(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 309 208 A1

(12) # EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
13.04.2011 Bulletin 2011/15

(21) Application number: **09750463.3**

(22) Date of filing: **28.04.2009**

(51) Int Cl.:
F25B 1/00 *(2006.01)*

(86) International application number:
PCT/JP2009/058336

(87) International publication number:
WO 2009/142101 (26.11.2009 Gazette 2009/48)

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO SE SI SK TR
Designated Extension States:
AL BA RS

(30) Priority: **20.05.2008 JP 2008131981**

(71) Applicant: **Sanden Corporation**
Isesaki-shi
Gunma 372-8502 (JP)

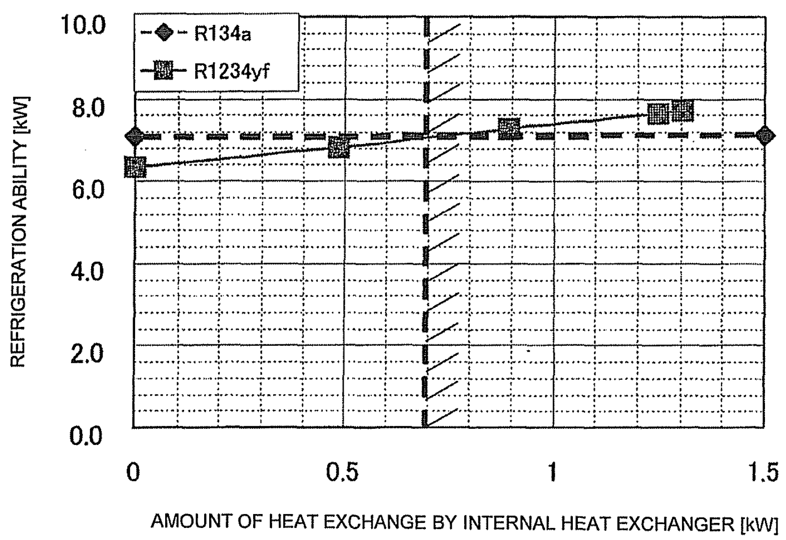
(72) Inventor: **KANEKO, Akira**
Isesaki-shi
Gunma 372-8502 (JP)

(74) Representative: **Prüfer & Partner GbR**
European Patent Attorneys
Sohnckestraße 12
81479 München (DE)

(54) **REFRIGERATION CYCLE**

(57) A refrigeration cycle provided with a compressor, a condenser, a pressure reduction and expansion means, an evaporator, and an internal heat exchanger for exchanging heat between the refrigerant at the exit side of the condenser and the refrigerant at the exit side of the evaporator, wherein the refrigeration cycle uses R1234yf as the refrigerant and the amount of heat exchange by the internal heat exchanger is greater than or equal to a specific value that has been determined beforehand by a simulation or an experiment. When a currently used refrigerant is changed to a new refrigerant R1234yf, the refrigeration cycle can be operated with a refrigeration ability as same as or greater than that of refrigeration cycles using a conventional refrigerant R134a.

FIG. 2



EP 2 309 208 A1

Description

Technical Field of the Invention

[0001] The present invention relates to a refrigeration cycle, and specifically relates to a refrigeration cycle which can be operated in a high refrigeration ability when a new-type refrigerant is used.

Background Art of the Invention

[0002] Known is a vapor compression type refrigeration cycle as used in an air conditioning system for vehicles, which has a basic configuration as shown in Fig.1. In Fig. 1, refrigeration cycle 1 has compressor 2 for compressing refrigerant, condenser 3 for condensing compressed refrigerant, expansion valve 4 as a pressure reduction and expansion means for reducing in pressure and expanding condensed refrigerant, evaporator 5 for evaporating pressure-reduced and expanded refrigerant and internal heat exchanger 6 for exchanging heat between refrigerant at the exit side of the condenser and refrigerant at the exit side of the evaporator, where the refrigerant is circulated in the arrow direction as changing in state in refrigerant cycle 1. It has been known that internal heat exchanger 6 provided in refrigeration cycle 1 can generally improve its refrigeration ability. However, internal heat exchanger 6 has not been used actually because the advantage thereby is relatively low when using typical refrigerant R134a.

[0003] As described above, R134a can be quoted as a typical refrigerant at present, and new type refrigerants have been researched and developed aiming further improvement of global warming potential (GWP), etc., as disclosed in Non-patent document 1. R1234yf has been announced recently as a new refrigerant aiming at such an improvement, and it is becoming possible that it is examined and studied for applying to refrigeration cycle as used for an automotive air conditioning system.

