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(19) **United States**(12) **Patent Application Publication**
Yin et al.(10) **Pub. No.: US 2008/0302113 A1**(43) **Pub. Date: Dec. 11, 2008**(54) **REFRIGERATION SYSTEM HAVING HEAT PUMP AND MULTIPLE MODES OF OPERATION****Publication Classification**(51) **Int. Cl.****F25B 1/00** (2006.01)**F25B 7/00** (2006.01)**F25B 27/00** (2006.01)**F25D 17/00** (2006.01)(52) **U.S. Cl. 62/115; 62/335; 62/498; 62/238.7; 62/118**(76) Inventors: **Jian-min Yin**, Racine, WI (US); **Michael J. Wilson**, Racine, WI (US); **Stephen B. Memory**, Kenosha, WI (US); **Samuel J. Collier**, Danville, KY (US); **Todd M. Bandhauer**, Avondale Estates, GA (US)

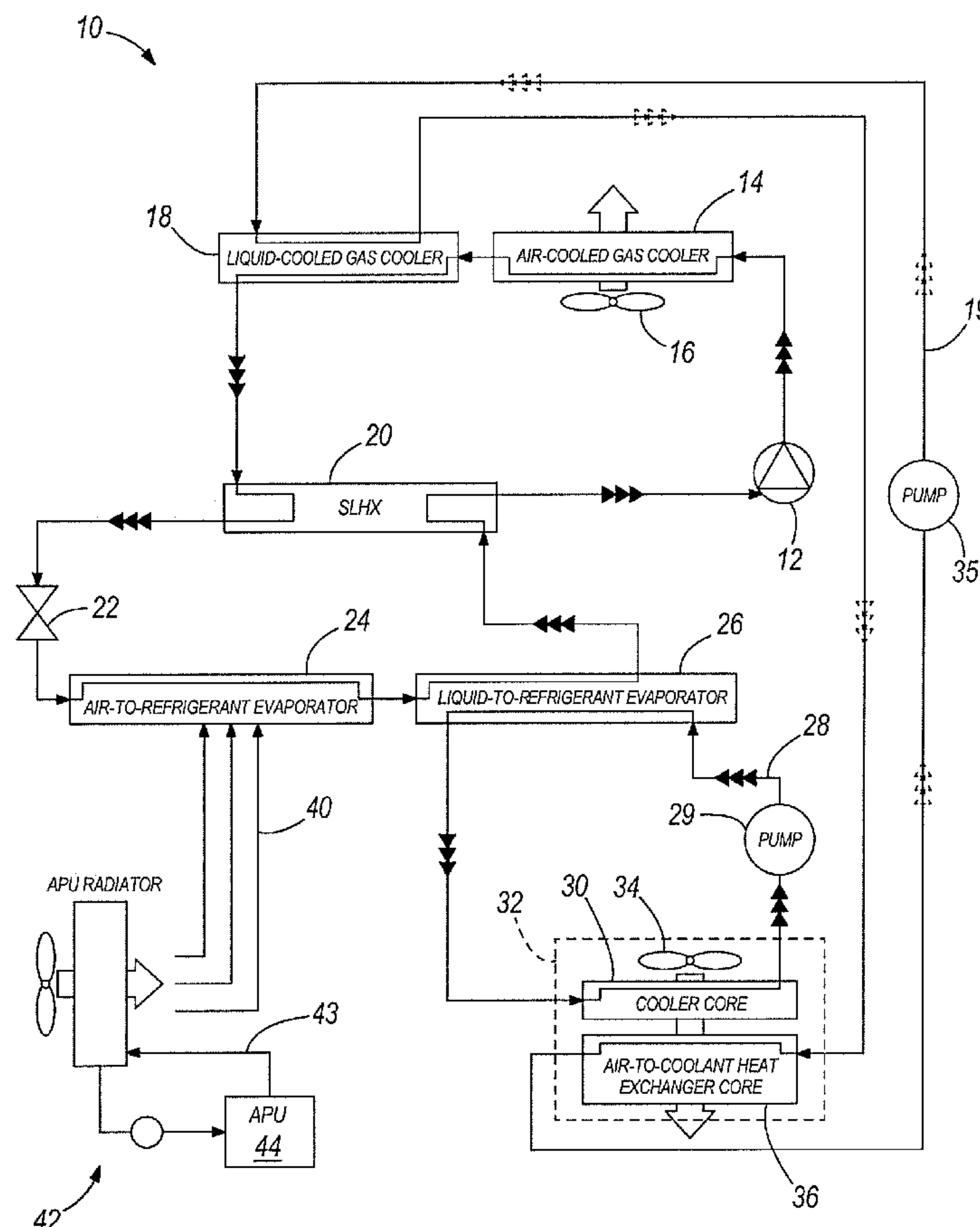
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MILWAUKEE, WI 53202 (US)(21) Appl. No.: **12/134,263**(22) Filed: **Jun. 6, 2008****Related U.S. Application Data**

(60) Provisional application No. 60/933,713, filed on Jun. 8, 2007.

(57) **ABSTRACT**

The present invention provides a refrigeration system including a first refrigerant circuit including a first heat exchanger for transferring heat from refrigerant, a second refrigerant circuit including a second heat exchanger for transferring heat to refrigerant, and a third refrigerant circuit. The third refrigerant circuit includes a compressor, a condenser connected to the first refrigerant circuit such that heat exchange can occur between the refrigerants of the first and refrigerant circuits, an expansion device, and an evaporator connected to the second refrigerant circuit such that heat exchange can occur between the refrigerant of the second and third refrigerant circuits. The refrigerant can travel along the third refrigerant circuit in a common direction during operation in both heating and cooling modes. Refrigerant can be prevented from moving between first, second, and third refrigerant circuits during operation in heating and cooling modes.



