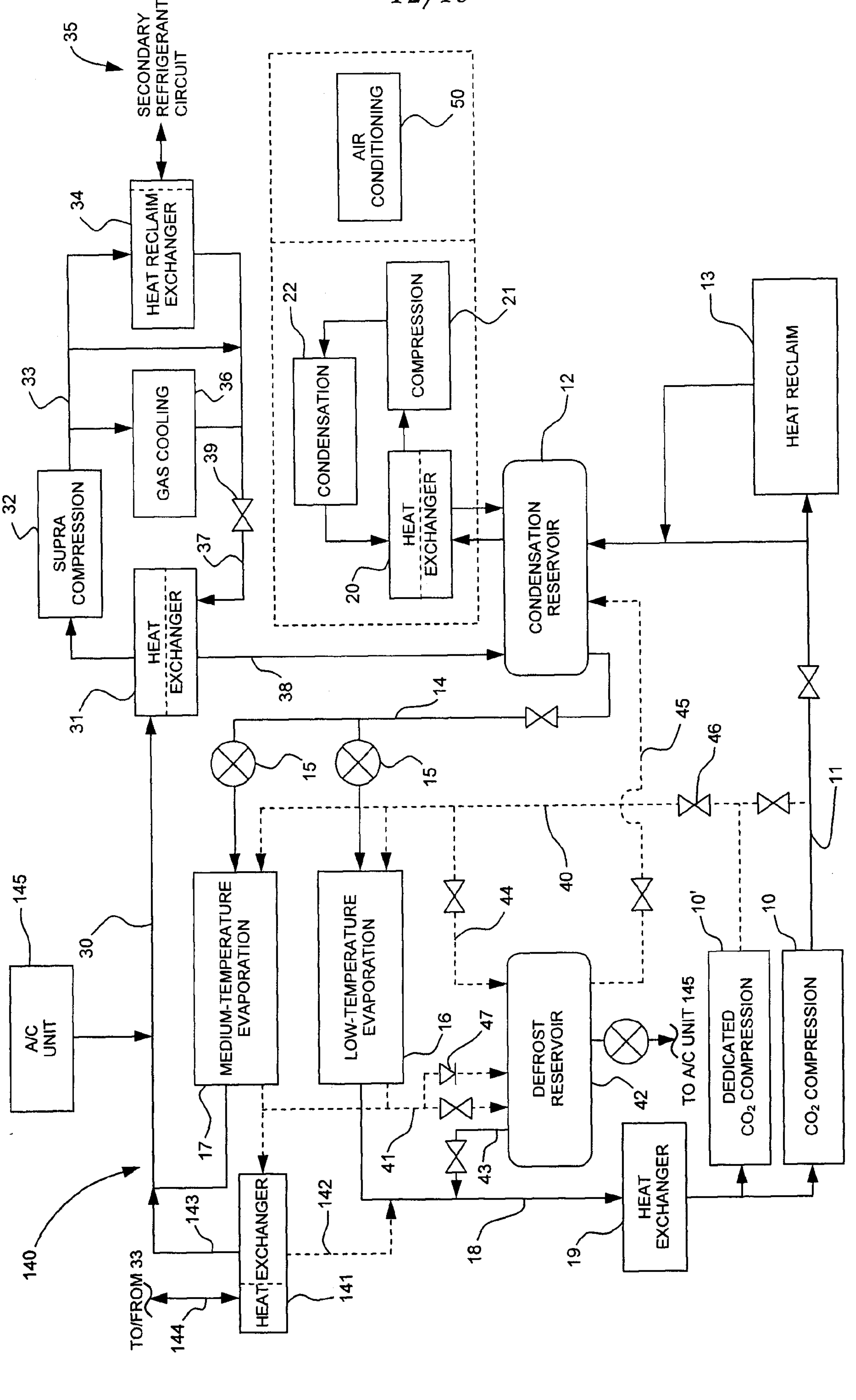
HEAT EXCHANGER
20
TO 133
HEAT RECLAIM
13
SUPRA COMPRESSION
32
33
GAS COOLING
36
39
37
CONDENSATION RESERVOIR
12
134
HEAT EXCHANGER
31
38
132
131
14
135
15
15
45
46
11
SECOND SUCTION ACCUMULATOR
FROM 20
TO 136
133
MEDIUM-TEMPERATURE EVAPORATION
LOW-TEMPERATURE EVAPORATION
40
44
DEFROST RESERVOIR
42
47
16
17
41
43
30
CO2 COMPRESSION
10
FIRST SUCTION ACCUMULATOR
FROM 133
136
HEAT EXCHANGER
19
18
130