Prior art documents

Non-patent documents

[0004] Non-patent document 1: Refrigeration, Vol. 83, No. 965, March issue, 2008

Summary of the Invention

Problems to be solved by the Invention

[0005] However, when the new-type refrigerant R1234yf is merely applied to a conventional refrigeration cycle it is very likely that both refrigeration ability and coefficient of performance (COP) are lowered below those of a refrigeration cycle using conventional refrigerant R134a. Further in that case, use of above-described internal heat exchanger 6 may be effective for improving the refrigeration ability, however, amount of the effect is not clarified.

[0006] Accordingly, focusing on the above-described new-type refrigerant, an object of the present invention is to provide a refrigeration cycle, which can be operated in a high refrigeration ability greater than or equal to a refrigeration cycle using the conventional refrigerant R134a even when refrigerant is changed to the new-type refrigerant R1234yf.

Means for solving the Problems

[0007] To achieve the above-described object, a refrigeration cycle according to the present invention is a refrigeration cycle comprising a compressor for compressing refrigerant, a condenser for condensing compressed refrigerant, a pressure reduction and expansion means for reducing in pressure and expanding condensed refrigerant, an evaporator for evaporating pressure-reduced and expanded refrigerant, and an internal heat exchanger for exchanging heat between refrigerant at an exit side of the condenser and refrigerant at an exit side of the evaporator, **characterized in that** R1234yf is used as refrigerant for the refrigeration cycle, and an amount of heat exchange by the internal heat exchanger is greater than or equal to a specific value that has been determined beforehand by a simulation or an experiment.

[0008] Fig. 2 shows how the refrigeration ability can be improved by using the internal heat exchanger when the new-type refrigerant R1234yf is used in the refrigeration cycle having the same basic configuration as shown in Fig. 1, in comparison between one case where the conventional refrigerant R134a is used without using an internal heat exchanger and the other case where the new-type refrigerant R1234yf is used as using an internal heat exchanger, under the same calculational condition such as condensation temperature, evaporation temperature, superheating degree and subcooling degree. The horizontal axis of Fig. 2 shows quantity of heat exchange by the internal heat exchanger (the ability of the internal heat exchanger), and the vertical axis thereof shows the refrigeration ability as a whole refrigeration cycle.

In a case where the new-type refrigerant R1234yf with characteristics different from that of R134a is used the refrigeration ability changes as shown in Fig. 2 by providing the internal heat exchanger. On the other hand, in a case where the conventional refrigerant R134a is used without using the internal heat exchanger the quantity of heat exchange by internal heat exchanger is shown as constant because the internal heat exchanger is not used. In other words, if the quantity of heat exchange by the internal heat exchanger is greater than or equal to a specific value, such as 0.7kW in the comparative characteristic diagram shown in Fig. 2, the improvement of refrigeration ability by providing the internal heat exchanger can be achieved surely in a case where the new-type refrigerant R1234yf is used. However, it can be found that when the quantity of heat exchange by the internal heat exchanger is less than the specific value, such as 0.7kW in the comparative characteristic diagram shown in Fig. 2, the refrigeration ability with R1234yf is less than that with R134a, which means that the advantage of providing the internal heat exchanger as seen in the R134a case cannot be obtained. Therefore, it can be found that only if the quantity of heat exchange by the internal heat exchanger is set greater than or equal to a specific value, or a predetermined value, the case with R1234yf can achieve refrigeration ability greater than or equal to the case with R134a, so as to actually improve the refrigeration ability. The present invention is based on this technical idea and **characterized in that**, when R1234yf is used as refrigerant for the refrigeration cycle an amount of heat exchange by the internal heat exchanger is greater than or equal to a specific value that has been determined beforehand by a simulation or an experiment. Namely, used is the region identified by hatching, which is the right side region of the point of intersection with a characteristic line in the R134a case and another characteristic line in the R1234yf case, in Fig. 2. In other words, the specific value of the amount of heat exchange by the internal heat exchanger is set so that a total refrigeration ability of the refrigeration cycle using R1234yf as refrigerant is greater than or equal to a total refrigeration ability of a refrigeration cycle using R134a as refrigerant under the same conditions.