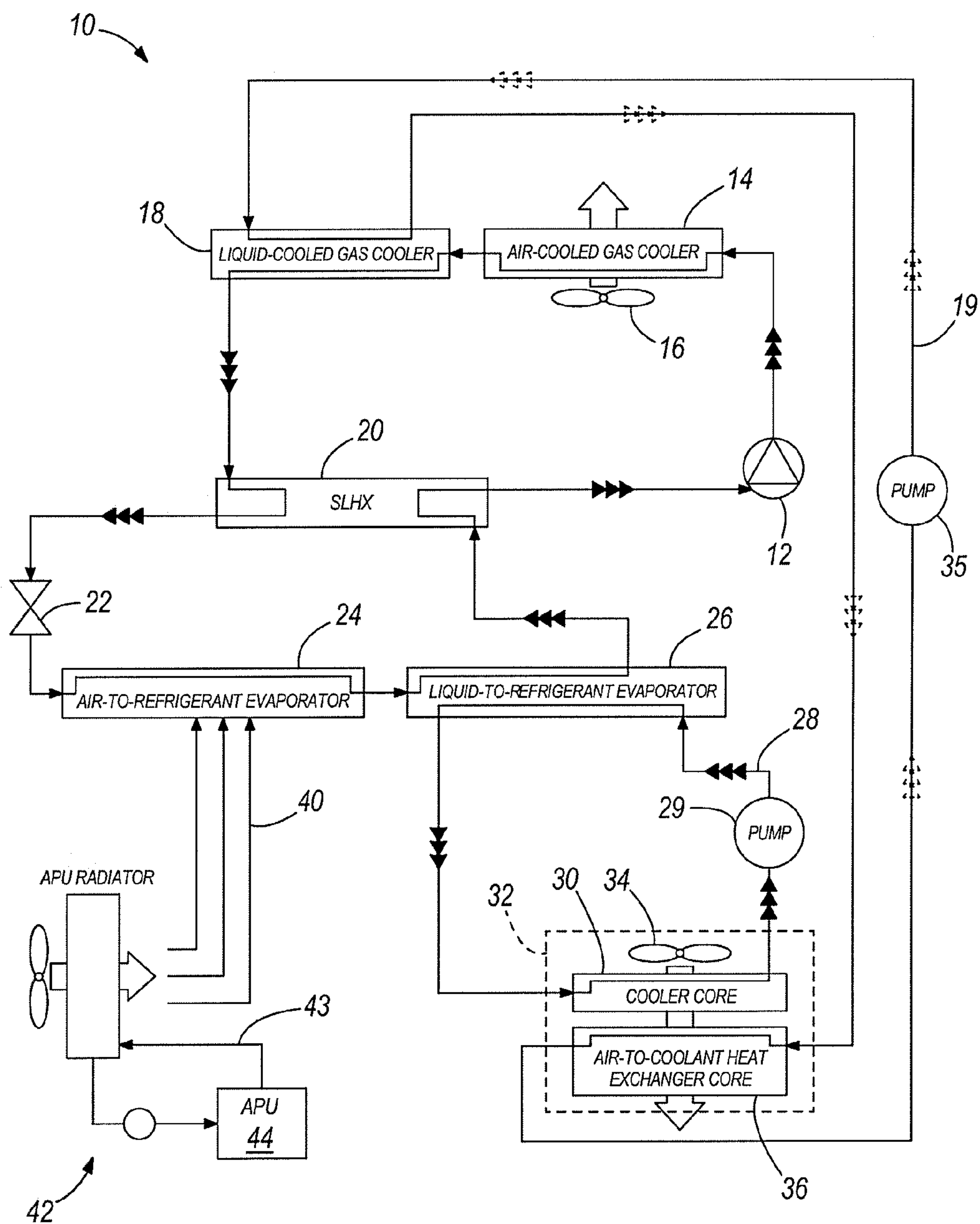


FIG. 1A

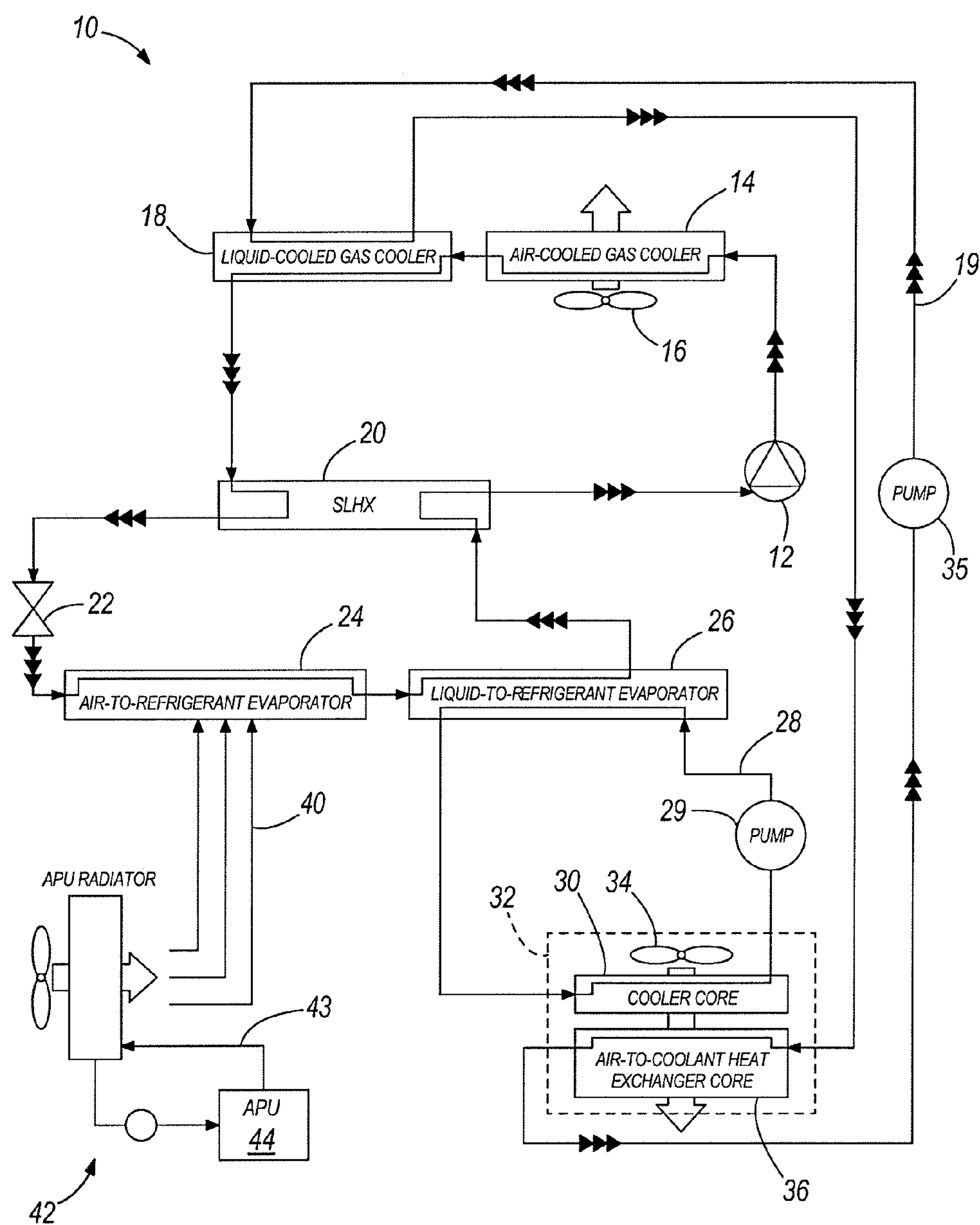


FIG. 1B

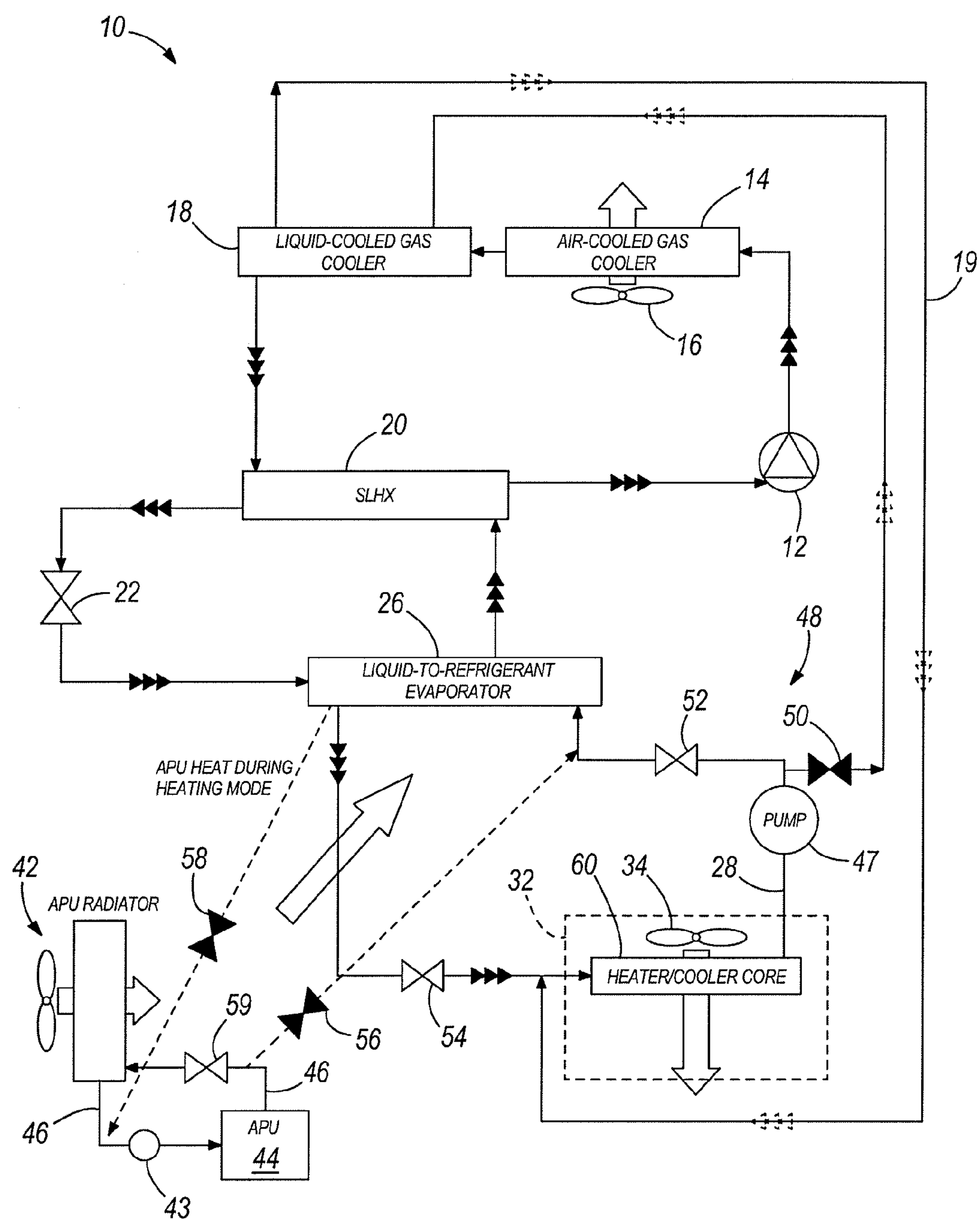


FIG. 2A

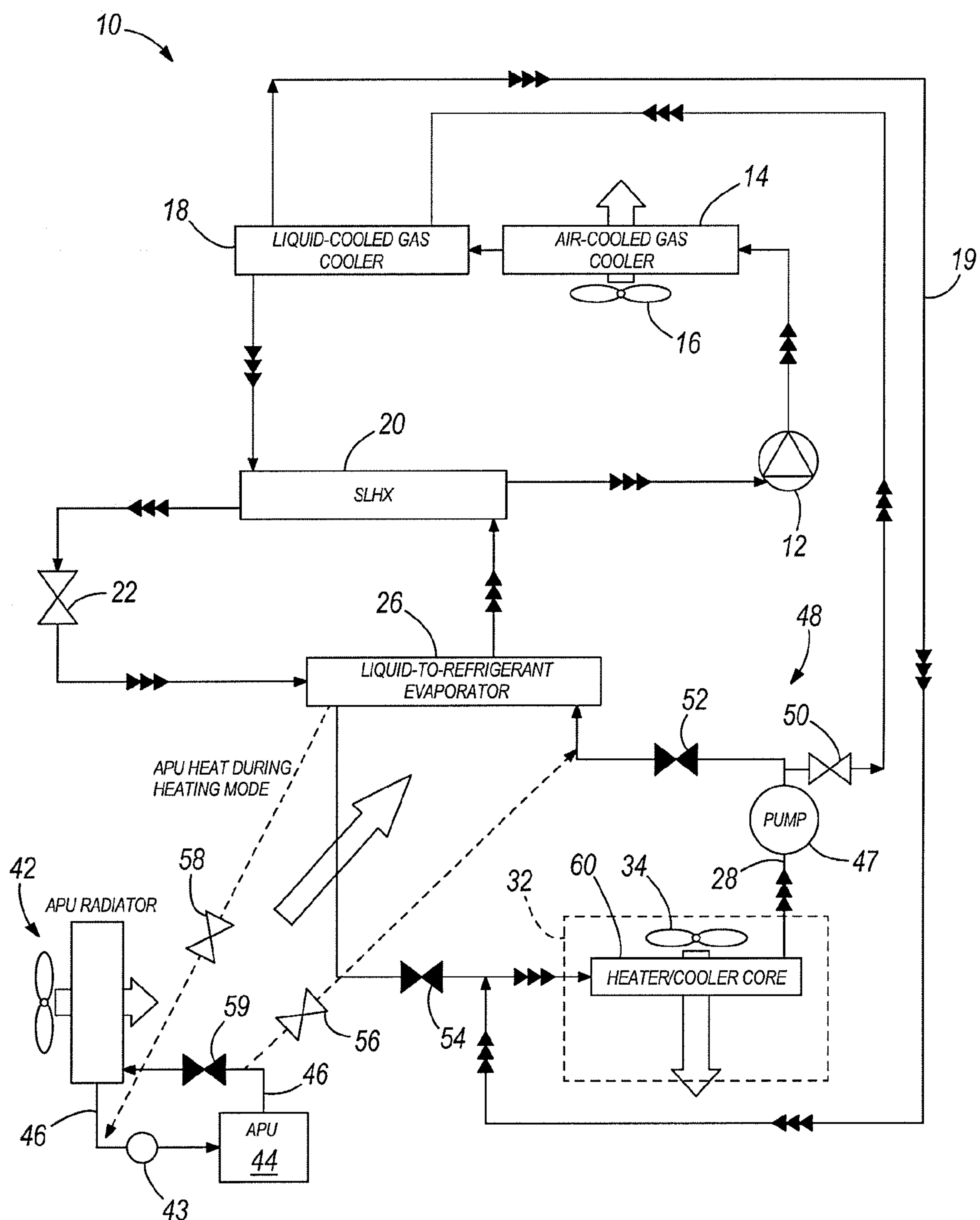


FIG. 2B

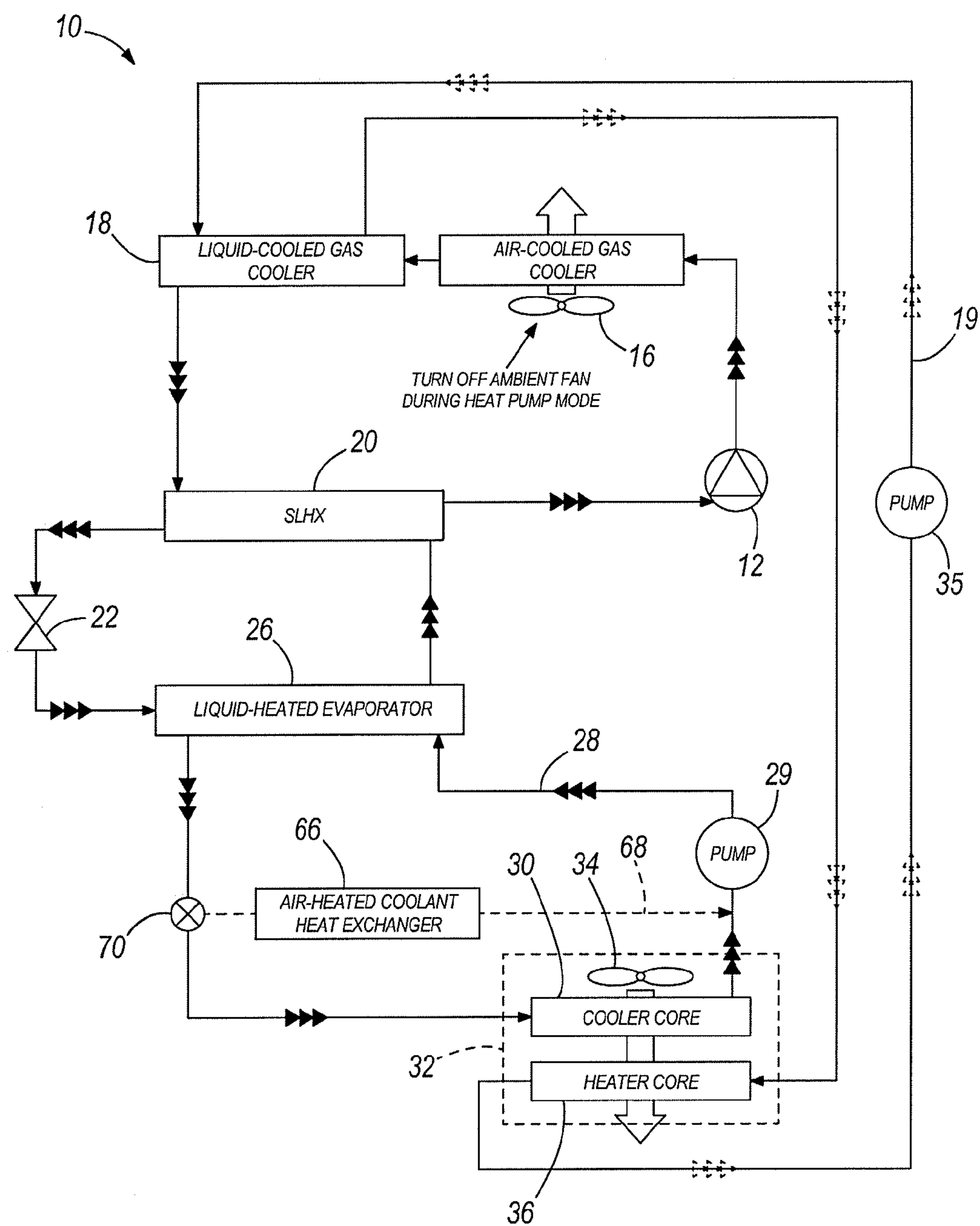


FIG. 3A

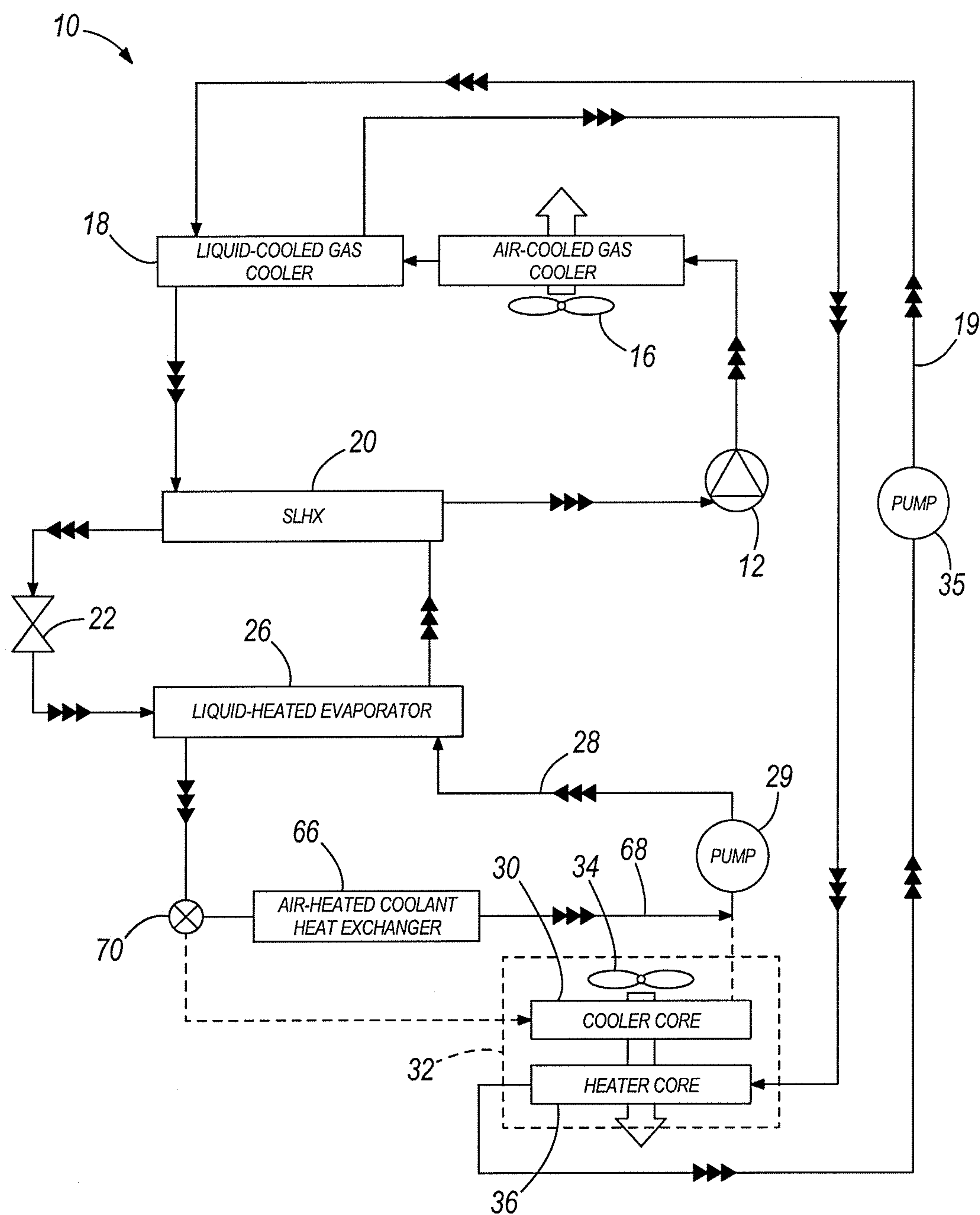


FIG. 3B

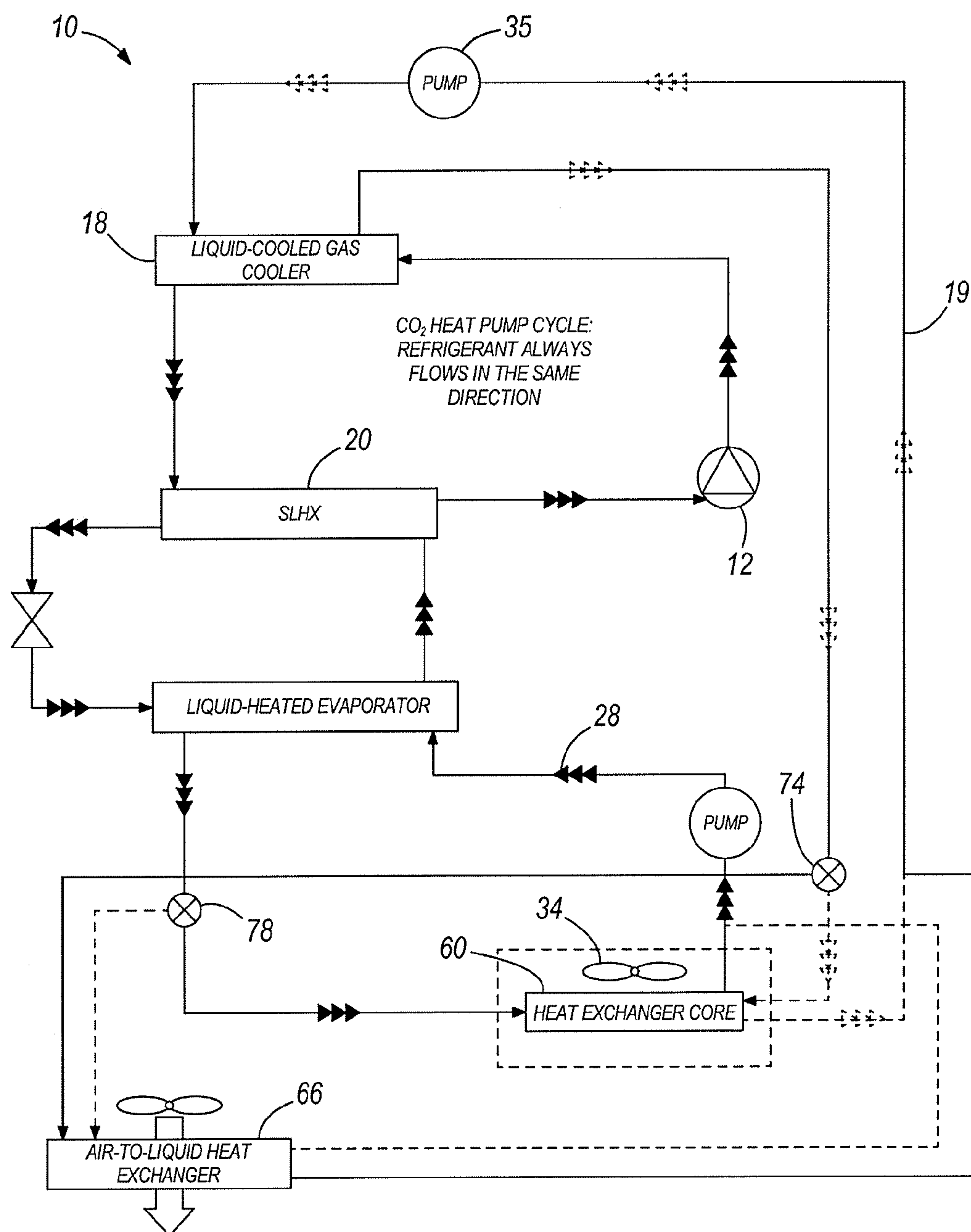


FIG. 4A

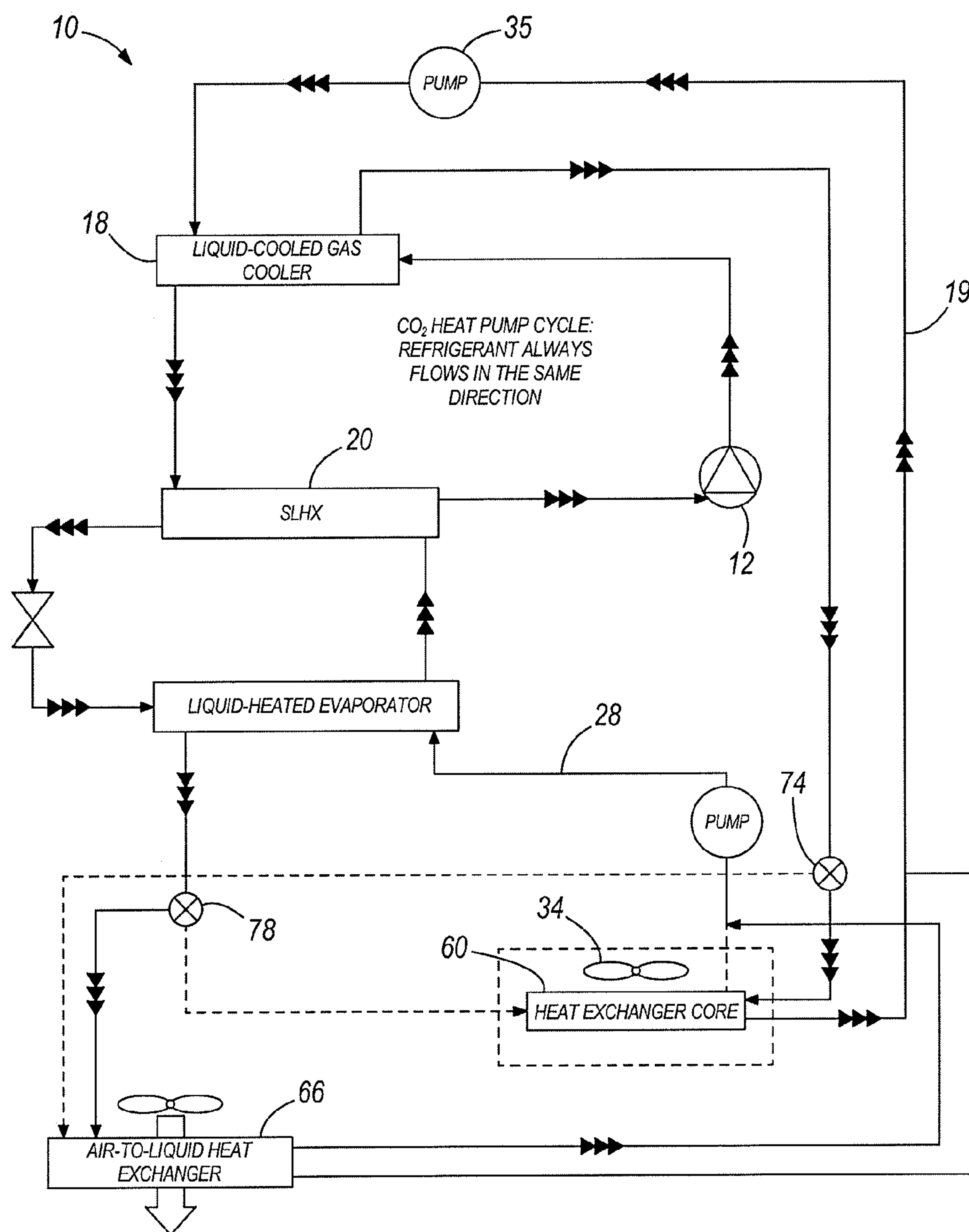


FIG. 4B

REFRIGERATION SYSTEM HAVING HEAT PUMP AND MULTIPLE MODES OF OPERATION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority to U.S. Provisional Patent Application Ser. No. 60/933,713, filed Jun. 8, 2007, the entire contents of which is hereby incorporated by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to a refrigeration system and a method of manufacturing a refrigeration system, and more particularly to a refrigeration system having both an air heating or heat pump mode and an air conditioning or cooling mode.

