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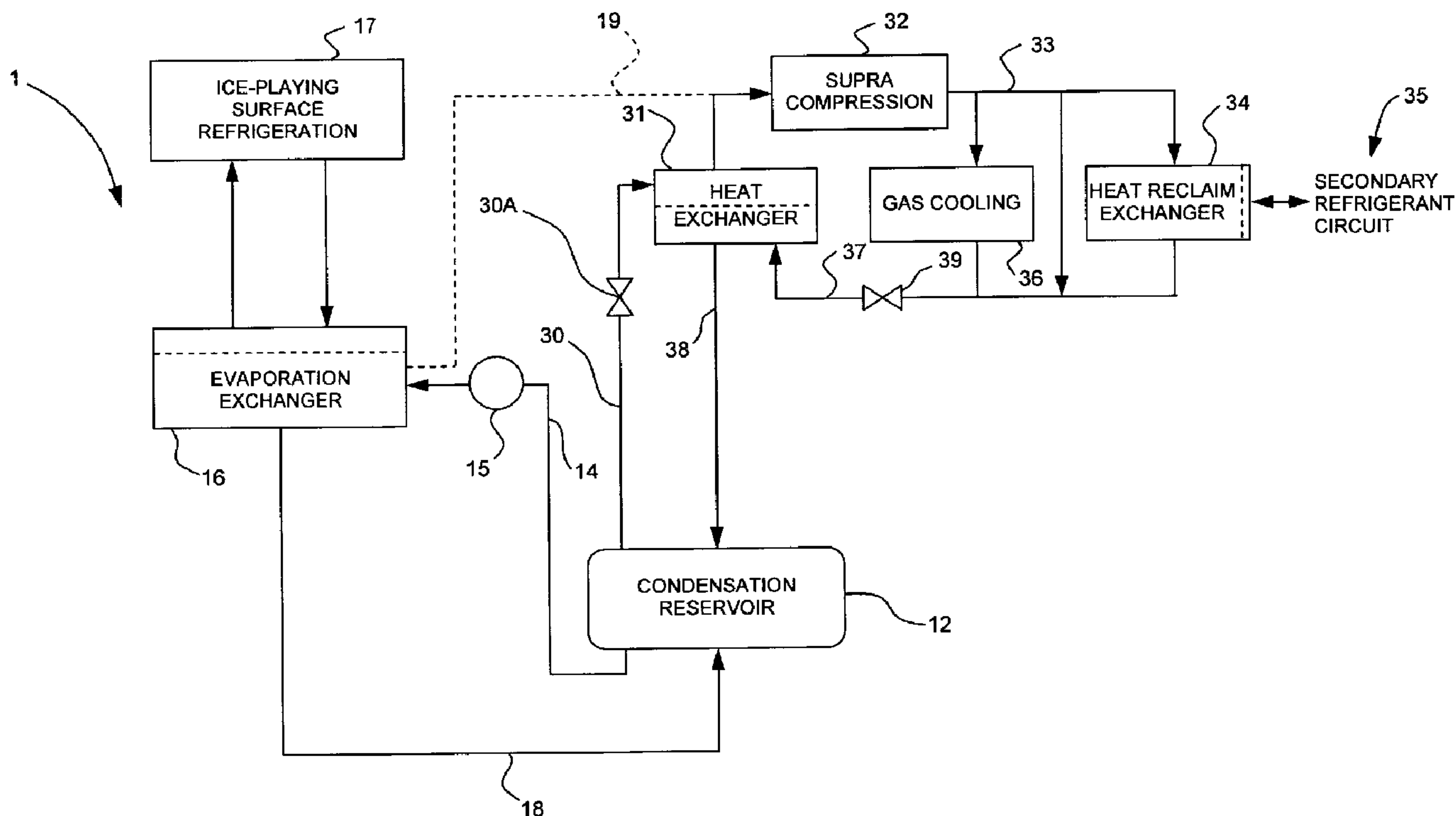
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(54) Titre : SYSTEME DE REFRIGERATION AU CO₂ POUR SURFACES DE SPORTS SUR GLACE

(54) Title: CO₂ REFRIGERATION SYSTEM FOR ICE-PLAYING SURFACES



(57) Abrégé/Abstract:

A CO₂ refrigeration system comprises a condensation reservoir. CO₂ refrigerant is accumulated in the reservoir. The CO₂ refrigerant circulates between supracompression and evaporation loops. The supracompression loop comprises a compression stage for compression CO₂ refrigerant to a supracompression state, a cooling stage in which CO₂ refrigerant releases heat, and a pressure-regulating unit in a line extending from the cooling stage to the condensation reservoir. The pressure-regulating unit maintains a pressure differential between the cooling stage and the condensation reservoir. The evaporation loop comprises an evaporation stage in which CO₂ refrigerant from the condensation reservoir absorbs heat in a heat exchanger. The heat exchanger

(57) **Abrégé(suite)/Abstract(continued):**

is connected to an ice-playing surface refrigeration circuit. A second refrigerant cycles in the ice-playing surface refrigeration circuit. The CO₂ refrigerant absorbs heat from the second refrigerant in the heat exchanger. A CO₂ condensation exchanger is also provided.

ABSTRACT

CO₂ REFRIGERATION SYSTEM
FOR ICE-PLAYING SURFACES

A CO₂ refrigeration system comprises a condensation reservoir. CO₂ refrigerant is accumulated in the reservoir. The CO₂ refrigerant circulates between supracompression and evaporation loops. The supracompression loop comprises a compression stage for compression CO₂ refrigerant to a supracompression state, a cooling stage in which CO₂ refrigerant releases heat, and a pressure-regulating unit in a line extending from the cooling stage to the condensation reservoir. The pressure-regulating unit maintains a pressure differential between the cooling stage and the condensation reservoir. The evaporation loop comprises an evaporation stage in which CO₂ refrigerant from the condensation reservoir absorbs heat in a heat exchanger. The heat exchanger is connected to an ice-playing surface refrigeration circuit. A second refrigerant cycles in the ice-playing surface refrigeration circuit. The CO₂ refrigerant absorbs heat from the second refrigerant in the heat exchanger. A CO₂ condensation exchanger is also provided.

CO2 REFRIGERATION SYSTEM FOR ICE-PLAYING SURFACES

FIELD OF THE APPLICATION

The present application relates to refrigeration systems used in industrial refrigeration applications, such as rinks, curling centers and arenas, to refrigerate an ice-skating or ice-playing surface, and more particularly to such refrigeration systems using CO₂ 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 CO₂ are used as refrigerants. Although ammonia and hydrocarbons have negligible ozone-depletion potential and global-warming potential as does CO₂, these refrigerants are highly flammable and therefore represent a risk to local safety. On the other hand, CO₂ is environmentally benign and locally safe.