[0009] In order to set the amount of heat exchange by the internal heat exchanger greater or equal to the specific value, concretely, the size or thermal efficiency of the internal heat exchanger can be set arbitrarily if specification of the evaporator or the condenser used in each refrigeration cycle is preliminarily known. In a refrigeration cycle which is configured based on this concept, because the approximate ability of the internal heat exchanger is known, refrigeration ability as a whole refrigeration cycle can be obtained stably, where the refrigeration ability is kept greater than or equal to the refrigeration ability in the R134a case by properly controlling the opening degree of the decompression-expansion means according to the superheating degree of refrigerant at the outlet side connecting to the compressor side of the internal heat exchanger.

[0010] Such a refrigeration cycle according to the present invention is basically applicable to any refrigeration cycle which aims to use the new-type refrigerant R1234yf, and is specifically suitable to a refrigeration cycle used in an automotive air conditioning system which is required to achieve efficient operation for a long term.

Effect according to the Invention

[0011] The refrigeration cycle according to the present invention makes it possible that when the refrigerant is replaced to the new-type refrigerant R1234yf, the improvement of coefficient of performance (COP) can be greatly achieved, and superior characteristics, such as improvement of the global warming potential (GWP), etc., which the new-type refrigerant R1234yf has in itself can be performed.

Brief explanation of the drawings

[0012]

[Fig. 1] Fig. 1 is a schematic framework showing a basic equipment layout of a refrigeration cycle as an object of the present invention.

[Fig. 2] Fig. 2 is a relational diagram which shows a relation between "AMOUNT OF HEAT EXCHANGE BY INTERNAL EXCHANGER" and "REFRIGERATION ABILITY" in comparison between characteristics of refrigerants R1234yf and R134a.

[Fig. 3] Fig. 3 is a relational diagram which shows a relation between "CONDENSATION TEMPERATURE" and "ABILITY RATE OF INTERNAL HEAT EXCHANGER" where refrigerant R1234yf is used.

[Fig. 4] Fig. 4 is a Mollier diagram which shows an example of operating state of a refrigeration cycle under a certain condition for refrigerant R1234yf and R134a.

[Fig. 5] Fig. 5 is a Mollier diagram which shows an example of operating state of a refrigeration cycle under another condition for refrigerant R1234yf and R134a.

[Fig. 6] Fig. 6 is a Mollier diagram which shows an example of operating state of a refrigeration cycle under yet another condition for refrigerant R1234yf and R134a.

Embodiments for carrying out the Invention

[0013] Hereinafter, the present invention will be explained with its embodiments as referring to figures.
A basic configuration of equipments of a refrigeration cycle according to the present invention can be the same one as shown in Fig. 1. In Fig. 1 refrigeration cycle 1 has compressor 2 for compressing refrigerant, condenser 3 for condensing compressed refrigerant, expansion valve 4 as a pressure reduction and expansion means for reducing in pressure and expanding condensed refrigerant, evaporator 5 for evaporating pressure-reduced and expanded refrigerant and internal heat exchanger 6 for exchanging heat between refrigerant at the exit side of the condenser and refrigerant at the exit side of the evaporator, where the refrigerant is circulated in the arrow direction as changing in state in refrigerant cycle 1, as described above.

[0014] In addition, the present invention basically uses the region identified by hatching, which is the right side region of the point of intersection with a characteristic line in the R134a case and another characteristic line in the R1234yf case, in Fig. 2, as described above. In other words, an internal heat exchanger is provided as using the new-type refrigerant R1234yf, so that the refrigeration ability can be improved from the conventional case using refrigerant R134a.
Characteristic A in Fig. 3 shows how "ability rate of internal heat exchanger", which means an improvement effect of an ability by an internal heat exchanger to a refrigeration ability as a whole refrigeration cycle, will change when the condition of the amount of heat exchange by the internal heat exchanger at the point of intersection with a characteristic line in the R134a case and another characteristic line in the R1234yf case in Fig. 2 is changed to another condition thereof, such as different condensation temperature of the refrigerant. Further to the characteristic A, Characteristic B in Fig. 3 shows a relation of "ABILITY RATE OF INTERNAL HEAT EXCHANGER TO REFRIGERATION ABILITY" as a whole refrigeration cycle to "CONDENSATION TEMPERATURE" if the efficiency of the internal heat exchanger is assumed to be 100%. In other words if the ability of internal heat exchanger is positioned within characteristic line A and characteristic line B the refrigeration ability improvement effect is supposed to be greater than or equal to the case where R134a is used. Because the efficiency of heat exchanger is actually less than 100%, an actual setting or a controlling region is supposed to be positioned within the characteristic lines A and B.