Fig. 11


SECONDARY REFRIGERANT CIRCUIT
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HEAT RECLAIM EXCHANGER
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AIR CONDITIONING
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COMPRESSION
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CONDENSATION
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SUPRA COMPRESSION
32
GAS COOLING
36
33
39
37
HEAT EXCHANGER
31
38
HEAT EXCHANGER
20
CONDENSATION RESERVOIR
12
HEAT RECLAIM
13
14
15
15
45
46
11
40
44
MEDIUM-TEMPERATURE EVAPORATION
LOW-TEMPERATURE EVAPORATION
A/C UNIT
145
30
DEFROST RESERVOIR
TO A/C UNIT 145
16
47
42
41
43
17
DEDICATED CO_2 COMPRESSION
10'
CO_2 COMPRESSION
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HEAT EXCHANGER
19
18
HEAT EXCHANGER
141
142
143
140
TO/FROM 33
144

Fig. 12

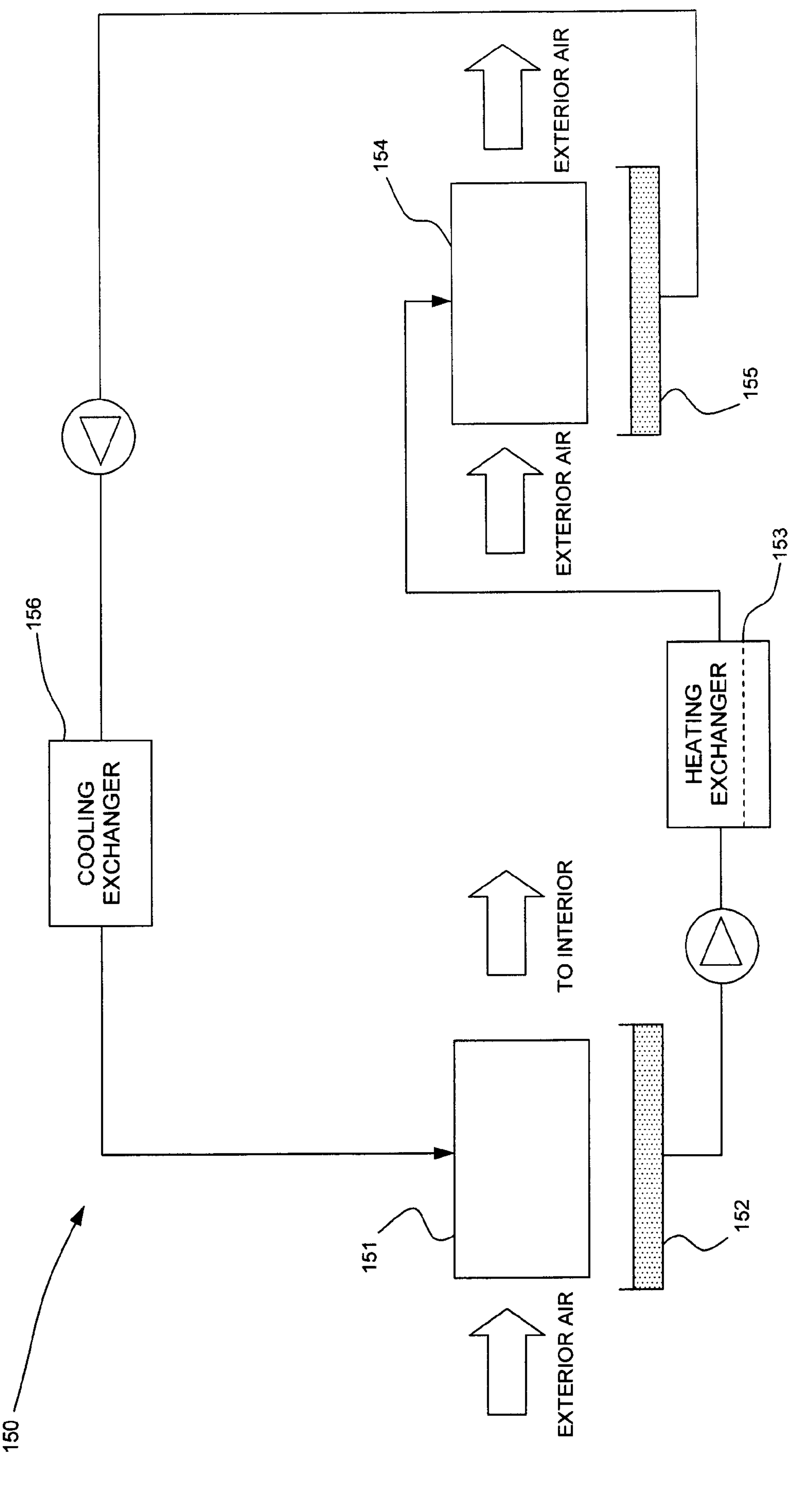
EXTERIOR AIR
154
155
EXTERIOR AIR
153
HEATING EXCHANGER
156
COOLING EXCHANGER
TO INTERIOR
151
152
EXTERIOR AIR
150