Ice-playing surfaces typically have large-scale heat exchangers disposed under the ice surface to refrigerate the ice surface. Considering the specific use of such refrigeration systems, and thus the requirement for a refrigerant at a precise range of temperature, brine is currently used in such refrigeration systems. The brine circulates in a closed circuit and is in a heat-exchange relation with a refrigeration circuit. However, these refrigeration circuits often use refrigerants that are harmful to the environment.

SUMMARY OF THE APPLICATION

It is therefore an aim of the present disclosure to provide a CO₂ refrigeration system for ice surfaces, that addresses issues associated with the prior art.

5 Therefore, in accordance with the present application, there is provided a CO₂ refrigeration system comprising a CO₂ condensation reservoir in which CO₂ refrigerant is accumulated and circulates between a supra-compression loop and an evaporation loop; the supra-
10 compression loop comprising a compression stage in which CO₂ refrigerant from at least the CO₂ condensation reservoir is compressed to at least a supracompression state, a cooling stage in which the CO₂ refrigerant from the compression stage releases heat, and a pressure-regulating unit in a
15 line extending from the cooling stage to the CO₂ condensation reservoir to maintain a pressure differential therebetween; and the evaporation loop comprising an evaporation stage in which the CO₂ refrigerant from at least the CO₂ condensation reservoir absorbs heat in a heat
20 exchanger, the heat exchanger being connected to an ice-playing surface refrigeration circuit in which cycles a second refrigerant, such that the CO₂ refrigerant absorbs heat from the second refrigerant in the heat exchanger.

Further in accordance with the present
25 application, there is provided a CO₂ refrigeration system comprising a CO₂ condensation exchanger for heat exchange between a supracompression loop of CO₂ refrigerant and an evaporation loop of CO₂ refrigerant; the supracompression loop comprising a compression stage in which CO₂ refrigerant
30 having absorbed heat in the condensation exchanger is compressed to at least a supracompression state, a cooling stage in which the CO₂ refrigerant from the compression stage releases heat, and a pressure-regulating unit in a line extending from the cooling stage to the condensation
35 exchanger to maintain a pressure differential therebetween; and the evaporation loop comprising a condensation reservoir in which CO₂ refrigerant having released heat in the

condensation exchanger is accumulated in a liquid state, and an evaporation stage in which the CO₂ refrigerant from the condensation reservoir absorbs heat to cool an ice-playing surface, to then return to one of the condensation reservoir and the condensation exchanger.

Still further in accordance with the present application, there is provided a CO₂ refrigeration system comprising a CO₂ condensation reservoir in which CO₂ refrigerant is accumulated and circulates between a supra-compression loop and an evaporation loop; the supra-compression loop comprising a compression stage in which CO₂ refrigerant from at least the CO₂ condensation reservoir is compressed to at least a supracompression state, a cooling stage in which the CO₂ refrigerant from the compression stage releases heat, and a pressure-regulating unit in a line extending from the cooling stage to the CO₂ condensation reservoir to maintain a pressure differential therebetween; the evaporation loop comprising an evaporation stage of pipes under an ice-playing surface in which circulates the CO₂ refrigerant to absorb heat to cool an ice-playing surface, to then return to the CO₂ condensation reservoir; and a geothermal well loop in heat-exchange relation with the CO₂ refrigerant, the geothermal well loop having a geothermal heat exchanger for heat exchange between the CO₂ refrigerant of one of the evaporation loop and the compression loop and another refrigerant absorbing heat from the CO₂ refrigerant, the geothermal well loop extending to a geothermal well in which the other refrigerant releases heat geothermally.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram of a CO₂ refrigeration system for skating surfaces in accordance with a first embodiment;

Fig. 2 is a block diagram of a CO₂ refrigeration system for skating surfaces in accordance with a second embodiment;

Fig. 3 is a block diagram of a CO₂ refrigeration system with a geothermal well in accordance with a third embodiment;

Fig. 4 is a block diagram of a CO₂ refrigeration system with a geothermal well in accordance with a fourth embodiment; and

Fig. 5 is a schematic view of a modulated pressure-relief system for use with the CO₂ refrigeration systems of the previous figures.

10 DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to Fig. 1, a CO₂ refrigeration system in accordance with an embodiment is illustrated at 1. The CO₂ refrigeration system 1 has a CO₂ refrigeration circuit comprising a CO₂ condensation reservoir 12. The condensation reservoir 12 accumulates CO₂ refrigerant in a liquid and gaseous state, and may be in a heat-exchange relation with a closed condensation circuit that absorbs heat from the CO₂ refrigerant, with examples given hereinafter.

Line 14 directs CO₂ refrigerant from the condensation reservoir 12 to an evaporation stage via pump(s) 15 or expansion valve(s). As is shown in Fig. 1, the CO₂ refrigerant is supplied in a liquid state by the condensation reservoir 12 into line 14. The pump 15 ensures a suitable flow of liquid CO₂ refrigerant to the evaporation exchanger 16. In some instances, expansion valve(s) 15 may be used to control the pressure of the CO₂ refrigerant, which is then fed to the evaporation exchanger 16. Any appropriate means may be used to put the CO₂ refrigerant in suitable condition, such as heat exchangers to vaporize the refrigerant.

The evaporation exchanger 16 features the heat exchange between the CO₂ refrigerant and the refrigerant of the ice-playing surface. The ice-playing surface refrigerant circulating in the ice-playing surface is typically brine, but may be other types of fluid, such as

alcohol-based fluid (e.g., glycol) or the like. In one embodiment, the CO₂ circulates in pipes upon which fins are provided. The pipes of the evaporator exchanger 16 are typically positioned in a bath of the ice-playing surface refrigerant. In another embodiment, the refrigeration system 1 is retrofitted to an existing ice-playing surface refrigeration circuit 17. It is pointed out that the expansion valve(s) 15 may be part of a refrigeration pack in the mechanical room, as opposed to being at the evaporation exchanger 16.

The CO₂ refrigerant exiting the evaporation stage 16 is returned to the condensation reservoir 12 via line 18. Alternatively, the CO₂ refrigerant may be directed to the inlet of compressors of the transcritical circuit or loop, via line 19. In such a case, it may be required to provide some form of protection in line 19 to vaporize the CO₂ refrigerant fed to the inlet of the compressors, such as an evaporator, a heat exchanger or source of heat, valves, among numerous possibilities.