SUMMARY

[0003] In principal, a CO₂ heat pump system can be switched from a heat pump or heating mode (HP) to air conditioning or cooling (A/C) mode by changing the flow direction in the system cycle so that the A/C mode evaporator operates as a HP mode gas cooler, and the A/C mode gas cooler operates as an HP mode evaporator. However, there are some practical limitations to this method, which include, but are not limited to, the need for valves able to accommodate high pressure CO₂, appropriately sized accumulators, and heat exchangers in such a system able to withstand higher system pressures for a fully-reversible system.

[0004] In accordance with one feature of the present invention, a refrigeration system is provided that can be operated in both HP and A/C modes without changing the general direction of refrigerant flow through the system. This is done by employing two secondary coolant loops, and adding additional heat exchangers. One desirable application for this system is the cabin heating and cooling required for truck idle-off. In some embodiments, CO₂ can be used as a refrigerant in at least one refrigerant circuit.

[0005] In some embodiments, the invention provides a refrigeration system having both a heating mode for providing heat to a load space and a cooling mode for removing heat from the load space. The system can include a first refrigerant circuit including a first heat exchanger for transferring heat from refrigerant of the first refrigerant circuit to air, a second refrigerant circuit including a second heat exchanger for transferring heat from air to refrigerant of the second refrigerant circuit, and a third refrigerant circuit. The third refrigerant circuit can include a compressor for increasing pressure of refrigerant of the third refrigerant circuit, a condenser connected to the compressor for receiving refrigerant from the compressor and connected to the first refrigerant circuit such that heat exchange can occur between the refrigerant traveling through the first refrigerant circuit and the refrigerant traveling through the third refrigerant circuit, an expansion device for reducing the pressure of the refrigerant of the third refrigerant circuit, and an evaporator connected to the expansion device and connected to the second refrigerant circuit such that heat exchange can occur between the refrigerant traveling through the second refrigerant circuit and the refrigerant traveling through the third refrigerant circuit. The refrigerant can travel along the third refrigerant circuit in a common direction during operation in both the heating mode

and the cooling mode. The refrigerant can be prevented from moving between the first refrigerant circuit, the second refrigerant circuit, and the third refrigerant circuit during operation in the heating and cooling modes.

