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(54) Benævnelse: **USE OF REFRIGERANT COMPOSITION**

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DESCRIPTION

[0001] The present invention relates to a refrigerant composition and more particularly to a refrigerant composition comprising 1,1-difluoroethylene (R-1132a; vinylidene fluoride) that is useful in a mobile or automotive heat pump system, especially systems for electric vehicles.

[0002] The listing or discussion of a prior-published document or any background in the specification should not necessarily be taken as an acknowledgement that a document or background is part of the state of the art or is common general knowledge.

[0003] US 2017/335159 describes an air-conditioner working fluid for an electric vehicle containing trifluoroethylene, difluoromethane, and 1,3,3,3-tetrafluoropropene.

[0004] The introduction of electric vehicles, where there is no combustion engine to provide a source of heat for the passenger cabin, has meant increasing focus on use of the vehicle air-conditioning unit to run as a heat pump in cold weather. This can be accomplished by reversing the direction of refrigerant flow around the air-conditioning circuit, so that refrigerant is evaporated at low temperature using heat from ambient air and condensed at high temperature against air circulated into the passenger cabin. By using the air-conditioning system in this way, it is possible to deliver more heat to the cabin per unit of electrical energy drawn from the battery than if it were used to provide heat by electrical resistance heating of the incoming cabin air.

[0005] The need for passenger air heating is at its highest when outside air is at its coldest, which presents particular challenges for operating the air-conditioning unit as a heat pump. In particular:

- Ambient air temperature can be as low as -25 to -30°C, meaning that to achieve heat pump operation in these conditions the refrigerant should evaporate at temperatures below -30°C.
- Passenger air from the vent into the cabin is ideally heated to 40-50°C, meaning the refrigerant must condense at temperatures higher than 40°C
- Refrigerant evaporation pressure should not fall below 1 atmosphere to avoid ingress of air to the system.
- The same refrigerant fluid should give acceptable performance in air-conditioning and heat pump modes of operation.
- Global Warming Potential (GWP) should be below 150 for new fluids to comply with EU F-Gas regulations.

[0006] 1,1,1,2-tetrafluoroethane (R-134a) was for some years the refrigerant of choice in automotive air conditioning systems following the phase out of dichlorodifluoromethane (R-12) which being a CFC has a high ozone depletion potential. The EU F-Gas Directive was then implemented which mandates a Global Warming Potential (GWP) limit of 150 for new car mobile air-conditioning (MAC) systems. As a result, the use of R-134a has now been largely superseded for new systems in Europe by the use of flammable 2,3,3,3-tetrafluoropropene (R-1234yf). R-1234yf is slightly less efficient than R-134a and new system designs now include extra equipment (an internal heat exchanger) to recover the loss in efficiency.

[0007] Mobile air conditioning systems that use either R-134a or R-1234yf as the refrigerant cannot operate efficiently in heat pump mode if the ambient temperature is lower than about -15 to - 20°C, because their evaporation pressure at the required evaporation temperature would drop below atmospheric pressure. Carbon dioxide (R-744) is a high pressure refrigerant which can work well as a low temperature heat pump fluid. However, its performance in air-conditioning mode for car systems is known to be worse (less energy efficient) than either R-134a or R-1234yf at moderate to high ambient air temperatures.

[0008] There is a need for a refrigerant composition that can operate efficiently in a mobile, e.g. automotive, heat pump system for heating vehicles, especially electric vehicles. There is a need to find a working refrigerant fluid for use in a combined mobile heat pump/air-conditioner system in an electric vehicle that is capable of operating as a heat pump cycle working fluid with a positive (greater than atmospheric suction pressure) at evaporation temperatures down to about -30C, whilst also giving acceptable performance (energy efficiency) when used in the air-conditioning mode. Furthermore, any new refrigerant to be developed for an automotive system must have a Global Warming Potential (GWP) of less than

150 to comply with European environmental legislation.

[0009] We have found that compositions of 1,1-difluoroethylene (R-1132a; vinylidene fluoride) with other hydrofluorocarbon refrigerants offer the potential for improved performance compared to R-1234yf when used in automotive heat pump systems, particularly for electric vehicles. The compositions can also offer acceptable performance when used in air-conditioning mode. The compositions are capable of abstracting heat from the environment at lower ambient temperatures than is possible with R-1234yf or R-134a and in addition can offer improved energy efficiency. This is an especially desirable combination of properties for use in electric vehicles, which must otherwise use battery energy to provide heat for passenger comfort.

[0010] Accordingly, in a first aspect the present invention provides a use as a refrigerant in a heat pump system in an electric vehicle of a composition comprising from 3 to 30% by weight 1,1-difluoroethylene (R-1132a) based on the total weight of the composition and at least one fluorocarbon refrigerant compound selected from the group consisting of 2,3,3,3-tetrafluoropropene (R-1234yf), difluoromethane (R-32), 1,3,3,3-tetrafluoropropene (R-1234ze(E)) and 1,1-difluoroethane (R-152a).

[0011] Conveniently, the refrigerant composition further comprises at least one of trifluoroethylene (R-1123), trifluoroiodomethane (CF_3I), carbon dioxide (R-744, CO_2) and 1,1,1,2-tetrafluoroethane (R-134a).