The transcritical circuit or loop (i.e., supra-compression circuit) is provided to compress the CO₂ refrigerant exiting from the condensation reservoir 12 to a transcritical state, for heating purposes, or supra-compressed state. In both compression states, the CO₂ refrigerant is pressurized with a view to maintaining the condensation reservoir 12 at a high enough pressure to allow vaporized CO₂ refrigerant to be circulated in the evaporation stage 16, as opposed to liquid CO₂ refrigerant. In one embodiment, the pressure is high enough for the CO₂ refrigerant to circulate to the evaporation exchanger 16 via the action of the pump 15.

A line 30 (using valve 30A) relates the condensation reservoir 12 to a heat exchanger 31 and subsequently to a supracompression stage 32. The heat exchanger 31 or any other appropriate means may be provided to vaporize the CO₂ refrigerant fed to the supracompression stage 32 (e.g., feed from a top of the condensation

reservoir 12, multiple reservoirs in specific arrangement, etc). The supracompression stage 32 features one or more compressors (e.g., BockTM, DorinTM), that compress the CO₂ refrigerant to a supracompressed or transcritical state.

5 In the supracompressed or transcritical state, the CO₂ refrigerant is used to heat a secondary refrigerant via heat-reclaim exchanger 34, or may be used directly in a heating unit, with a fluid such as air blown thereon to heat parts of the building related to the ice-playing surface.

10 In the heat-reclaim exchanger 34, the CO₂ refrigerant is in a heat-exchange relation with the secondary refrigerant circulating in the secondary refrigerant circuit 35, or with a fluid blown on the heat exchanger 34. In the event that a secondary refrigerant is used, the secondary refrigerant is

15 preferably an environmentally sound refrigerant, such as water or glycol, that is used as a heat-transfer fluid. Because of the supracompressed or transcritical state of the CO₂ refrigerant, the secondary refrigerant circulating in the circuit 35 reaches a high temperature. Accordingly, due

20 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 may be the largest of the circuits of the refrigeration system 1 in terms of quantity

25 of refrigerant. Therefore, the compression of the CO₂ 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. It is pointed out that heat-reclaim exchanger 34 may include

30 individual heating units used to produce heat locally. Such heating units 35 are typically a coil and fan assembly. The control of the amount of refrigerant sent to each heating unit 35 is described hereinafter.

A gas-cooling stage 36 is provided in the

35 transcritical circuit. The gas-cooling stage 36 absorbs excess heat from the CO₂ refrigerant in the transcritical state, with a view to re-injecting the CO₂ refrigerant into

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 CO₂ 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 CO₂ refrigerant is compressed to a supra-compressed state, namely at a high enough pressure to allow the expansion of the CO₂ refrigerant at the exit of the condensation reservoir 12, so as to reduce the amount of CO₂ refrigerant circulating in the refrigeration circuit. A bypass line is provided to illustrate that the heat-reclaim exchanger 34 and the gas-cooling stage 36 may be 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 CO₂ refrigerant to the condensation reservoir 12, and thus to the refrigeration circuit. The line 37 may feed the heat exchanger 31 such that the CO₂ refrigerant exiting the stages 34 and 36 releases heat to the CO₂ refrigerant fed to the supra-compression stage 32, for the CO₂ refrigerant fed to the supracompression stage 32 to be in a gaseous state.

In the case of transcritical compression, a CO₂ transcritical pressure-regulating valve 39 is provided to maintain appropriate pressures at the stages 34 and 36, and in the condensation reservoir 12. The CO₂ transcritical pressure-regulating valve 39 is for instance a DanfossTM valve. Any other suitable pressure-control, pressure-regulating, pressure-reducing device may be used as an

alternative to the valve 39, such as any type of valve or loop.

The condensation circuit and the supracompression circuit allow the condensation reservoir 12 to store
5 refrigerant at a relatively medium pressure. The pump 15 then ensures the circulation of the CO₂ refrigerant in the evaporation exchanger 16. In the embodiment featuring expansion valve 15, as CO₂ refrigerant is vaporized downstream of the expansion valve 15, the amount of CO₂
10 refrigerant in the refrigeration circuit is reduced, especially if the expansion valve 15 is in the refrigeration pack.

It is considered to operate the supracompression circuit (i.e., supracompression 32) with higher operating
15 pressure. CO₂ refrigerant has a suitable efficiency at a higher pressure. More specifically, more heat can be extracted when the pressure is higher.

Referring now to Fig. 2, there is illustrated a CO₂ refrigeration system 2 for ice-playing surfaces. The CO₂
20 refrigeration system 2 is similar to the CO₂ refrigeration system 1 of Fig. 1, whereby like elements will bear like reference numerals. One difference between refrigeration systems 1 and 2 is that the refrigeration system 2 features two closed circuits of refrigerant in addition to the ice-
25 playing surface refrigeration circuit 17. More specifically, the CO₂ refrigeration circuit 2 of Fig. 2 has a condensation exchanger 50 by which the refrigerant circulating in the main refrigeration circuit 40 (i.e., CO₂ or other refrigerants, if suitable) is in a heat-exchange
30 relation with CO₂ refrigerant circulating in the transcritical/supracompression circuit. Accordingly, in the condensation exchanger 50, the CO₂ refrigerant circulating in the supracompression/transcritical circuit is used to absorb heat from the refrigerant circulating in the main
35 refrigeration circuit 40. In an embodiment, both refrigerants are CO₂.

Referring to Fig. 3, there is illustrated a CO₂ refrigeration system 3 similar to the CO₂ refrigeration systems 1 and 2, whereby like elements and components will bear like reference numerals. The valve 30A in line 30 may
5 be an expansion valve, evaporative pressure-regulating valve, control valve or the like so as to ensure that the compressors 32 are fed with vaporized CO₂ refrigerant. The refrigeration system 3 has one or more heating units 35 at the outlet of the supracompression stage 32, in any given
10 arrangement with the exchanger 34 and gas-cooling stage 36. The heating units 35 are typical direct-heating units, having coils in which CO₂ refrigerant circulates and upon which air is blown for heating purposes.

According to an embodiment, there are a plurality
15 of the heating units 35. In another embodiment, the heating units 35 are in a parallel relation, and they may or may not be fed with CO₂ refrigerant as a function of the heating requirements. Moreover, the speed of the fans of the heating units 35 may also be controlled for this purpose. A
20 valve or valves 35A are used to control the amount of CO₂ refrigerant sent to each of the heating units 35 and/or to heat-reclaim exchanger 34. For instance, if two of the heating units 35 cover two different zones having different heating requirements, the valves 35A and fans of each unit
25 may be adjusted to meet the local heating requirements. One configuration is to have thermostats for the various zones to adjust the amount of refrigerant sent to the heating units 35 via the adjustment of the valves 35A.