[0015] Since the intersectional point of the characteristic lines A and B in the calculation result shown in Fig. 3 is positioned at where the ability rate of the internal heat exchanger to refrigeration ability is 6.6%, if the ability rate is no less than 7% the refrigeration ability is to be surely improved by providing the internal heat exchanger, according to the relational characteristics shown in Fig. 3. The upper limit value of the ability rate is not specifically limited, and the refrigeration ability has been confirmed to be improved, even in a condition around 30%, according to the calculation result shown in Fig. 3.

[0016] An example of calculation results under a certain condition is shown in Table 1, as for the above-described cases of R134a and R1234yf. The preconditions for calculation are as follows.

* Evaporation temperature: 0 deg
* Condensation temperature: 50 deg
* Superheating degree at evaporator exit: 5 deg
* Subcooling degree at condenser exit: 5 deg
* Pressure loss at heat exchanger/circuit: Assumed to be zero.
* Compressor efficiency: Assumed to be 100%.

[0017]

[Table 1]

		R134a	R1234yf						
REFRIGERATION ABILITY	W (%)	7977	92.5	94.9	97.2	99.5	101.6	103.6	104.4
RADIATION ABILITY	W (%)	9822	93.3	95.4	97.4	99.2	101.0	102.7	103.4
POWER CONSUMPTION	W (%)	1845	96.9	97.5	97.9	98.3	98.6	99.0	99.0
COEFFICIENT OF PERFORMANCE (COP)	—	4.32	95.6	97.5	99.3	101.2	103.0	104.9	105.6
AMOUNT OF HEAT EXCHANGE BY INTERNAL HEAT EXCHANGER	W	≒0	≒0	480	916	1315	1684	2027	2157
COMPRESSOR SUCTION TEMPERATURE	°C (%)	5	100.0	256.0	408.0	558.0	702.0	844.0	900.0
COMPRESSOR DISCHARGE TEMPERATURE	°C (%)	59.9	87.8	99.3	110.9	122.5	133.9	145.2	149.7
REFRIGERANT DENSITY AT THE INLET OF COMPRESSOR	kg/m^3 (%)	14.1	121.3	116.3	112.8	108.5	105.7	102.8	101.4

[0018] In the case of the new-type refrigerant R1234yf, the refrigeration ability per unit volume can be kept no less than the level with the conventional refrigerant R134a by increasing the amount of heat exchange of the internal heat exchanger as shown in the region surrounded by a bold border in Table 1. Therefore, the compressor does not have to be operated rapidly any more. In addition, because the density of compressor suction refrigerant becomes low the circulating volume of refrigerant decreases, and a pressure loss can be reduced. Further, the compressor suction side refrigerant superheating degree becomes greater and the compressor discharge temperature becomes higher than R134a, so that the efficiency can be improved. Furthermore, the coefficient of performance (COP) can be kept no less than the same level with R134a because the increase of the compressor power (consumption power) is comparatively small.

[0019] Fig. 4 - Fig. 6 show an example of comparative result between R1234yf and R134a on the Mollier diagram. Fig. 4 - Fig. 6 show respective cases which have varied thermal efficiencies of the internal heat exchanger in the R1234yf case. The conditions in each Fig. are as follows.

[0020] (1) The Mollier diagram shown in Fig. 4:

* Evaporation temperature: 0 deg
* Condensation temperature: 50 deg
* Superheating degree at evaporator exit: 5 deg
* Subcooling degree at condenser exit: 5 deg
* As for R134a, characteristics without internal heat exchanger are shown.
* As for R1234yf, characteristics with internal heat exchanger of which thermal efficiency is 75.3% are shown.

[0021] (2) The Mollier diagram shown in Fig. 5:

* Evaporation temperature: 0 deg
* Condensation temperature: 50 deg
* Superheating degree at evaporator exit: 5 deg
* Subcooling degree at condenser exit: 5 deg
* As for R134a, characteristics without internal heat exchanger are shown.
* As for R1234yf, characteristics with internal heat exchanger of which thermal efficiency is 93.0% are shown.

[0022] (3) The Mollier diagram shown in Fig. 6:

* Evaporation temperature: 0 deg
* Condensation temperature: 50 deg
* Superheating degree at evaporator exit: 5 deg
* Subcooling degree at condenser exit: 5 deg
* As for R134a, characteristics without internal heat exchanger are shown.
* As for R1234yf, characteristics with internal heat exchanger of which thermal efficiency is 99.9% are shown.