[0006] In some embodiments, the present invention provides a refrigeration system having both a heating mode for providing heat to a load space and a cooling mode for removing heat from the load space. The refrigeration system can include a first refrigerant circuit extending between a compressor, an evaporator, an expansion device, and a condenser. The first refrigerant circuit can define a flow path for a refrigerant traveling in a direction along the refrigerant circuit during operation of the refrigeration system in the heating mode and the cooling mode. The refrigeration system can also include a second refrigerant circuit extending between the condenser and a heat exchanger, the second refrigerant circuit including a first refrigerant pump, and a third refrigerant circuit extending between the evaporator and the heat exchanger. The third refrigerant circuit can include a second refrigerant pump. The second refrigerant pump can be operational during operation in the heating mode and can be idle during operation in the cooling mode.

[0007] The present invention also provides a method of operating a refrigeration system. The method can include the acts of directing a refrigerant along a refrigerant circuit in a direction between a compressor, an evaporator, an expansion device, and a condenser during operation of the refrigeration system in a cooling mode, operating a first pump when the refrigeration system is operating in the cooling mode to circulate refrigerant through a heat exchanger, and transferring heat from a load space to the refrigerant in the refrigerant circuit when the refrigeration system is operating in the cooling mode. The method can also include the acts of stopping the first pump when the refrigeration system is operating in a heating mode, directing the refrigerant along the refrigerant circuit in the direction during operation of the refrigeration system in the heating mode, operating a second pump when the refrigeration system is operating in the heating mode to circulate refrigerant through the heat exchanger in heat exchange relation with the refrigerant of the refrigerant circuit, and transferring heat to the load space from the refrigerant in the refrigerant circuit when the refrigeration system is operating in the heating mode.

[0008] Other aspects of the invention will become apparent by consideration of the detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1A is a schematic illustrating a refrigeration system according to some embodiments of the present invention and showing the refrigeration system operating in a cooling mode.

[0010] FIG. 1B is a schematic illustrating the refrigeration system of FIG. 1A and showing the refrigeration system operating in a heating mode.

[0011] FIG. 2A is a schematic illustrating a refrigeration system according to an alternate embodiment of the present invention and showing the refrigeration system operating in a cooling mode.

[0012] FIG. 2B is a schematic illustrating the refrigeration system of FIG. 2A and showing the refrigeration system operating in a heating mode.

[0013] FIG. 3A is a schematic illustrating a refrigeration system according to another alternate embodiment of the present invention and showing the refrigeration system operating in a cooling mode.

[0014] FIG. 3B is a schematic illustrating the refrigeration system of FIG. 3A and showing the refrigeration system operating in a heating mode.

[0015] FIG. 4A is a schematic illustrating a refrigeration system according to a yet another alternate embodiment of the present invention and showing the refrigeration system operating in a cooling mode.

[0016] FIG. 4B is a schematic illustrating the refrigeration system of FIG. 4A and showing the refrigeration system operating in a heating mode.

DETAILED DESCRIPTION

[0017] Before any embodiments of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The invention is capable of other embodiments and of being practiced or of being carried out in various ways. Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. The use of “including,” “comprising,” or “having” and variations thereof herein is meant to encompass the items listed thereafter and equivalents thereof as well as additional items.

[0018] Unless specified or limited otherwise, the terms “mounted,” “connected,” “supported,” and “coupled” and variations thereof are used broadly and encompass both direct and indirect mountings, connections, supports, and couplings. Further, “connected” and “coupled” are not restricted to physical or mechanical connections or couplings.

[0019] Also, it is to be understood that phraseology and terminology used herein with reference to device or element orientation (such as, for example, terms like “central,” “upper,” “lower,” “front,” “rear,” and the like) are only used to simplify description of the present invention, and do not alone indicate or imply that the device or element referred to must have a particular orientation. In addition, terms such as “first,” “second,” and “third” are used herein for purposes of description and are not intended to indicate or imply relative importance or significance.

[0020] FIGS. 1A and 1B show a schematic illustrating a refrigeration system 10 according to some embodiments of the present invention. During operation in an air conditioning or cooling (A/C) mode, refrigerant, such as, for example, CO₂, leaves a compressor 12 and enters a first evaporator, which, in the illustrated embodiment of FIGS. 1A and 1B, is an air-cooled gas cooler 14. In the embodiment shown in FIG. 1A, the flow of refrigerant is shown by three solid arrows. Depending on one or more of the operating conditions, the anticipated heating or cooling load, and the type of refrigerant employed, the refrigerant may exit the compressor in a supercritical state. While reference is made herein to the use of CO₂ as a refrigerant, in some embodiments, other refrigerants, including, but not limited to, water, R12, engine coolant, any other organic refrigerant, R245fa, glycol, air, and the like can also or alternatively be used. As shown in FIG. 1A, a fan 16 can be positioned adjacent to or along an airflow path opening onto the air-cooled gas cooler 14 to reject heat from the gas

cooler 14 to the ambient environment via transfer of heat from the refrigerant to an ambient air flow provided by the fan 16.

[0021] The refrigerant can then enter a second evaporator, which, in the illustrated embodiment of FIG. 1A, is a liquid-cooled gas cooler 18 that is cooled by a secondary, high temperature coolant loop 19. In the illustrated embodiment of FIG. 1A, liquid coolant flows through the loop 19 during A/C operation (possibly at a lower mass flow rate than refrigerant from the air-cooled gas cooler 14) to further reduce the temperature of the refrigerant, however, compared to the air-cooled gas cooler 14, the heat load of the liquid-cooled gas cooler 18 can be small. In other embodiments, the heat load of the liquid-cooled gas cooler 18 can be substantially equal to or larger than the heat load experienced by the air-cooled gas cooler 14, depending upon one or more of the relative sizes and cooling capacities of the air-cooled gas cooler 14 and the liquid-cooled gas cooler 18, the mass flow rates of refrigerant and coolant flows through and across the air-cooled gas cooler 14 and the liquid-cooled gas cooler 18, the presence or absence of a fan 16 for the air-cooled gas cooler 14, and the types and cooling capacities of the coolants used in the air-cooled gas cooler 14 and the liquid-cooled gas cooler 18.

[0022] As shown in FIG. 1A, from the liquid-cooled gas cooler, the refrigerant can enter the high pressure side of a suction line heat exchanger (SLHX) 20 for more cooling before going through an expansion device or valve 22. After the refrigerant exits the expansion valve 22, the refrigerant can enter an air-to-refrigerant evaporator 24. A fan (not shown) can be positioned adjacent to or along an airflow path opening onto the evaporator 24. In some embodiments, the fan can be turned off during periods of reduced cooling demand and/or to limit power consumption and improve efficiency of the refrigeration system 10. In embodiments in which the fan can be turned off or operated at a reduced speed, the heat duty of the evaporator 24 can be limited to far less than the heat duty of a liquid-to-refrigerant evaporator 26 that receives the refrigerant from the heat exchanger 24.

[0023] In the liquid-to-refrigerant evaporator 26, the refrigerant can evaporate, receiving heat energy from and thereby cooling down a coolant (e.g., glycol, water, R12, engine coolant, any organic refrigerant, R245fa, air, and the like) flowing through the liquid-to-refrigerant evaporator 26 from another secondary, low temperature coolant loop 28. It should be noted that the air-heated evaporator 24 can be placed either upstream or downstream of the liquid-heated evaporator 24 with respect to the flow of the refrigerant. The same can be said of the liquid-cooled gas cooler 18 with respect to the air-cooled gas cooler 14. However, it can be desirable to avoid excess heating and/or boiling of the slow moving or stagnant liquid in the liquid-cooled gas cooler 18 during operation of the refrigeration system 10 in the A/C mode.

