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(54) **Title:** LIQUID LINE SUBCOOLER AND METHOD OF SUBCOOLING WORKING FLUID ENTERING METERING DEVICE

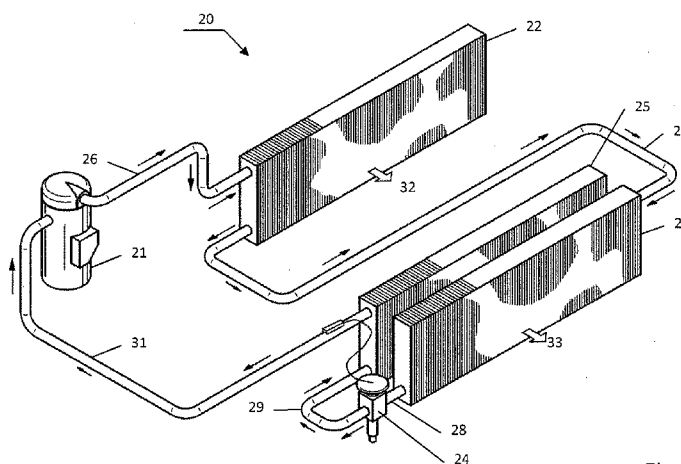


Fig. 3

(57) **Abstract:** A heat transfer system (20) employing refrigeration principles including a compressor, a condenser, a metering device (24), and an evaporator (25) utilizing a heat exchanging liquid line subcooler (23) for subcooling the working fluid flowing between the condenser and metering device (24) is described. In one embodiment, the subcooler (23) is located in close proximity to the evaporator and in the path of cold air passing through and out from the evaporator (25). In another embodiment, the subcooler (23) is physically abutting the evaporator (25) and located in the path of cold air passing through and out from the evaporator (25) so as to be able to further reduce the temperature of the working fluid flowing in the subcooler (23) through heat exchange between the evaporator (25) and the subcooler (23) by forced convection and thermal conduction to increase the liquid portion of the liquid-vapor mixture in the working fluid entering the metering device (24).

LIQUID LINE SUBCOOLER AND METHOD OF SUBCOOLING WORKING FLUID ENTERING METERING DEVICE

BACKGROUND OF THE INVENTION

5 1. Field of the invention

This invention relates to heat transfer systems using refrigeration principles or the like to extract heat from heat sources, and is more particularly concerned with a refrigeration systems employing heat exchanging liquid line subcooler that uses the working fluid that flows through the evaporator to further subcool the working fluid exiting the condenser prior to the working fluid entering the metering device to improve system cooling capacity without additional expenditure of energy when the working fluid evaporates in the evaporator. Consequently, the additional cooling capacity will provide more heat extraction capacity at the energy source and eventually turn into more heat capacity for the heating of water or air.

15 2. Description of the Prior Art

In a typical refrigeration system, working fluid flowing out of the evaporator, after absorbing heat energy from the heat source, will have to dissipate heat in the condenser to produce the required heating capacity for heating water or air. To raise this energy to a higher temperature level, the gaseous working fluid is superheated by the compression process within the compressor and pumped into an outdoor condenser where the heat of compression is rejected to the outside air or water. While heating up the water or air, the working fluid will undergo de-superheating and condensation processes, condensing the working fluid from vapor to a high pressure and relatively low enthalpy liquid for expansion in the metering device and subsequently through an evaporator to extract heat from another heat source. The low pressure and high enthalpy gaseous working fluid exiting the evaporator reenters again the compressor to complete the refrigeration cycle.

The thermodynamic characteristics of a typical refrigeration system are illustrated by the pressure-enthalpy diagram as shown in FIG 1. Gaseous working fluids at low pressure travel along the suction line from the evaporator to the compressor at a slightly superheated condition and undergo polytropic compression in process 11-12. The gaseous working fluid is then compressed to condensing

pressure at point 12. Heat is rejected at constant pressure along the condensation process 12-13, where the working fluid condenses from superheated vapor state into saturated liquid state. The working fluid in liquid form at point 13 is passed through a metering device where the pressure is reduced at constant enthalpy along the process 13-14 to the system suction pressure at point 14. The working fluid which consists of a mixture of liquid and vapor is then evaporated at constant pressure 14-11 to complete the refrigeration cycle. The evaporation of the liquid working fluid in process 14-11 represents the useful work of heat absorption in the evaporator.

A metering device disposed downstream of condenser could be used to throttles the high pressure working fluid in liquid form to a much lower pressure to achieve the required low temperature for the purpose of absorbing heat from the heat source. Due to this throttling process, a portion of the working fluid in liquid form is converted to vapor form. Since it is this liquid portion that will subsequently evaporate to cause the cooling, the gaseous portion does not do any useful work in the system, further subcooling of the liquid portion prior to the throttling process will serve to reduce this gaseous portion of the mixture and thus increase useful work.