[0023] Besides, though each example as described above is shown as a simulation result by calculation, even the above-described specific value which has been obtained by an experiment can be used, and alternatively, even the above-described specific value which has been determined by referring to both the simulation result and the experimental result can be used.

<u>Industrial Applications of the Invention</u>

[0024] The refrigeration cycle according to the present invention is applicable for every refrigeration cycle where the new-type refrigerant R1234yf will be used, and specifically suitable as a refrigeration cycle used for an automotive air conditioning system.

<u>Explanation of symbols</u>

[0025]

1: refrigeration cycle
2: compressor
3: condenser
4: expansion valve as pressure reduction/expansion means
5: evaporator
6: internal heat exchanger

Claims

1. A refrigeration cycle comprising a compressor for compressing refrigerant, a condenser for condensing compressed refrigerant, a pressure reduction and expansion means for reducing in pressure and expanding condensed refrigerant, an evaporator for evaporating pressure-reduced and expanded refrigerant, and an internal heat exchanger for exchanging heat between refrigerant at an exit side of said condenser and refrigerant at an exit side of said evaporator, **characterized in that** R1234yf is used as refrigerant for said refrigeration cycle, and an amount of heat exchange by said internal heat exchanger is greater than or equal to a specific value that has been determined beforehand by a simulation or an experiment.

2. The refrigeration cycle according to claim 1, wherein said specific value of said amount of heat exchange by said internal heat exchanger is set so that a total refrigeration ability of said refrigeration cycle using R1234yf as refrigerant is greater than or equal to a total refrigeration ability of a refrigeration cycle using R134a as refrigerant under same conditions.

3. The refrigeration cycle according to claim 1, wherein said specific value of said amount of heat exchange by said internal heat exchanger is set as an ability rate to said total refrigeration ability of said refrigeration cycle.

4. The refrigeration cycle according to claim 3, wherein said ability rate of said specific value of said amount of heat exchange by said internal heat exchanger to said total refrigeration ability of said refrigeration cycle is set at 7% or greater.

5. The refrigeration cycle according to claim 1, wherein an opening degree of said pressure reduction and expansion means is controlled depending upon a superheated degree of refrigerant at an exit side of said internal heat exchanger connected to said compressor.

6. The refrigeration cycle according to claim 1, wherein said refrigeration cycle is used in an air conditioning system for vehicles.