Fig. 13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2009/001536

A. CLASSIFICATION OF SUBJECT MATTER
IPC: ***F25B 9/00*** (2006.01)
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC: ***F25B 9/00*** (2006.01) ; IPC: ***F25B 7/00*** (2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
Epooque; Intellect;
CO2, refrigerent; supra-compression; transcritical compression; secondary circuit; high low pressure compressor and combinations thereof

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2008/112554 A1 (Pachai et al) 18 September 2008 (18-09-2008)	1-19
A	EP 1,921,399 A2 (Shapiro) 14 May 2008 (14-05-2008)	1-19
A	US 2005/0279127 A1 (Jia et al) 22 December 2005 (22-12-2005)	1-19
A	US 2006/0230765 A1 (Fedorov et al) 19 October 2006 (19-10-2005)	1-19
A	WO 2008/019689 A2 (Knudsen Koling A/S) 21 February 2008 (21-02-2008)	1-19

[ ] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 January 2010 (25-01-2010)	2 February 2010 (02-02-2010)

Name and mailing address of the ISA/CA
Canadian Intellectual Property Office
Place du Portage I, C114 - 1st Floor, Box PCT
50 Victoria Street
Gatineau, Quebec K1A 0C9
Facsimile No.: 001-819-953-2476

Authorized officer
Sam Abounehme (819) 997-2773

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2009/001536

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of the first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons :

1. [ ] Claim Nos. :
because they relate to subject matter not required to be searched by this Authority, namely :

2. [ ] Claim Nos. :
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically :

3. [ ] Claim Nos. :
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows :

Group A - Claims 1 - 19 are directed to a CO2 refrigeration system.
Group B - Claim 20 is directed to a method for relieving CO2 refrigerant pressure .
Group C - Claims 21 - 23 are directed to a method for feeding vaporized CO2 refrigerant and oil to a compressor.

1. [ ] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. [ ] As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claim Nos. :

4. [X] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim Nos. : 1- 19

Remark on Protest [ ] The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

[ ] The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

[ ] No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CA2009/001536

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
WO2008112554A1	18-09-2008	US2008223074A1	18-09-2008
		WO2008112549A2	18-09-2008
		WO2008112549A3	24-12-2008
		WO2008112566A2	18-09-2008
		WO2008112566A3	05-02-2009
		WO2008112568A2	18-09-2008
		WO2008112568A3	24-12-2008
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		WO2008112569A3	27-11-2008
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		WO2008112591A2	18-09-2008
		WO2008112591A3	11-12-2008
		WO2008112593A1	18-09-2008
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		WO2008112594A3	13-11-2008
		WO2008112595A1	18-09-2008
EP1921399A2	14-05-2008	US2008289350A1	27-11-2008
US2005279127A1	22-12-2005	BRPI0512179A	12-02-2008
		DE112005001236T5	03-05-2007
		GB0620901D0	29-11-2006
		GB2430247A	21-03-2007
		JP2008503705T	07-02-2008
		WO2006009790A2	26-01-2006
		WO2006009790A3	11-05-2006
US2006230765A1	19-10-2006	None	
WO2008019689A2	21-02-2008	WO2008019689A3	03-04-2008