A reservoir 55 may be provided between lines 37
30 and 38 to receive CO₂ refrigerant, and ensure it is fed in suitable condition to the condensation exchanger 50. For instance, the line 38 may tap into a bottom of the reservoir 55 to direct liquid CO₂ refrigerant to the condensation exchanger 50. A valve 56 (e.g., expansion valve) may be
35 provided to ensure that the CO₂ refrigerant is in a suitable state to absorb heat from the CO₂ refrigerant. In an embodiment, valve 56 is used as pressure differential valve

instead of valve 39 (not required in such a case to reduce the pressure), with the supracompression pressure maintained upstream of valve 56. With this configuration, the pressure of the CO₂ refrigerant in the main refrigeration circuit 40
5 may be kept lower, or other refrigerants may be used in the main refrigeration circuit 40.

Still referring to Fig. 3, a heat exchanger 60 is illustrated as extending from the condensation reservoir 12 and in fluid communication therewith so as to receive a feed
10 of CO₂ refrigerant. The heat exchanger 60 is in fluid communication with a geothermal well 61 by a geothermal circuit. A refrigerant (e.g., glycol, or any appropriate refrigerant such as alcohol-based refrigerants or the like) circulates in the geothermal circuit, so as to absorb heat
15 from the CO₂ refrigerant in the heat exchanger 60 and release the heat in the well 61. Appropriate pumps 62 and/or 63 or flow controlling means may be used to ensure that there is a suitable flow of refrigerant to the heat exchanger 60. The pumps 62 and 63 are variably controlled.

20 In Fig. 3, although the refrigeration system 3 is shown with an evaporation exchanger 16 and ice-rink cooling, the refrigeration system 3 may be used for any appropriate type of refrigeration, with or without an evaporation exchanger 16. Moreover, the refrigeration system 3 may be
25 operated without a geothermal well in appropriate conditions.

Referring to Fig. 4, a CO₂ refrigeration system 4 similar to the CO₂ refrigeration systems 1, 2 and 3 is illustrated, whereby like elements and components will bear
30 like reference numerals. The refrigeration system 4 features a geothermal well loop, but does not have a condensation exchanger 50 as does the refrigeration system 3. The CO₂ refrigeration system 4 may be used to refrigerate a skating rink or the like. For simplicity
35 purposes, the evaporation stage is generally shown as 17. In the embodiment in which the CO₂ refrigerant is sent directly in the pipes of the ice-playing surface as part of

the evaporation stage 17, the pump(s) 15 is well suited to induce a suitable flow of liquid CO₂ refrigerant into the pipes of the ice-playing surface.

5 The refrigeration systems 1-3 may be used with existing ice-playing surface piping, or as part of new ice-rink refrigeration systems. The evaporation exchanger 16 is modified to receive CO₂ refrigerant. It may be required that the coils be modified in view of the specifications of the CO₂ refrigerant versus the brine or other refrigerant
10 used in the ice-playing surface piping. The CO₂ refrigeration systems 1-3 advantageously use the existing hardware related to the ice-playing surface refrigeration. It is pointed out that the CO₂ refrigeration systems 1-3 need not be used only in a retrofit configuration.

15 Referring to Fig. 5, there is illustrated a modulated pressure-relief system which may be used with any one of the CO₂ refrigeration systems 1-4 of the previous figures, if appropriate. The modulated pressure-relief system has a line 70 that is in fluid communication with the
20 evaporators of the refrigeration system. A pair of valves 71 and 72 are in a parallel arrangement with the line 70, and are part of exhaust lines opened to the atmosphere, for exhausting CO₂ refrigerant. Valve 71 is a modulating valve, automatically operable from a set point pressure. The
25 modulating valve 71 therefore gradually opens upon the pressure in the line reaching the set point pressure. Any other gradually-opening type of valve may be used as valve 71. For instance, valve 71 may be operated by a controller (e.g., central processing unit of the CO₂ refrigeration
30 systems), or may be a mechanical valve with an appropriate controlled-opening mechanism.

Valve 72 is a pressure-relief valve. The pressure-relief valve 72 has its own set point pressure, which is higher than the set point pressure of the
35 modulating valve 71. The pressure-relief valve 72 opens when the set point pressure is reached. Accordingly, if the pressure is high in the evaporators, but not at the set

point of relief, the pressure increase in the evaporators 70 will be modulated to reduce the pressure increase. The opening of valve 72 in a relief condition may be controlled so as to be a slow release to limit the release of
5 refrigerant to the atmosphere. Valve 72 may be any appropriate type of relief valve, such as a mechanical valve, or a valve controlled by the controller of the CO₂ refrigeration system.

The CO₂ refrigeration systems described above for
10 Figs. 1-4 are generally separated into a supracompression loop and an evaporation loop. The supracompression loop comprises the supracompression stage, while the evaporation loop comprises the evaporation stage. The loops may be separated from one another by the condensation exchanger 50
15 (Figs. 2 and 3), in which case the CO₂ refrigerant does not circulate between loops. In Figs. 1 and 4, the loops are interrelated by the condensation reservoir 12, in which case the CO₂ refrigerant circulates between loops.

The CO₂ refrigeration systems described above for
20 Figs. 1-4 are used for ice-playing surfaces, which may include ice-skating surfaces of arenas or of outdoor applications, skating rinks (e.g., speed skating), the playing surface of curling centers, or any other application in which a relatively large-scale refrigerated surface is
25 used. Moreover, although the word "ice" is used (and thus water), it is understood that the medium used for the surface may be any appropriate fluid reaching a solid state.

CLAIMS:

1. A CO₂ refrigeration system comprising a CO₂ condensation reservoir in which CO₂ refrigerant is accumulated and circulates between a supracompression loop and an evaporation loop;

the supracompression loop comprising a compression stage in which CO₂ refrigerant from at least the CO₂ condensation reservoir is compressed to at least a supra-compression state, a cooling stage in which the CO₂ refrigerant from the compression stage releases heat, and a pressure-regulating unit in a line extending from the cooling stage to the CO₂ condensation reservoir to maintain a pressure differential therebetween; and

the evaporation loop comprising an evaporation stage in which the CO₂ refrigerant from at least the CO₂ condensation reservoir absorbs heat in a heat exchanger, the heat exchanger being connected to an ice-playing surface refrigeration circuit in which cycles a second refrigerant, such that the CO₂ refrigerant absorbs heat from the second refrigerant in the heat exchanger.

2. The CO₂ refrigeration system according to claim 1, wherein the cooling stage comprises at least one of a gas-cooling unit, a heat-reclaim exchanger, and a heating unit.