Traditionally, subcooling of the liquid working fluid is done within the condenser using air or water as cooling medium. Other enhancement methods have been developed and utilized to increase the liquid formation. One of the approaches is disclosed in U.S. Patent No. 7,013,658. This system utilizes the colder condensate water formed on the evaporator surfaces during system operation for further subcooling of the refrigerant between the condenser and the expansion device to increase system capacity and efficiency. Another approach is shown in U.S. Patent No. 6,446,450 which expands a small portion of condensed liquid working fluid to an intermediate pressure to subcool the remaining portion of liquid working fluid which subsequently enters the evaporator after expansion.

BRIEF SUMMARY OF THE INVENTION

The present invention relates to a heat transfer system utilizing a novel approach for subcooling working fluid by heat exchange between the high pressured working fluid in liquid form and the working fluid that flow through the evaporator.

5 A conventional heat transfer system using refrigeration principles comprises a compressor, a condenser, a metering device, and an evaporator interconnected in that sequence in a closed loop with a working fluid circulating therein. In accordance with one aspect of the present invention, the heat transfer system is further provided with a liquid line subcooler that facilitates subcooling of the
10 working fluid exiting the condenser prior to entering metering device by using the working fluid that flow through the evaporator. Two examples of a metering device are an expansion valve or a capillary tube.

In accordance with another aspect of the present invention, the subcooler is physically disposed in the path of forced air passing through the evaporator to
15 facilitate heat transfer by forced convection between the liquid working fluid in the subcooler and the cold air.

In accordance with another aspect of the present invention, the subcooler is in thermal contact with the evaporator and also disposed in the path of forced air passing through the evaporator to facilitate heat transfer by conduction and by
20 forced convection to further reduce the temperature of working fluid prior to entering metering device such as an expansion valve or a capillary tube.

One advantage of the present invention is the increase in the proportion of liquid in the liquid/vapor mixtures of the working fluid leaving the metering device without incurring more energy expenditure for the compressor as the subcooling
25 results in a greater heat extraction capacity at the evaporator.

Another advantage of the present invention is that the heat transfer system will have a better cooling effect on the compressor and thus helps to prolong its life span.

A further advantage of the present invention is the reduction in the
30 frequency or duration of defrosting when the evaporator is operating below freezing temperatures of water.

Still another advantage of the present invention is an increase in the performance of the compressor as direct contact between the warm subcooling coil and the cold evaporator coil will raise the suction temperature when the working fluid returns to the compressor.

5 Yet another further advantage of the present invention is the resulting increase in the Coefficient of Performance (COP) of the system and the resultant energy saving.

BRIEF DESCRIPTION OF THE DRAWINGS

10 The various advantages and benefits of the present invention will become apparent to those skilled in the art upon reading and understanding the following detailed description when considered in connection with the accompanying drawings wherein :

FIG 1 is a pressure-enthalpy diagram of a refrigeration process with the effect of the present invention shown in dotted lines.

FIG 2 is a schematic view of a conventional heat transfer system employing refrigeration principles.

FIG 3 is a schematic view of a heat transfer system provided with a subcooler in accordance to one embodiment of the present invention

20 FIG 4 is a schematic view of a heat transfer system provided with a subcooler in accordance to another embodiment of the present invention

FIG 5 is a schematic view of one example of a series of cooling fins facilitating thermal contact between the evaporator and the subcooler.

25 FIG 6 is a schematic view of another example of a series of cooling fins facilitating thermal contact between the evaporator and the subcooler.

FIG 7 is the front view of FIG 6.

DETAILED DESCRIPTION OF THE INVENTION

30 In the following descriptions, similar elements or parts or components are given the same reference numbers.

Referring to FIG 2, a conventional heat transfer system (20) employing refrigeration principles is shown to include a compressor (21), a condenser (22), a

metering device (24), and an evaporator (25) connected within a closed circuit. From the compressor (21), the working fluid in vapour form is compressed into a high pressure and temperature vapour prior to entering the condenser (22). This high pressure and high temperature vapour then flows into the condenser (22) along the line (26). In the condenser (22) heat is rejected to outdoor air (32) so that the working fluid in vapour form can condense back into liquid form. The liquefied working fluid then enters a metering device (24) which can be an expansion valve or a capillary tube or any other type of metering device used in refrigeration circuits. This metering device (24) restricts the flow by forcing the refrigerant to go through a small aperture which causes a flash throttling to occur where the liquid working fluid undergoes a reduction both in pressure and temperature, resulting in two-phase fluid (mixture of liquid and vapor phases). At this reduced pressure, the liquid portion of the mixture can evaporate at low temperature enabling it to absorb heat from the heat source within the evaporator. After evaporation, the gaseous working fluid is then routed back to the compressor (21) along the vapor line (31) to complete the refrigeration cycle.