FIG. 1

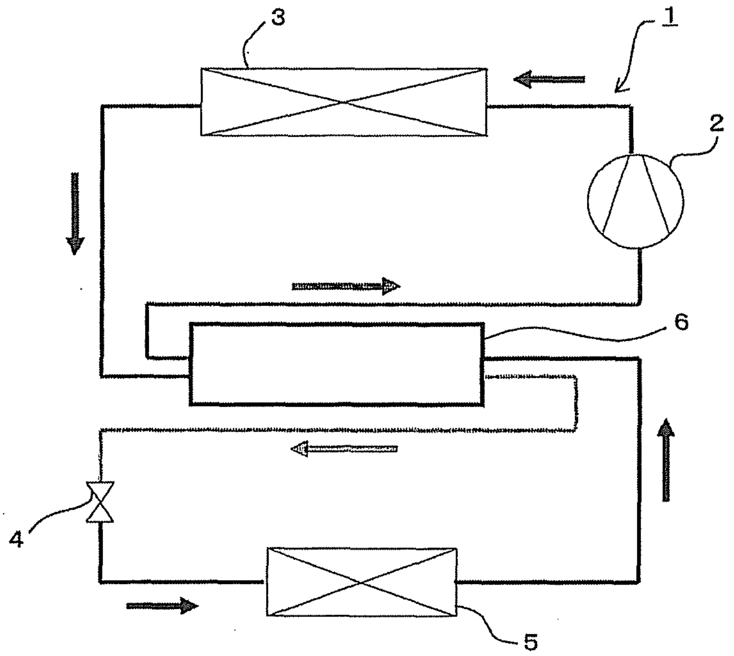

1
2
3
4
5
6

FIG. 2

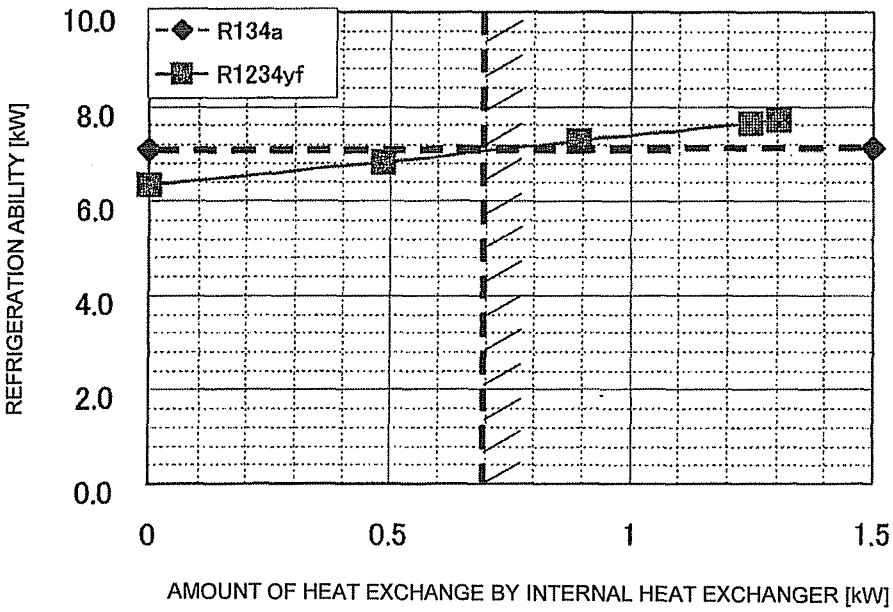

R134a
R1234yf
REFRIGERATION ABILITY [kW]
10.0
8.0
6.0
4.0
2.0
0.0
0
0.5
1
1.5
AMOUNT OF HEAT EXCHANGE BY INTERNAL HEAT EXCHANGER [kW]

FIG. 3

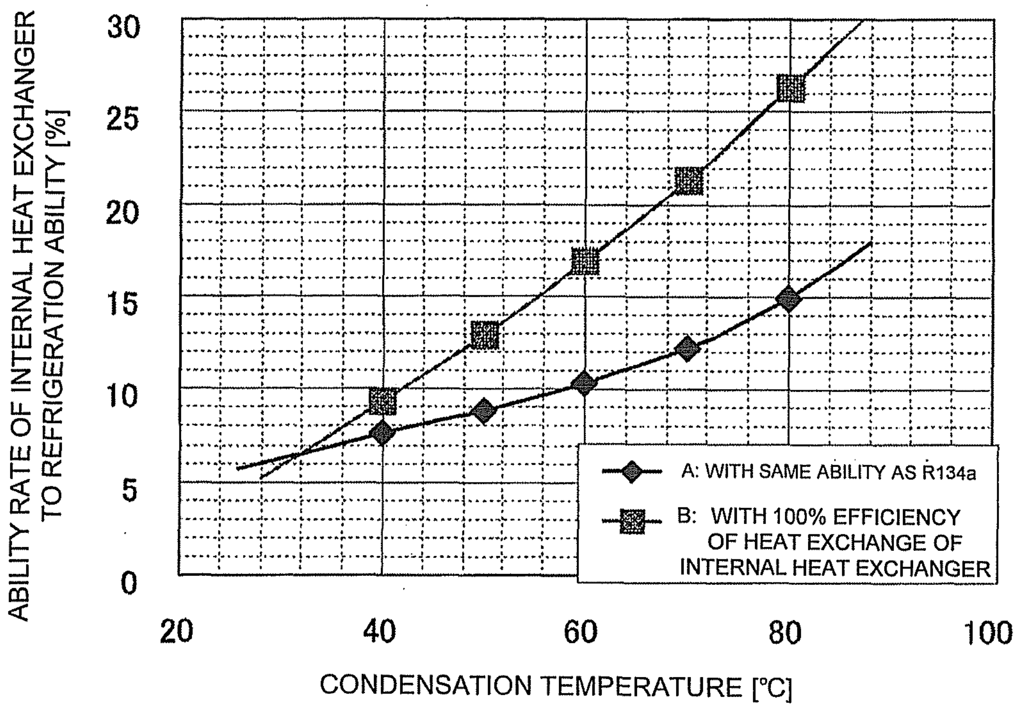

ABILITY RATE OF INTERNAL HEAT EXCHANGER TO REFRIGERATION ABILITY [%]
30
25
20
15
10
5
0
20
40
60
80
100
CONDENSATION TEMPERATURE [°C]
A: WITH SAME ABILITY AS R134a
B: WITH 100% EFFICIENCY OF HEAT EXCHANGE OF INTERNAL HEAT EXCHANGER