[0024] After traveling through the evaporator 26, the refrigerant can reject heat to the high pressure refrigerant in the SLHX 20. An accumulator (not shown in FIGS. 1A-2B) can be positioned upstream of the SLHX 20 on the low-pressure-side. This accumulator can be a separate unit, or alternatively, can be directly integrated with the SLHX 20.

[0025] In addition to the liquid-refrigerant evaporator 26, the low temperature coolant loop 28 can include a pump 29 for moving liquid coolant through the liquid side of the evaporator 26. While heat from the coolant is transferred to the refrigerant in the evaporator 26, a heat exchanger cooler core 30, which can be mounted in an inside space 32, such as, for example, the cabin of a truck or another vehicle, can operate

to transfer heat away from the low temperature coolant in the coolant loop 28. The cooler core 30 can be accompanied by an air mover 34, such as a fan or blower, and can cool down the air inside the space 32 and/or remove humidity from the air in the space 32. In some embodiments, if the air stream through or across the heat exchanger 30 is cooled below the dew point, a small amount of liquid coolant can be circulated through the hot coolant loop 19 to reheat the air entering the cabin (as shown by three dashed arrows).

[0026] FIG. 1B shows a schematic illustrating the refrigeration system 10 during operation in the heating (HP) mode. As shown by three solid arrows, the refrigerant flows through the system 10 in the same direction as described above with respect to operation in the A/C mode. However, the fan 16 adjacent to the air-cooled gas cooler 14 is deactivated and high temperature liquid coolant is pumped through the high temperature coolant loop 19 by a pump 35 to provide cooling to the refrigerant in the liquid-cooled gas cooler 18. In the cold temperature loop 28, the cold pump 29 is turned off and the air-to-refrigerant fan 34 can be activated. This allows for additional heating inside of the space 32 by the transfer of heat from the high temperature coolant to the air flow in an air-to-coolant heat exchanger heater core 36. To increase the coefficient of performance (COP) of the system 10 while operating in HP mode during cold weather, a waste heat air stream 40 from a waste heat source 42, such as a cooling system 43 for an auxiliary power unit 44 can be routed through the air-to-refrigerant evaporator 24.

[0027] In other embodiments, the waste heat source 42 and/or a different waste heat source 42 can also or alternatively provide heat to a liquid-to-liquid heat exchanger evaporator or an integrated auxiliary power unit (APU) stack cooler and evaporator coolant loop. In the latter-case, the waste heat source 42 can remove the need for an extra air-heated evaporator, and the “cooler” core can add heat to the space air.

[0028] FIGS. 2A and 2B illustrate an alternate embodiment of a refrigeration system 10 according to the present invention. The refrigeration system shown in FIGS. 2A and 2B is similar in many ways to the illustrated embodiments of FIGS. 1A and 1B described above. Accordingly, with the exception of mutually inconsistent features and elements between the embodiment of FIGS. 2A and 2B and the embodiments of FIGS. 1A and 1B, reference is hereby made to the description above accompanying the embodiments of FIGS. 1A and 1B for a more complete description of the features and elements (and the alternatives to the features and elements) of the embodiment of FIGS. 2A and 2B.

[0029] FIG. 2A illustrates a simpler version of the refrigeration system 10. In this embodiment of the refrigeration system 10, the low temperature fluid loop 28, the high temperature loop 19, and the coolant lines 46 of an APU coolant system 43 are directly plumbed into each other, and only one liquid pump 47 (not including the APU coolant loop pump) is required for the loops 19 and 28.

[0030] As shown in FIG. 2A, a matrix 48 of liquid valves 50, 52, 54, 56, 58 and 59 can be used to direct the coolant flows to the desired location during HP and A/C modes. This allows for the elimination of the air-to-refrigerant evaporator 24, and for the functions of the cooler and heater cores 30 and 36 to be combined in one heat exchanger in the form of a heater/cooler core 60.

[0031] For example, during operation in A/C mode, by opening valve 59 (shown unshaded), closing valves 56 and 58 (shown in solid), opening valves 52 and 54, and closing valve

50, the APU coolant will not enter the low temperature loop 28 (which is heating the evaporator 26), and no coolant will pass to the liquid-cooled gas cooler 18 via the high temperature loop 19, while the coolant in the low temperature loop 28 rejects heat to the refrigerant in the evaporator 26 and receives heat from the air stream passing through the heater/cooler core 60. In some applications, it may be desirable for a small amount of cold liquid to pass through the valve 50 and the liquid-cooled gas cooler 18. This can allow the refrigerant temperature to fall below the ambient temperature, thus potentially improving system COP.

[0032] As shown in FIG. 2B, in HP mode, by closing or modulating the valve 59 (now shown in solid), opening the valves 56 and 58 (now shown unshaded), closing the valves 52 and 54 and opening the valve 50, the APU coolant can be directed to the liquid-to-refrigerant evaporator 26, and then circulated directly back to the APU 44 without passing through the combined heater/cooler core 60, while the coolant in the high temperature loop 19 is circulated through the liquid-cooled gas cooler 18 to receive heat from the refrigerant and then through the heater/cooler core 60 to reject heat to the air stream passing therethrough.

[0033] FIGS. 3A and 3B illustrate an alternate embodiment of a refrigeration system 10 according to the present invention. The refrigeration system shown in FIGS. 3A and 3B is similar in many ways to the illustrated embodiments of FIGS. 1A-2B described above. Accordingly, with the exception of mutually inconsistent features and elements between the embodiment of FIGS. 3A and 3B and the embodiments of FIGS. 1A-2B, reference is hereby made to the description above accompanying the embodiments of FIGS. 1A-2B for a more complete description of the features and elements (and the alternatives to the features and elements) of the embodiment of FIGS. 3A and 3B.

[0034] The refrigeration system 10 of FIGS. 3A and 3B differs from that of FIGS. 1A and 1B in that the air-to-refrigerant evaporator 24 has been eliminated and replaced with an air-heated coolant heat exchanger 66 that has been added to a bypass line 68 in the low temperature fluid loop 28, with a three-way valve 70 (or series of two-way valves) controlling the flow of coolant through the cooler core 30 and the ambient air-heated coolant heat exchanger 66.

[0035] As shown in FIG. 3A, during operation in the A/C mode, the valve 70 can direct coolant through the cooler core 30, rather than the heat exchanger 66, so that the coolant flowing in the low temperature loop 28 can absorb heat from the air flow passing through the cooler core 30. The operation of the high temperature loop can be substantially similar to the version of the system 10 in FIGS. 1A and 1B. It should be appreciated that the heat exchanger 66 could be replaced by any other type of heat exchanger that would utilize any other heat source, such as, for example, a liquid waste heat stream from a generator.

[0036] As shown in FIG. 3B, during operation in the HP mode, the valve 70 is used to direct the coolant through the heat exchanger 66, rather than through the cooler core 30, so that heat from the ambient air passing through the heat exchanger 66 is transferred to the coolant flowing in the low temperature loop 28.

[0037] FIGS. 4A and 4B illustrate an alternate embodiment of a refrigeration system 10 according to the present invention. The refrigeration system shown in FIGS. 4A and 4B is similar in many ways to the illustrated embodiments of FIGS. 1A-3B described above. Accordingly, with the exception of

mutually inconsistent features and elements between the embodiment of FIGS. 4A and 4B and the embodiments of FIGS. 1A-3B, reference is hereby made to the description above accompanying the embodiments of FIGS. 1A-3B for a more complete description of the features and elements (and the alternatives to the features and elements) of the embodiment of FIGS. 4A and 4B.