Referring now to FIG 3, in one embodiment of the present invention a liquid line subcooler (23) is included between the condenser (22) and the metering device (24) in the conventional refrigeration system described in FIG. 2 above. More particularly, the subcooler (23) of the present invention is located in close proximity to the evaporator (25) and in the path of cold air (33) passing through and out from the evaporator (25) so as to facilitate subcooling of the working fluid flowing through the subcooler (23) by forced convection before the working fluid flows into the metering device. This will result in an increase in the liquid portion of the liquid-vapor mixture in the working fluid that flows through line (28) and into the metering device (24). The forced convection could be generated by an external source such as pump, fan, suction device, etc.

In another embodiment of the present invention, the subcooling referred to above can be achieved by forced convection and/or conduction as shown in FIG 4. In this embodiment, the subcooler (23) is also located in the path of cold air (33) passing through and out from the evaporator (25) so as to subcool the working fluid flowing in the subcooler (23) by forced convection before the working fluids flow

into the metering device (24). However, in addition, the subcooler (23) is arranged to be physically abutting the evaporator (25) so that the subcooler (23) is in thermal contact with the evaporator (25). This thermal contact with the evaporator (25) further enhances subcooling of the working fluid flowing in the subcooler (23) as heat exchange in this embodiment is effected both by forced convection and thermal conduction.

Referring to FIG 5, the evaporator (25) and the subcooler (23) are shown sharing the same series of cooling fins (50). Each of the fins (50) has one or more columns of vertically aligned holes (52, 53) configured to receive the tubing of the evaporator (25). The tubing of the evaporator (25) passes through correspondingly positioned holes (52) in each of the series of cooling fins (50) with the ends of intermediate tubing joined to the end of the adjacent tubing in the next row. The same series of cooling fins (50) is provided with one or more columns of vertically aligned holes (53) through which the tubing of the subcooler (23) passes through. In this way, heat exchange between working fluid in the evaporator (25) and the subcooler (23) could be affected by thermal conduction. The number of columns of vertically aligned holes (52, 53) depends on the number of rows of evaporator coil and subcooler coil respectively. FIG. 5 illustrates an evaporator with two rows of coil and a subcooler with one row of coil.

Referring to FIG. 6 and FIG. 7, each of the vertically aligned holes (52) for the row of evaporator (25) coil adjacent to the subcooler (23) coil share the same opening with the corresponding vertically aligned holes (53) for the subcooler (23) coil. In this way one row of evaporator (25) coil has an edge in direct contact with an edge of the row of subcooler (23) coil. In this configuration, thermal conduction is effected by direct thermal conduction between the evaporator (25) and subcooler (23) coils as well as through thermal conduction from the series of fins (50). The tubing for the evaporator (25) and the subcooler (23) are shown in FIG. 5 as circular in cross section. In this configuration, the evaporator coil and subcooler coil are in contact tangentially. The tubing for the evaporator (25) and the subcooler (23) may however be configured in other shapes, such as a square or a rectangular cross-sectional shape to increase the surface area in thermal contact between the coils. FIG. 6 illustrates tubing of evaporator (25) coil and subcooler (23) coil having

square cross section. The holes (52, 53) are appropriately sized and shaped to accommodate square tubing of evaporator (25) coil and subcooler (23) coil. With square tubing the contact area increases to the length of a side of the square multiply by the length of the tubing in contact. The contact area therefore increases substantially compared to that along a tangential line in the case of tubing with circular cross section. For tubing with non circular cross section, such as a square cross section, there is required a transition from square cross section tubing to a circular cross section tubing if the tubing in other parts of the heat transfer system (20) using refrigeration principles or the like is of circular cross section, else all the tubing in the heat transfer system (20) should have the same cross section as that of the tubing in the subcooler (23) coil.

The descriptions above cover the situations of subcooling of subcooler (23) by forced air convection and by forced air convection and thermal conduction. The situation where the subcooler (23) is subcooled purely by thermal conduction is obviously another possible embodiment of the present invention although the preferred mode is subcooling both forced air convection and thermal conduction.

Referring again to FIG 1, subcooling is the process of cooling condensed gas beyond what is required for the condensation process. The purpose of subcooling is to assure that no vapor will be left behind at the end of the condensing phase, thus assuring maximum capacity at the metering device (24). A liquid line subcooler (23) which is the subject of the present invention is used to further subcool the working fluid into the liquid form as shown in dotted line 13-15. As the high pressure subcooled liquid from the condenser is reduced in pressure along the line 15-16, its corresponding temperature is reduced and the head load on the condenser (22) is greater than that of the evaporator (25) and eventually turned into more heating capacity for the water or air.