FIG. 4

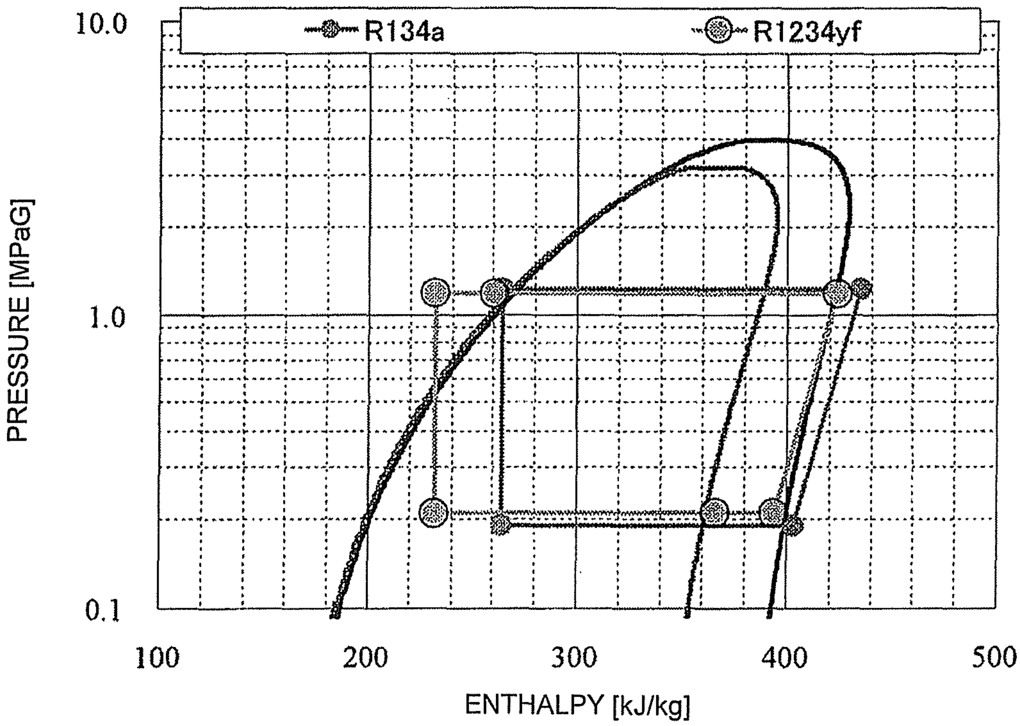

R134a
R1234yf
PRESSURE [MPaG]
10.0
1.0
0.1
100
200
300
400
500
ENTHALPY [kJ/kg]