3. The CO₂ refrigeration system according to claim 2, comprising a plurality of the heating unit, with valves provided in relation to the plurality of heating unit to individually control an amount of CO₂ refrigerant directed to each said heating unit.

4. The CO₂ refrigeration system according to claim 3, wherein a fan of each said heating unit is controlled by a controller as a function of a temperature demand and of said amount of amount of CO₂ refrigerant.

5. The CO₂ refrigeration system according to claim 1, further comprising a relief system to relieve excess CO₂ refrigerant pressure in the CO₂ refrigeration system, the relief system comprising at least a pair of valves in parallel and opening to an exhaust, with a first of the valves being automatically operable from a first set point pressure to gradually release pressure, and a second one of the valves having a second set point pressure higher than the first set point pressure.

6. The CO₂ refrigeration system according to claim 1, further comprising at least one pump in the evaporation loop to induce a flow of the CO₂ refrigerant therein.

7. The CO₂ refrigeration system according to claim 1, further comprising a geothermal well loop in heat exchange relation with the evaporation loop, the geothermal well loop having a geothermal heat exchanger for heat exchange between the CO₂ refrigerant of the evaporation loop and another refrigerant absorbing heat from the CO₂ refrigerant of the evaporation loop, the geothermal well loop extending to a geothermal well in which the other refrigerant releases heat geothermally.

8. The CO₂ refrigeration system according to claim 1, further comprising a line extending from the evaporation stage to at least one of the CO₂ condensation reservoir and the compression stage of the supracompression loop, to direct the CO₂ refrigerant exiting the evaporation stage thereat.

9. The CO₂ refrigeration system according to any one of claims 1-8, wherein the CO₂ refrigerant in the supra-compression loop is compressed to a transcritical state.

10. A CO₂ refrigeration system comprising a CO₂ condensation exchanger for heat exchange between a supra-compression loop of CO₂ refrigerant and an evaporation loop of CO₂ refrigerant;

the supracompression loop comprising a compression stage in which CO₂ refrigerant having absorbed heat in the condensation exchanger is compressed to at least a supra-compression state, a cooling stage in which the CO₂ refrigerant from the compression stage releases heat, and a pressure-regulating unit in a line extending from the cooling stage to the condensation exchanger to maintain a pressure differential therebetween; and

the evaporation loop in which circulates CO₂ refrigerant having released heat in the condensation exchanger, the evaporation loop comprising a condensation reservoir in which CO₂ refrigerant is accumulated in a liquid state, and an evaporation stage in which the CO₂ refrigerant from the condensation reservoir absorbs heat to cool an ice-playing surface, to then return to one of the condensation reservoir and the condensation exchanger.

11. The CO₂ refrigeration system according to claim 10, wherein the evaporation stage of the evaporation loop comprises a heat exchanger being connected to an ice-playing surface refrigeration circuit in which cycles a second refrigerant, such that the CO₂ refrigerant absorbs heat from the second refrigerant in the heat exchanger.

12. The CO₂ refrigeration system according to claim 10, wherein the evaporation stage of the evaporation loop comprises pipes under the ice-playing surface in which circulates the CO₂ refrigerant to refrigerate the ice-playing surface.

13. The CO₂ refrigeration system according to claim 12, further comprising at least one pump in the evaporation loop to induce a flow of the CO₂ refrigerant in a liquid state in the pipes under the ice-playing surface.

14. The CO₂ refrigeration system according to claim 10, wherein the cooling stage comprises at least one of a gas-cooling unit, a heat-reclaim exchanger, and a heating unit.

15. The CO₂ refrigeration system according to claim 14, comprising a plurality of the heating unit, with valves provided in relation to the plurality of heating unit to individually control an amount of CO₂ refrigerant directed to each said heating unit.

16. The CO₂ refrigeration system according to claim 15, wherein a fan of each said heating unit is controlled by a controller as a function of a temperature demand and of said amount of CO₂ refrigerant.

17. The CO₂ refrigeration system according to claim 10, further comprising a relief system to relieve excess CO₂ refrigerant pressure in the CO₂ refrigeration system, the relief system comprising at least a pair of valves in parallel and opening to an exhaust, with a first of the valves being automatically operable from a first set point pressure to gradually release pressure, and a second one of the valves having a second set point pressure higher than the first set point pressure.

18. The CO₂ refrigeration system according to claim 10, further comprising a geothermal well loop in heat-exchange relation with the evaporation loop, the geothermal well loop having a geothermal heat exchanger for heat exchange between the CO₂ refrigerant of the evaporation loop and another refrigerant absorbing heat from the CO₂

refrigerant of the evaporation loop, the geothermal well loop extending to a geothermal well in which the other refrigerant releases heat geothermally.

19. The CO₂ refrigeration system according to any one of claims 10-18, wherein the CO₂ refrigerant in the supra-compression loop is compressed to a transcritical state.

20. A CO₂ refrigeration system comprising a CO₂ condensation reservoir in which CO₂ refrigerant is accumulated and circulates between a supracompression loop and an evaporation loop;

the supracompression loop comprising a compression stage in which CO₂ refrigerant from at least the CO₂ condensation reservoir is compressed to at least a supra-compression state, a cooling stage in which the CO₂ refrigerant from the compression stage releases heat, and a pressure-regulating unit in a line extending from the cooling stage to the CO₂ condensation reservoir to maintain a pressure differential therebetween;

the evaporation loop comprising an evaporation stage of pipes under an ice-playing surface in which circulates the CO₂ refrigerant to absorb heat to cool an ice-playing surface, to then return to the CO₂ condensation reservoir; and

a geothermal well loop in heat-exchange relation with the CO₂ refrigerant, the geothermal well loop having a geothermal heat exchanger for heat exchange between the CO₂ refrigerant of one of the evaporation loop and the supra-compression loop and another refrigerant absorbing heat from the CO₂ refrigerant, the geothermal well loop extending to a geothermal well in which the other refrigerant releases heat geothermally.

21. The CO₂ refrigeration system according to claim 20, further comprising at least one pump in the evaporation loop to induce a flow of the CO₂ refrigerant in a liquid state in the pipes under the ice-playing surface.

22. The CO₂ refrigeration system according to claim 20, wherein the cooling stage comprises at least one of a gas-cooling unit, a heat-reclaim exchanger, and a heating unit.

23. The CO₂ refrigeration system according to claim 22, comprising a plurality of the heating unit, with valves provided in relation to the plurality of heating unit to individually control an amount of CO₂ refrigerant directed to each said heating unit.

24. The CO₂ refrigeration system according to claim 23, wherein a fan of each said heating unit is controlled by a controller as a function of a temperature demand and of said amount of CO₂ refrigerant.