The invention also relates to a method for subcooling the working fluid in a heat transfer system (20) by placing a liquid line subcooler (23) between said condenser (22) and said metering device (24) with said liquid line subcooler (23) physically abutting the evaporator (25) and/or located in the path of cold air passing through and out from the evaporator (25) so as to further reduce the temperature of the working fluid flowing in the subcooler (23) through heat exchange between the

evaporator (25) and the subcooler (23) by forced convection and/or thermal conduction to increase the liquid portion of the liquid-vapor mixture in the working fluid entering the metering device (24).

5 The above description includes merely the preferred embodiments of the present invention and is not meant to be restrictive in any way or manner. All modifications, equivalents or modification known to someone skilled in the art are included within the scope of the present invention.

CLAIMS

1. A heat transfer system (20) using refrigeration principles or the like to extract heat from heat sources comprising a compressor (21), a condenser (22), a metering device (24), and an evaporator (25) interconnected in that sequence in a closed loop with a working fluid circulating therein, wherein the heat transfer system (20) further comprises a liquid line subcooler (23) between said condenser (22) and said metering device (24), characterized in that said liquid line subcooler (23) is physically located in the path of cold air passing through and out from the evaporator (25) so as to further reduce the temperature of the working fluid flowing in the subcooler (23) through heat exchange between the evaporator (25) and the subcooler (23) by forced convection prior to said working fluid entering said metering device (24).
2. A heat transfer system (20) using refrigeration principles or the like to extract heat from heat sources comprising a compressor (21), a condenser (22), a metering device (24), and an evaporator (25) interconnected in that sequence in a closed loop with a working fluid circulating therein, wherein the heat transfer system (20) further comprises a liquid line subcooler (23) between said condenser (22) and said metering device (24), characterized in that said liquid line subcooler (23) is physically abutting the evaporator (25) and located in the path of cold air passing through and out from the evaporator (25) so as to further reduce the temperature of the working fluid flowing in the subcooler (23) through heat exchange between the evaporator (25) and the subcooler (23) by forced convection and thermal conduction prior to entering said metering device (24).
3. A heat transfer system (20) as in claim 2 wherein said evaporator (25) and said liquid line subcooler (23) are in thermal contact by virtue of said evaporator (25) and said liquid line subcooler (23) sharing the same series of cooling fins (50).
4. A heat transfer system (20) as in claim 2 wherein said evaporator (25) and said liquid line subcooler (23) are in thermal contact by virtue of one side of one or

the row of tubing of said evaporator (25) being physically in contact one side of the row of adjacent tubing of said liquid line subcooler (23) and with said evaporator (25) and said liquid line subcooler (23) sharing the same series of cooling fins (50).

5 5. A heat transfer system (20) using refrigeration principles or the like to extract heat from heat sources comprising a compressor (21), a condenser (22), a metering device (24), and an evaporator (25) interconnected in that sequence in a closed loop with a working fluid circulating therein, wherein the heat transfer system (20) further comprises a liquid line subcooler (23) between said condenser
10 (22) and said metering device (24), characterized in that said liquid line subcooler (23) is physically abutting the evaporator (25) so as to further reduce the temperature of the working fluid flowing in the subcooler (23) through heat exchange between the evaporator (25) and the subcooler (23) by thermal conduction prior to entering said metering device (24).

15

6. A heat transfer system (20) as in claim 5 wherein said evaporator (25) and said liquid line subcooler (23) are in thermal contact by virtue of said evaporator (25) and said liquid line subcooler (23) sharing the same series of cooling fins (50).

20 7. A heat transfer system (20) as in claim 5 wherein said evaporator (25) and said liquid line subcooler (23) are in thermal contact by virtue of one side of one row of tubing of said evaporator (25) being physically in contact one side of the row of adjacent tubing of said liquid line subcooler (23) and with said evaporator (25) and said liquid line subcooler (23) sharing the same series of cooling fins (50).

25

8. A method for subcooling the working fluid in a heat transfer system (20) comprising a compressor (21), a condenser (22), a metering device (24), and an evaporator (25) interconnected in that sequence in a closed loop with a working fluid circulating therein, the method comprising placing a liquid line subcooler (23)
30 between said condenser (22) and said metering device (24) with said subcooler located in the path of cold air passing through and out from the evaporator (25) so as to further reduce the temperature of the working fluid flowing in the subcooler

(23) through heat exchange between the evaporator (25) and the subcooler (23) by forced convection to increase the liquid portion of the liquid-vapor mixture in the working fluid entering the metering device (24)

5 9. A method for subcooling the working fluid in a heat transfer system (20) comprising a compressor (21), a condenser (22), a metering device (24), and an evaporator (25) interconnected in that sequence in a closed loop with a working fluid circulating therein, the method comprising placing a liquid line subcooler (23) between said condenser (22) and said metering device (24) with said liquid line
10 subcooler (23) physically abutting the evaporator (25) and located in the path of cold air passing through and out from the evaporator (25) so as to further reduce the temperature of the working fluid flowing in the subcooler (23) through heat exchange between the evaporator (25) and the subcooler (23) by forced convection and thermal conduction to increase the liquid portion of the liquid-vapor mixture in
15 the working fluid entering the metering device (24).