FIG. 5

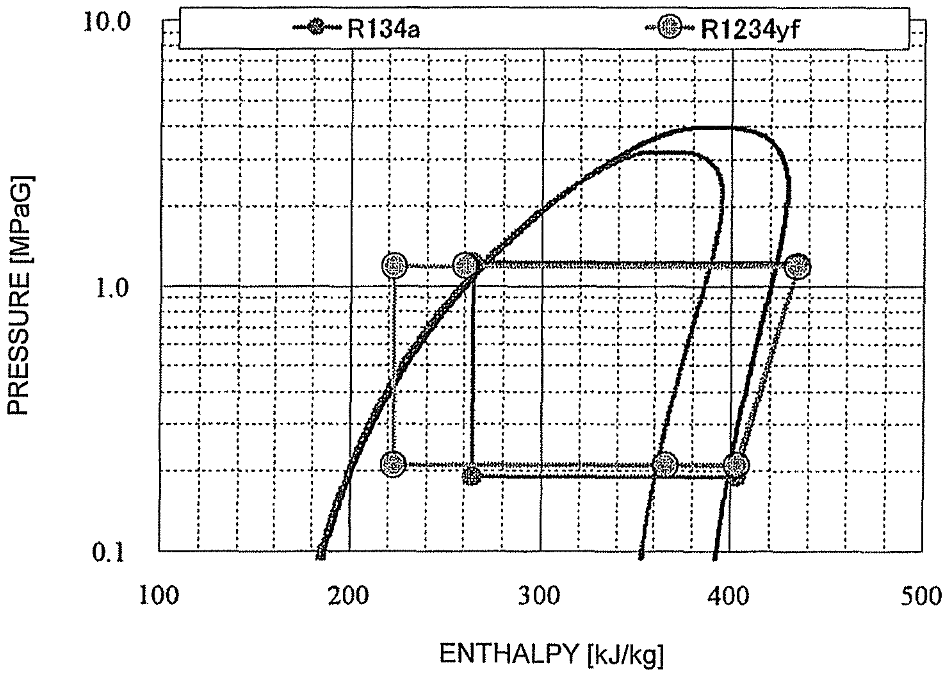
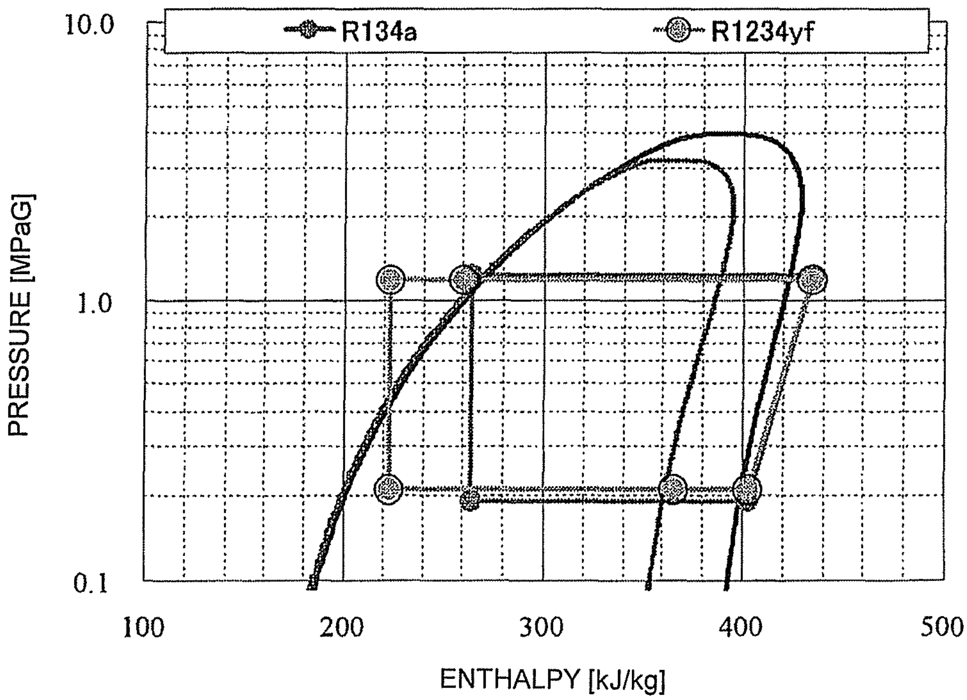

R134a
R1234yf
10.0
1.0
0.1
100
200
300
400
500
PRESSURE [MPaG]
ENTHALPY [kJ/kg]

FIG. 6


R134a
R1234yf
10.0
1.0
0.1
100
200
300
400
500
PRESSURE [MPaG]
ENTHALPY [kJ/kg]

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/058336

A. CLASSIFICATION OF SUBJECT MATTER
F25B1/00(2006.01)i

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)
F25B1/00

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2009
Kokai Jitsuyo Shinan Koho	1971-2009	Toroku Jitsuyo Shinan Koho	1994-2009

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2005-337700 A (Fuji Electric Retail Systems Co., Ltd.), 08 December, 2005 (08.12.05), Claim 7; Par. No. [0048] (Family: none)	1-6
Y	JP 2007-303379 A (Mitsubishi Electric Corp.), 22 November, 2007 (22.11.07), Par. No. [0154] & US 2007-261238 A1	1-6
Y	JP 2006-77998 A (Matsushita Electric Industrial Co., Ltd.), 23 March, 2006 (23.03.06), Par. No. [0005]; Fig. 6 & EP 1632733 A2	5

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search
15 May, 2009 (15.05.09)

Date of mailing of the international search report
26 May, 2009 (26.05.09)

Name and mailing address of the ISA/
Japanese Patent Office

Facsimile No.

Authorized officer

Telephone No.

Form PCT/ISA/210 (second sheet) (April 2007)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Non-patent literature cited in the description

- *Refrigeration,* March 2008, vol. 83 (965 **[0004]**