25. The CO₂ refrigeration system according to claim 20, further comprising a relief system to relieve excess CO₂ refrigerant pressure in the CO₂ refrigeration system, the relief system comprising at least a pair of valves in parallel and opening to an exhaust, with a first of the valves being automatically operable from a first set point pressure to gradually release pressure, and a second one of the valves having a second set point pressure higher than the first set point pressure.

26. The CO₂ refrigeration system according to any one of claims 20-25, wherein the CO₂ refrigerant in the supra-compression loop is compressed to a transcritical state.

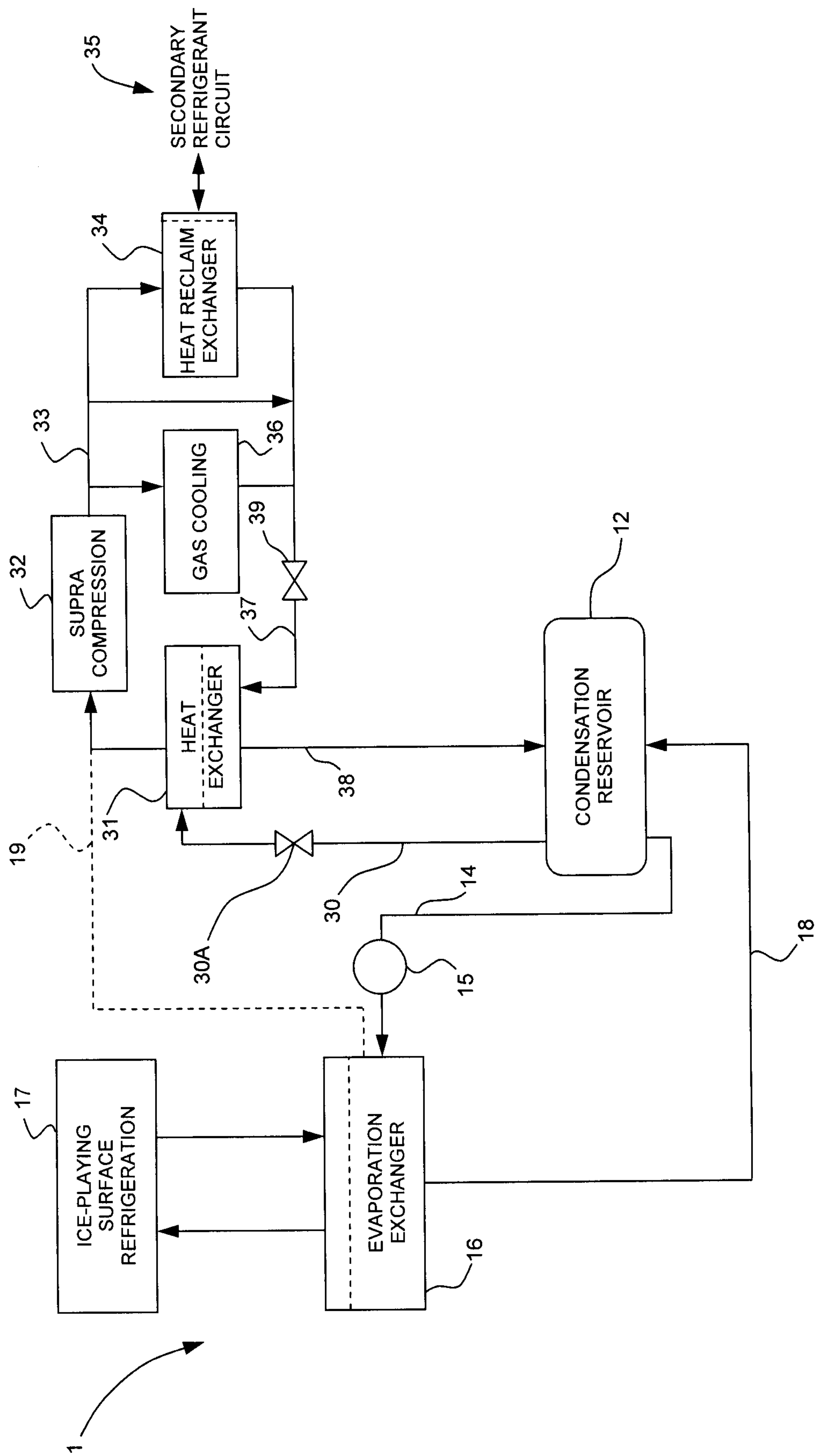


Fig. 1

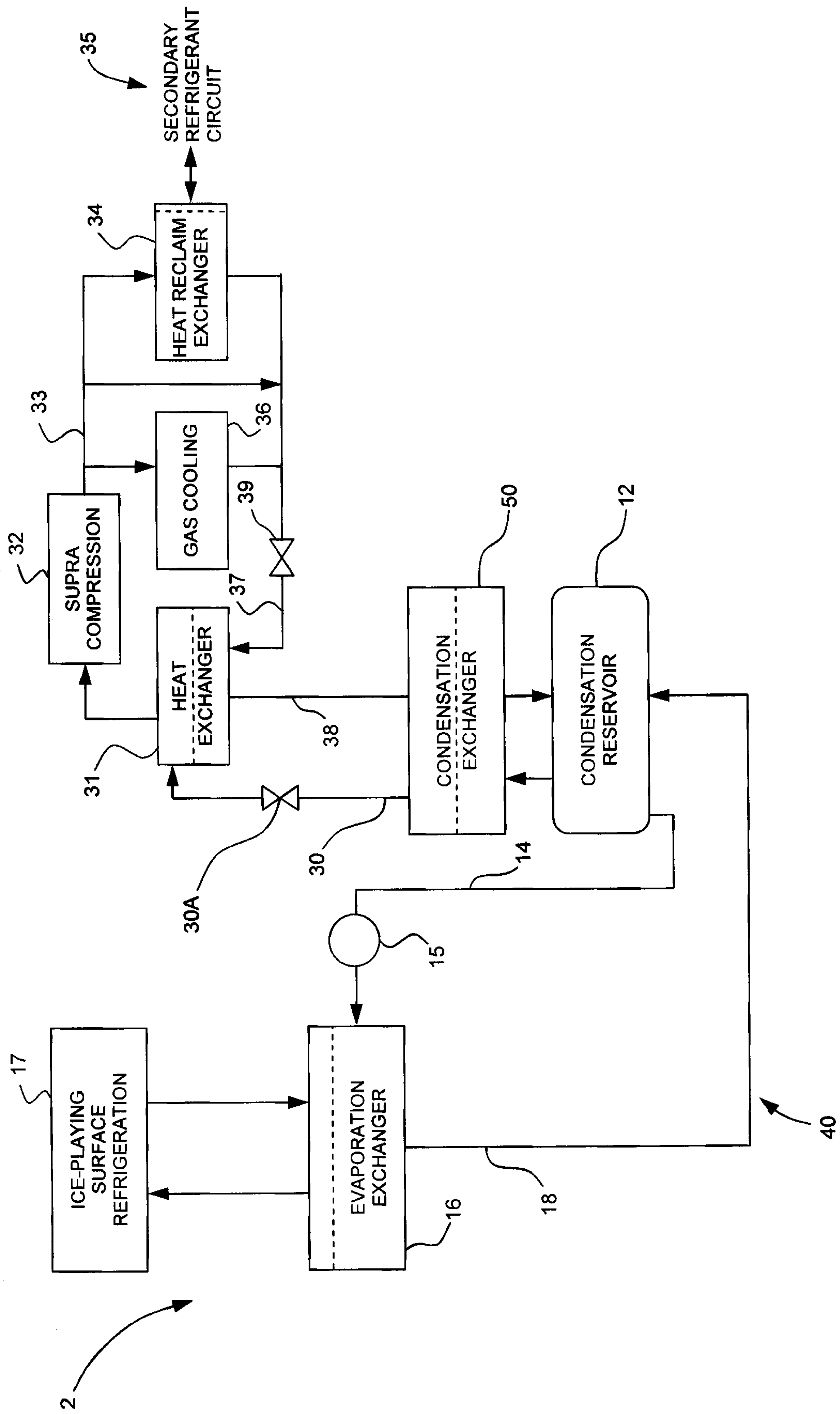


Fig. 2

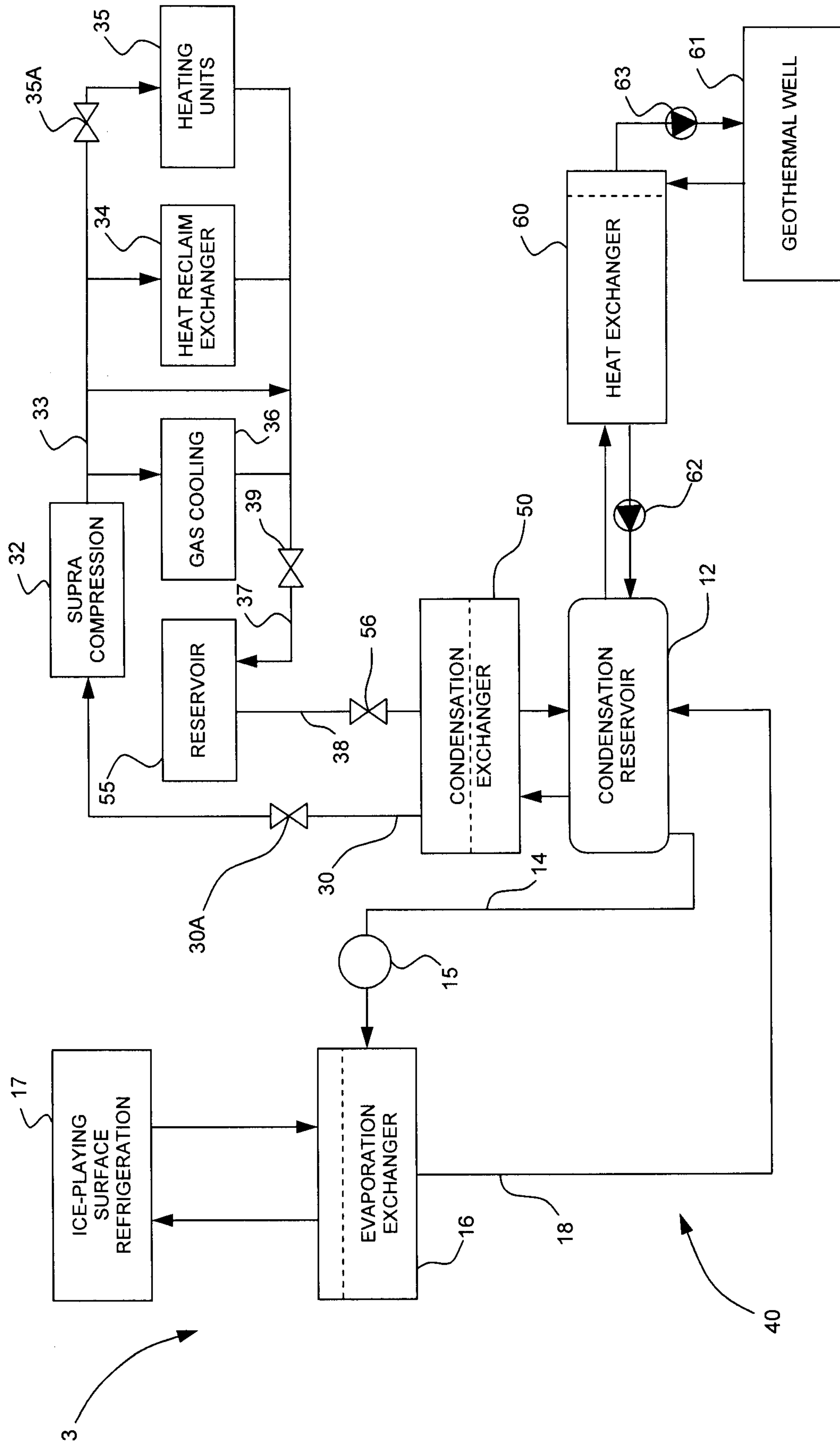


Fig. 3

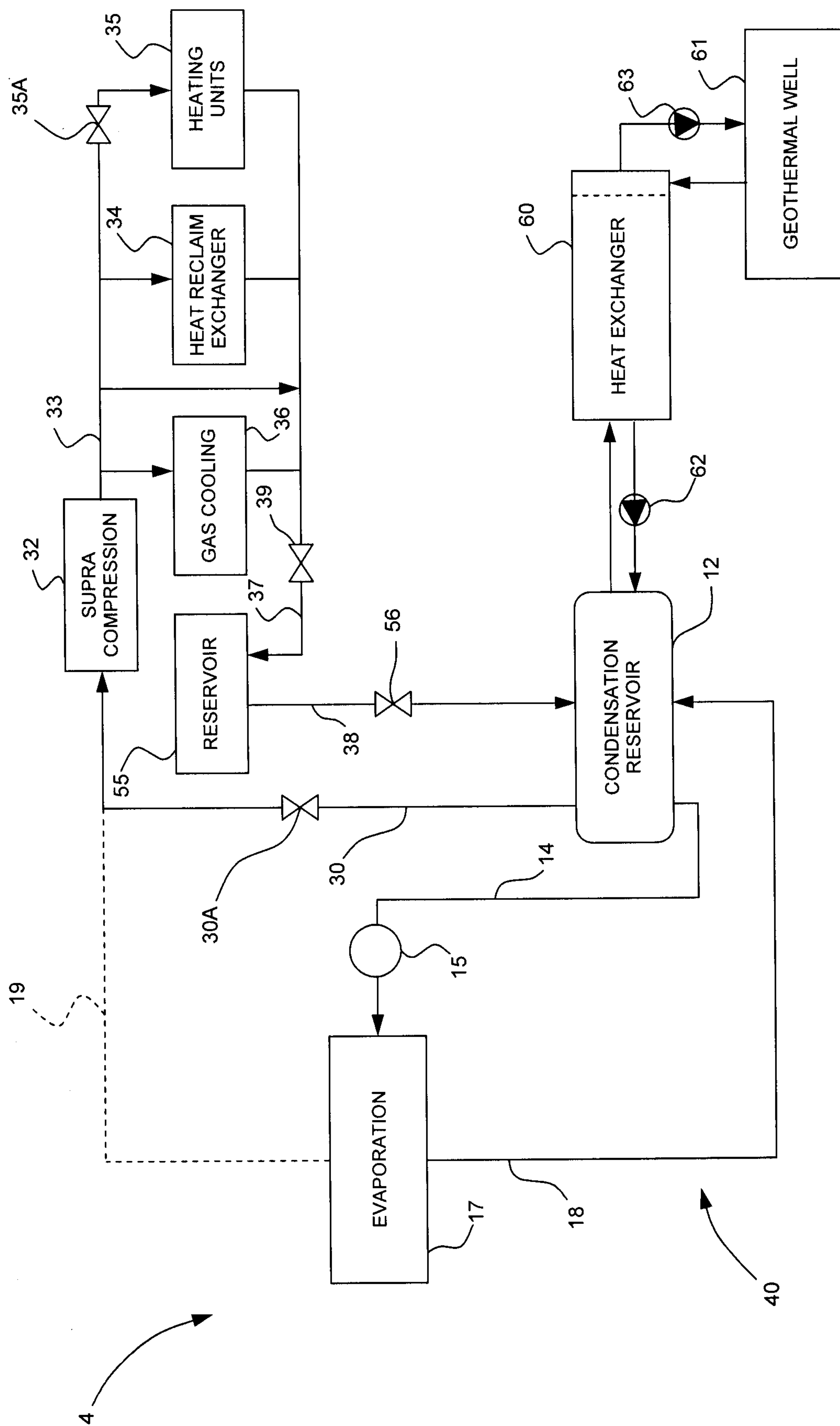


Fig. 4

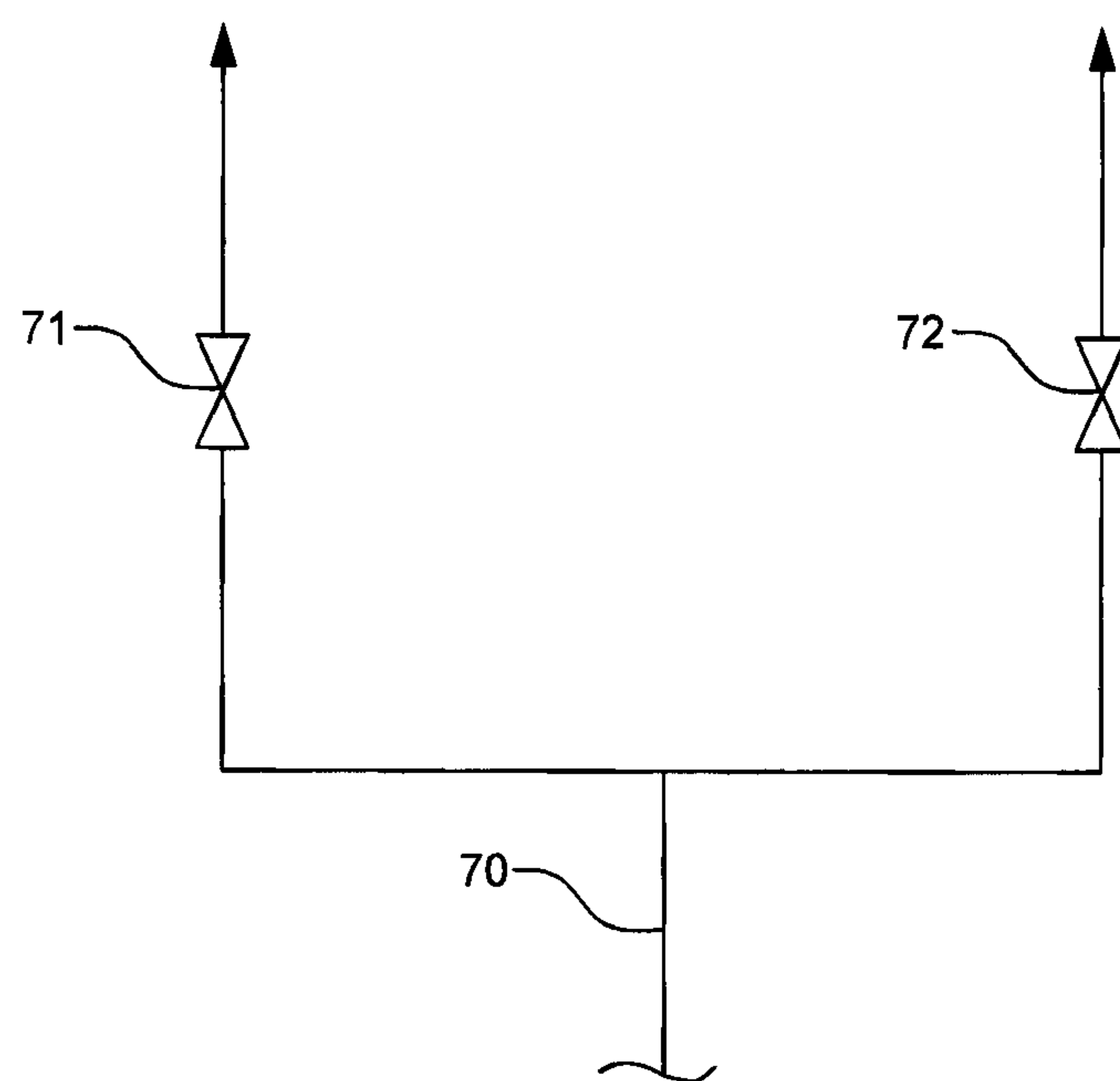


Fig. 5