10 10. A method for subcooling the working fluid in a heat transfer system (20) comprising a compressor (21), a condenser (22), a metering device (24), and an evaporator (25) interconnected in that sequence in a closed loop with a working fluid circulating therein, the method comprising placing a liquid line subcooler (23) between said condenser (22) and said metering device (24) with said liquid line
20 subcooler (23) physically abutting the evaporator (25) so as to further reduce the temperature of the working fluid flowing in the subcooler (23) through heat exchange between the evaporator (25) and the subcooler (23) by thermal conduction
25 to increase the liquid portion of the liquid-vapor mixture in the working fluid entering the metering device (24).

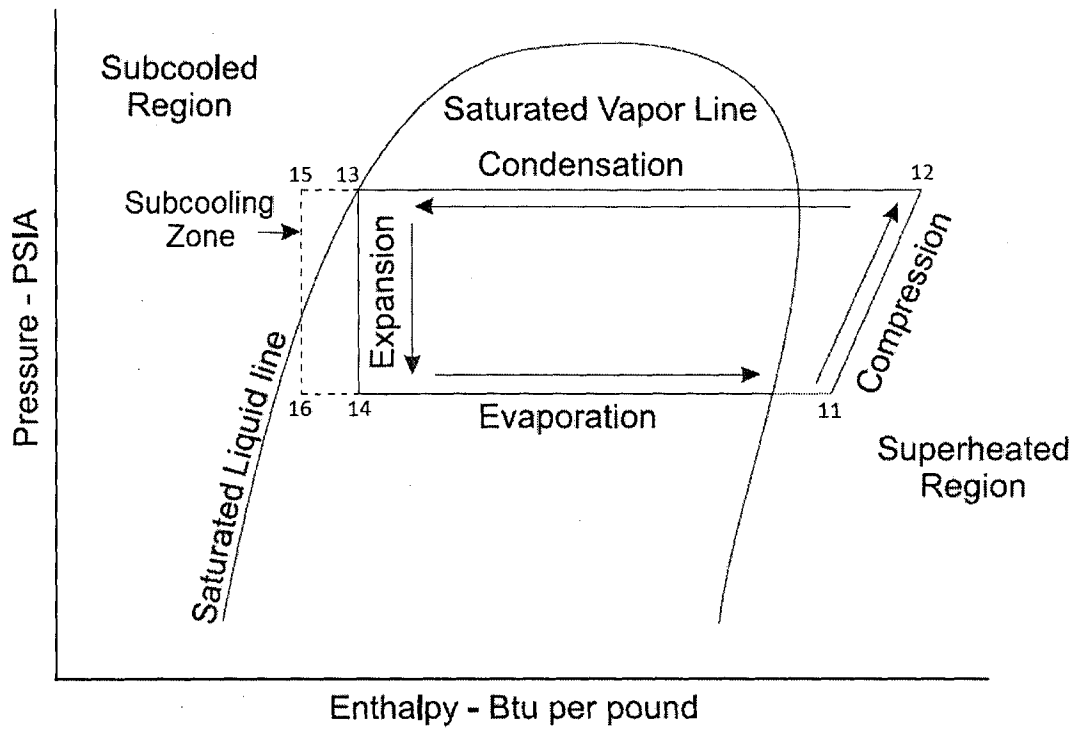


Fig. 1

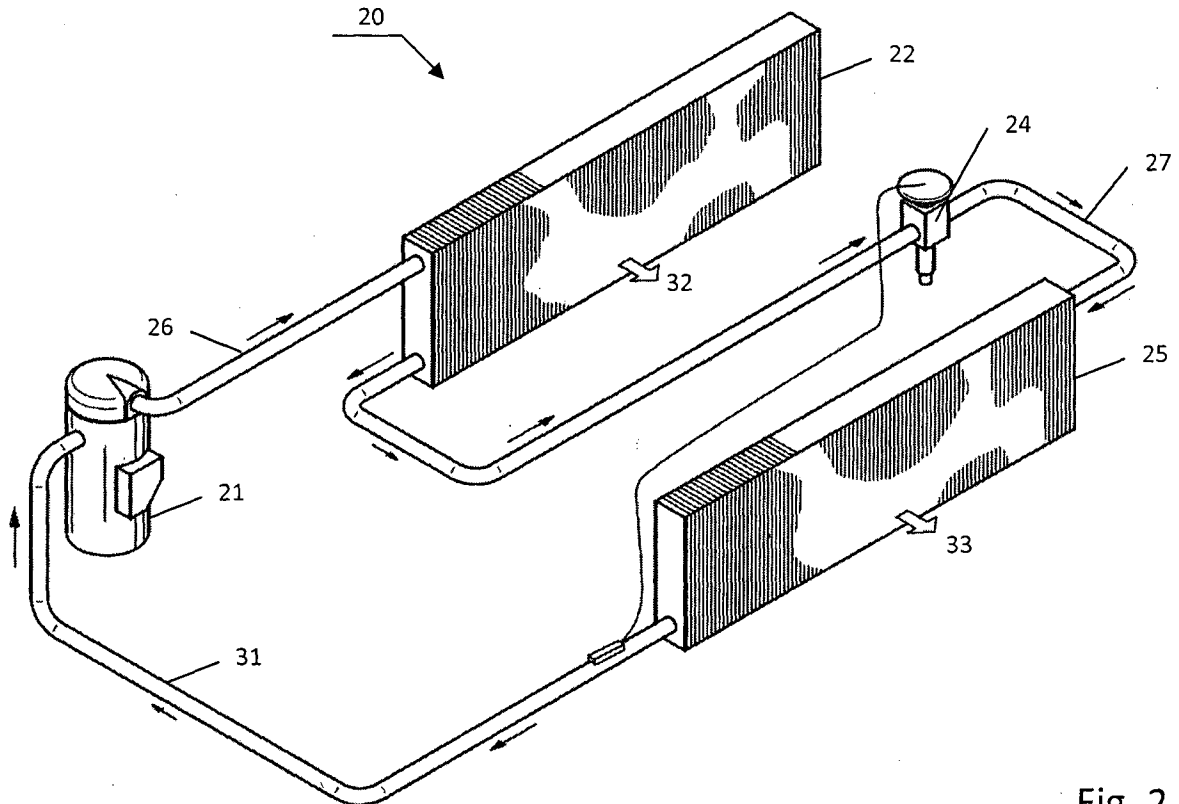


Fig. 2

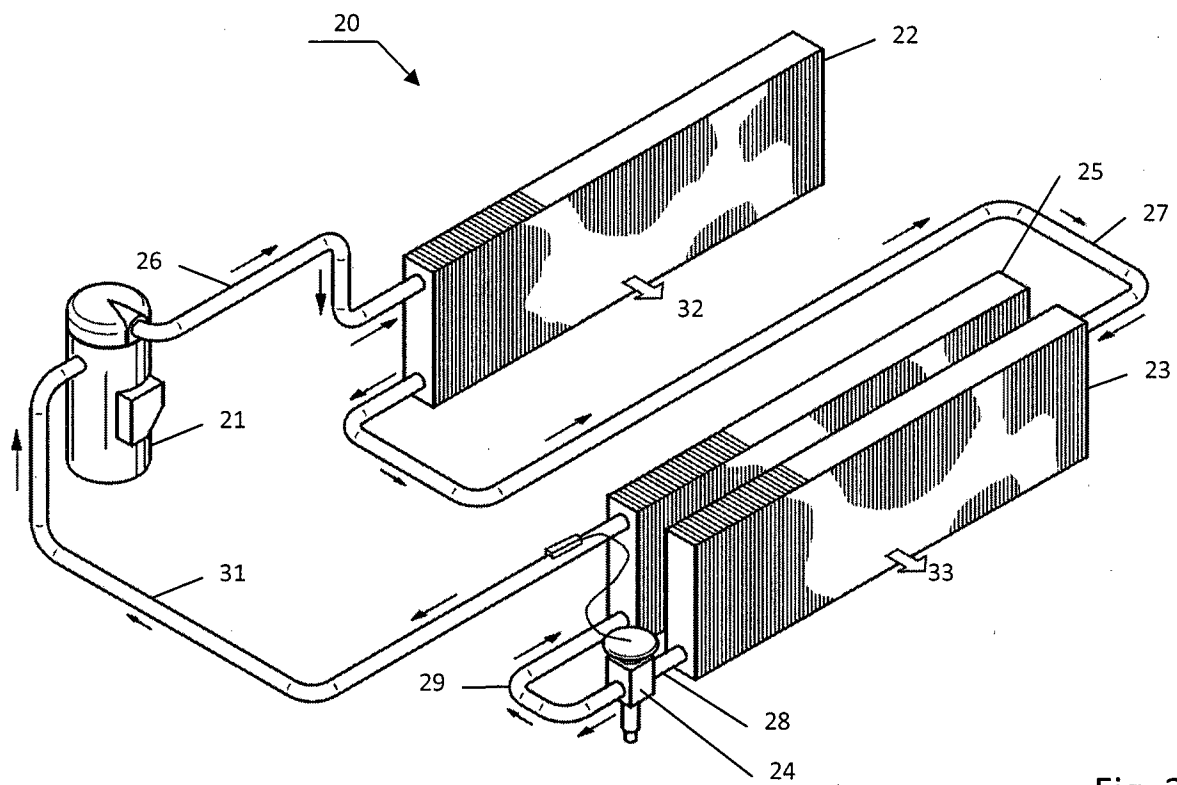


Fig. 3

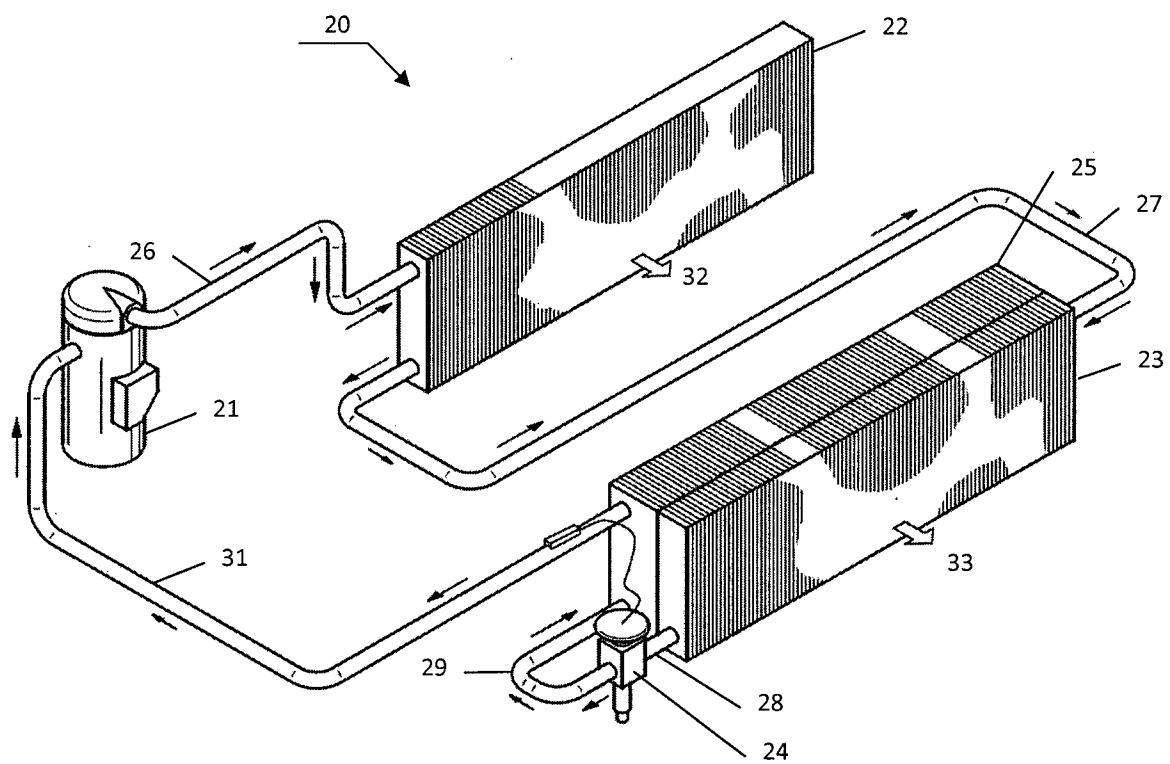


Fig. 4

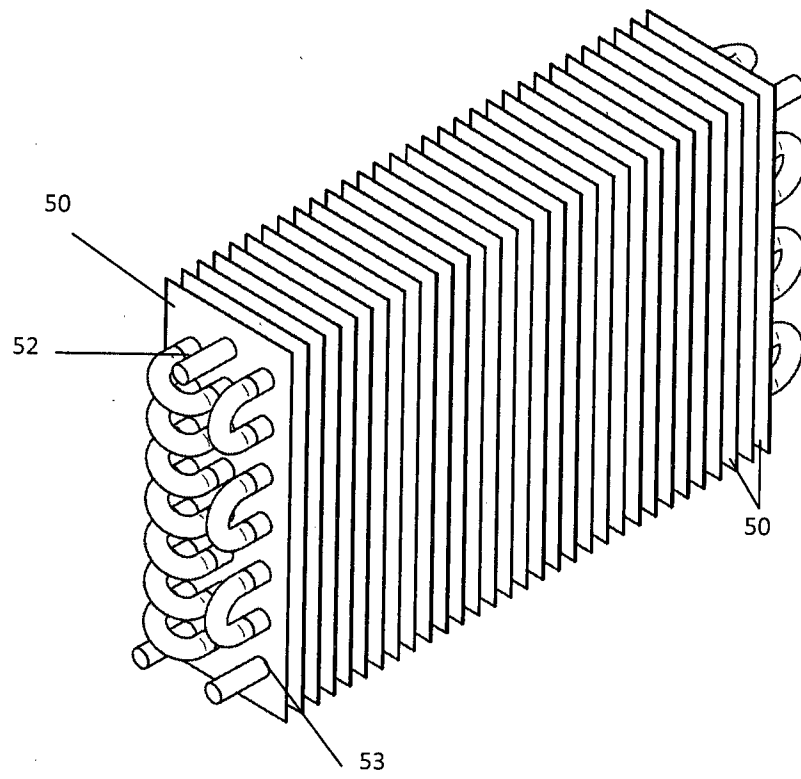


Fig. 5

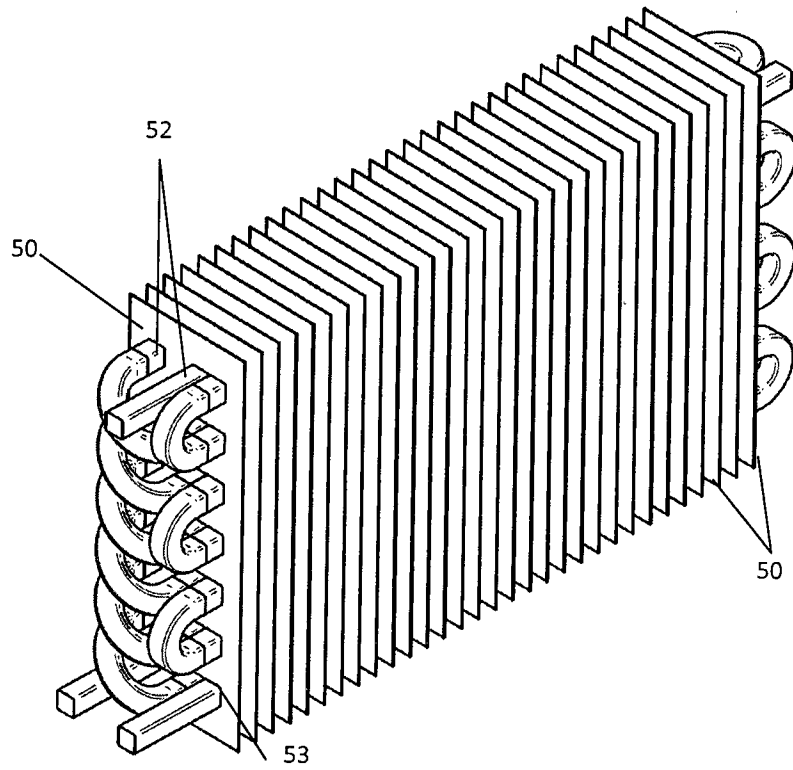


Fig. 6

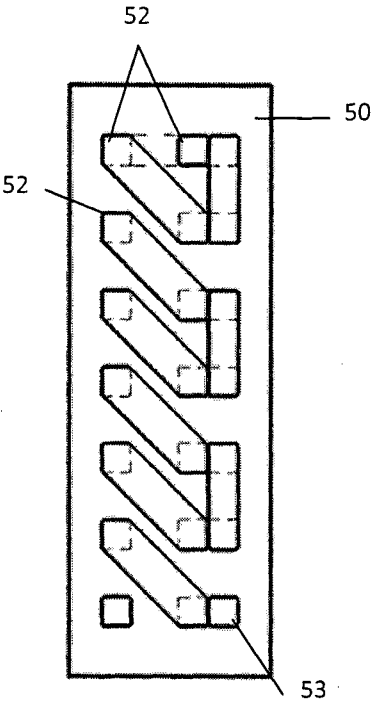


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/MY2012/000064

A. CLASSIFICATION OF SUBJECT MATTER
INV. F25B40/02 F28D1/04
ADD.

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)
F25B F28D

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 27 58 737 A1 (SIEMENS AG) 5 July 1979 (1979-07-05) page 3, line 22 - page 5, line 15; figure 2	1-10
X	----- EP 0 760 452 A2 (CARRIER CORP [US]) 5 March 1997 (1997-03-05) column 4, line 55 - column 10, line 30; figures 2-6	1-10
X	----- EP 0 846 923 A2 (CARRIER CORP [US]) 10 June 1998 (1998-06-10) column 2, line 43 - column 5, line 5; figures 1-3	1-10
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Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

10 July 2012

Date of mailing of the international search report

18/07/2012

Name and mailing address of the ISA/

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Szilagyi, Barnabas

INTERNATIONAL SEARCH REPORT

International application No
PCT/MY2012/000064

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Information on patent family members

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