[0038] As shown in FIGS. 4A and 4B, this system 10 differs from that of FIGS. 1A and 1B in that the liquid-cooled gas cooler 14 and the air-to-refrigerant evaporator 24 have both been eliminated, the functions of the cooler and heater cores 30 and 36 are combined in a heater/cooler core 60 such as discussed in connection with FIGS. 2A and 2B, and an air-heated coolant heat exchanger 66, such as discussed in connection with FIGS. 3A and 3B, has been plumbed into both the high temperature loop 19 and the low temperature loop 28 with a three-way valve 74 (or series of two-way valves) provided in the high temperature loop 19 and a three-way valve 78 provided in the low temperature loop 28 to control the coolant flow in both of the loops 19 and 20 through the heat exchangers 60 and 66.

[0039] As shown in FIG. 4A, during operation in the A/C mode, the valve 78 directs the coolant in the low temperature loop 19 through the core 60, rather than through the heat exchanger 66, to remove heat from the cabin 32, and the valve 74 directs the coolant from the high temperature loop 19 through the heat exchanger 66, rather than the core 60, to reject heat absorbed by the coolant from the gas cooler 18 to the ambient air flow through the heat exchanger 66.

[0040] As shown in FIG. 4B, during operation in the HP mode, the coolant in the high temperature loop 19 is directed by the valve 74 through the heater/cooler core 60, rather than through the heat exchanger 66, while the valve 78 in the low temperature loop 28 directs coolant through the heat exchanger 66, rather than the heater/cooler core 60, so as to absorb heat from the ambient air flowing through the heat exchanger 68.

[0041] The embodiments described above and illustrated in the figures are presented by way of example only and are not intended as a limitation upon the concepts and principles of the present invention. As such, it will be appreciated by one having ordinary skill in the art that various changes are possible.

1. A refrigeration system having both a heating mode for providing heat to a load space and a cooling mode for removing heat from the load space, the system comprising:

- a first refrigerant circuit including a first heat exchanger for transferring heat from refrigerant of the first refrigerant circuit to air;
- a second refrigerant circuit including a second heat exchanger for transferring heat from air to refrigerant of the second refrigerant circuit; and
- a third refrigerant circuit including:
 - a compressor for increasing pressure of refrigerant of the third refrigerant circuit;
 - a third heat exchanger connected to the compressor for receiving refrigerant from the compressor, and connected to the first refrigerant circuit such that heat exchange can occur between the refrigerant traveling through the first refrigerant circuit and the refrigerant traveling through the third refrigerant circuit;
 - an expansion device for reducing the pressure of the refrigerant of the third refrigerant circuit; and

an evaporator connected to the expansion device, and connected to the second refrigerant circuit such that heat exchange can occur between the refrigerant traveling through the second refrigerant circuit and the refrigerant traveling through the third refrigerant circuit, the refrigerant traveling along the third refrigerant circuit in a common direction during operation in both the heating mode and the cooling mode;

wherein refrigerant is prevented from moving between the first refrigerant circuit, the second refrigerant circuit, and the third refrigerant circuit during operation in the heating and cooling modes.

2. The refrigeration system of claim 1, wherein the third heat exchanger is a liquid-cooled gas cooler.

3. The refrigeration system of claim 2, further comprising an air-cooled gas cooler connected in series with the liquid-cooled gas cooler and to at least one of the compressor and the expansion device.

4. The refrigeration system of claim 1, wherein the evaporator is a liquid-heated evaporator.

5. The refrigeration system of claim 4, further comprising an air-heated evaporator connected in series with the liquid heated evaporator and to at least one of the expansion device and the compressor.

6. The refrigeration system of claim 1, further comprising a suction line heat exchanger connected to the third heat exchanger, the expansion valve, the evaporator, and the compressor along the third refrigerant circuit.

7. The refrigeration system of claim 1, wherein the refrigerant of the third refrigerant circuit is carbon dioxide.

8. The refrigeration system of claim 1, wherein the first heat exchanger and the second heat exchanger are combined in a single heat exchanger.

9. The refrigeration system of claim 1, further comprising a heat source separate from the first, second, and third refrigerant circuits for providing heat to the refrigeration system during operation in the heating mode.

10. A refrigeration system having both a heating mode for providing heat to a load space and a cooling mode for removing heat from the load space, the refrigeration system comprising:

- a first refrigerant circuit extending between a compressor, an evaporator, an expansion device, and a first heat exchanger, the first refrigerant circuit defining a flow path for a refrigerant traveling in a direction along the refrigerant circuit during operation of the refrigeration system in the heating mode and the cooling mode;
- a second refrigerant circuit extending between the condenser and a second heat exchanger, the second refrigerant circuit including a first refrigerant pump; and
- a third refrigerant circuit extending between the evaporator and the second heat exchanger, the third refrigerant circuit including a second refrigerant pump, the second refrigerant pump being operational during operation in the heating mode and being idle during operation in the cooling mode.

11. The refrigeration system of claim 10, wherein the second refrigerant circuit is separated from the first refrigerant circuit such that refrigerant is prevented from moving between the first and second refrigerant circuits, the second refrigerant circuit extending through the first heat exchanger such that heat exchange can occur between the refrigerant traveling through the first refrigerant circuit and a refrigerant traveling through the second refrigerant circuit.

12. The refrigeration system of claim **10**, wherein the third refrigerant circuit is separated from the first refrigerant circuit such that refrigerant is prevented from moving between the first and third refrigerant circuits, the third refrigerant circuit extending through the evaporator such that heat exchange can occur between the refrigerant traveling through the first refrigerant circuit and a refrigerant traveling through the third refrigerant circuit.

13. The refrigeration system of claim **10**, wherein the first refrigerant circuit includes a suction line heat exchanger.

14. The refrigeration system of claim **10**, wherein the second heat exchanger includes a first heat exchanger core and a second heat exchanger core, the first heat exchanger core being associated with the second refrigerant circuit, the second heat exchanger core being associated with the third refrigerant circuit.

15. The refrigeration system of claim **10**, further comprising a heat source separate from the first, second, and third refrigerant circuits for providing heat to the refrigeration system during operation in the heating mode.

16. The refrigeration system of claim **10**, wherein the evaporator is a liquid-heated evaporator and the first heat exchanger is a liquid-cooled gas cooler.

17. The refrigeration system of claim **16**, further comprising an air-cooled gas cooler connected in series with the liquid-cooled gas cooler.

18. The refrigeration system of claim **16**, further comprising an air-heated evaporator connected in series with the liquid-heated evaporator.

19. A method of operating a refrigeration system, the method comprising the acts of:

directing a refrigerant along a refrigerant circuit in a direction between a compressor, an evaporator, an expansion device, and a first heat exchanger during operation of the refrigeration system in a cooling mode;

operating a first pump when the refrigeration system is operating in the cooling mode to circulate refrigerant through a second heat exchanger;

transferring heat from a load space to the refrigerant in the refrigerant circuit when the refrigeration system is operating in the cooling mode;

stopping the first pump when the refrigeration system is operating in a heating mode;

directing the refrigerant along the refrigerant circuit in the direction during operation of the refrigeration system in the heating mode;

operating a second pump when the refrigeration system is operating in the heating mode to circulate refrigerant through the second heat exchanger in heat exchange relation with the refrigerant of the refrigerant circuit; and

transferring heat to the load space from the refrigerant in the refrigerant circuit when the refrigeration system is operating in the heating mode.

20. The method of claim **19**, further comprising heating the refrigerant with a heat source separate from the refrigerant circuit when the refrigeration system is operating in the heating mode.

21. The method of claim **19**, further comprising cooling the refrigerant using a suction line heat exchanger included along the refrigerant circuit.

22. The method of claim **19**, further comprising heating the refrigerant with an air-heated evaporator and a liquid-heated evaporator when the refrigeration system is operating in the cooling mode.

23. The method of claim **19**, further comprising cooling the refrigerant with an air-cooled condenser and a liquid-cooled condenser when the refrigeration system is operating in the heating mode.

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