[0012] In a further aspect, the invention provides a use as a refrigerant in a heat pump system in an electric vehicle of a composition comprising from 3 to 30% by weight 1,1-difluoroethylene (R-1132a) based on the total weight of the composition and trifluoroiodomethane (CF_3I).

[0013] Preferred compositions of the invention contain from 3 to 20 weight %, such as from about 3 to 15 weight % of the 1,1-difluoroethylene (R-1132a) based on the total weight of the refrigerant composition.

[0014] In an embodiment, the refrigerant composition comprises from 3 to 30% by weight 1,1-difluoroethylene (R-1132a), at least one tetrafluoropropene refrigerant compound selected from the group consisting of 2,3,3,3-tetrafluoropropene (R-1234yf) and 1,3,3,3-tetrafluoropropene (R-1234ze(E)) and optionally difluoromethane (R-32). In this embodiment, the R-1132a is preferably present in an amount of from 3 to 20 weight % based on the total weight of the refrigerant composition. Where difluoromethane is included, it is preferably present in an amount of from 1 to 21 weight % based on the total weight of the refrigerant composition. Whether the composition of this first embodiment is a binary or a ternary composition the selected tetrafluoropropene provides the balance of the refrigerant composition.

[0015] When trifluoroiodomethane (CF_3I) is included in the composition of the invention, typically it is present in an amount less than R-1234yf or R-1234ze(E). A preferred CF_3I-containing composition of the invention comprises from 3 to 30% by weight R-1132a, R-32, R-1234yf and CF_3I.

[0016] When carbon dioxide (CO_2) is included in the compositions of the invention, typically the combined content of R-1132a and CO_2 is less than about 30 weight %, such as less than about 20 weight %. A preferred CO_2-containing composition of the invention comprises from 3 to 30% by weight R-1132a, R-32, R-1234yf and CO_2.

[0017] In another embodiment, the refrigerant composition comprises from 3 to 30% by weight R-1132a, R-152a and optionally R-32.

[0018] In a further embodiment, the refrigerant composition comprises from 3 to 30% by weight R-1132a, R-152a and R-1234yfsuch as from 4 to 10 weight % R-1132a, from 2 to 30 weight % R-152a and from 60 to 94 weight % R-1234yf.

[0019] In a further embodiment, the refrigerant composition comprises from 3 to 30% by weight R-1132a, R-32, R-152a and at least one tetrafluoropropene refrigerant compound selected from the group consisting of R-1234yf and R-1234ze(E).

[0020] The refrigerant compositions of the invention may also contain R-134a, typically in an amount of from about 1 to about 10 weight % based on the total weight of the refrigerant composition. Preferred R-134a-containing compositions include those comprising R-1132a, CF_3I and R-134a; R-1132a, R-1234yf and R-134a; R-1132a, R-1234ze(E) and R-134a;

R-1132a, R-1234yf, R-32 and R-134a; R-1132a, R-1234ze(E), R-32 and R-134a; R-1132a, R-1234yf, CF_3I and R-134a; R-1132a, R-1234ze(E), CF_3I and R-134a; R-1132a, R-152a and R-134a; R-1132a, R-152a, R-32 and R-134a; R-1132a, R-1234yf, R-152a and R-134a; and R-1132a, R-1234ze(E), R-152a and R-134a.

[0021] When trifluoroethylene (R-1123) is included in the compositions of the invention, typically it is present in less than about 30 weight %, such as less than about 20 weight %. A preferred R-1123-containing composition of the invention comprises from 3 to 30% by weight R-1132a, R-1123 and R-1234yf or wherein the refrigerant composition comprises from 3 to 30% by weight R-1132a, R-152a, R-134a and R-1234yf. Preferred R-1123 containing compositions are those where the maximum molar content of R-1123 in the blend as formulated and in the vapour in equilibrium with the blend will be less than about 55% at temperatures of -40 °C or higher. This is to reduce the risk of R-1123 disproportionation (self-reaction). The above-described compositions and the tabulated compositions (see Examples 24 to 27 below) are predicted to meet these criteria.

[0022] Further compositions of the present invention comprise, optionally consist essentially of, R-1132a, R-32 and CO_2, preferably from about 3 to about 20 weight % R-1132a, from about 1 to about 32 weight % R-32 and from about 50 to about 95 weight % CO_2, such as from about 3 to about 15 weight % R-1132a, from about 2 to about 32 weight % R-32 and from about 55 to about 93weight % CO_2, such as from about 64 to about 93 weight % of carbon dioxide, from about 2 to about 25 weight % of difluoromethane and from about 3 to about 14 weight % of R-1132a, for example from about 65 to about 93 weight % of carbon dioxide, from about 2 to about 22 weight % of difluoromethane and from about 3 to about 14 weight % of R-1132a. These compositions may contain substantially no R-1234yf.

[0023] By "substantially no", we include the meaning that the compositions of the invention contain 0.5% by weight or less of the stated component, preferably 0.1% or less, based on the total weight of the composition.

[0024] As used herein, all % amounts mentioned in compositions herein, including in the claims, are by weight based on the total weight of the compositions, unless otherwise stated.

[0025] In an embodiment, the compositions may consist essentially of the stated components. By the term "consist essentially of", we include the meaning that the compositions of the invention contain substantially no other components, particularly no further (hydro)(fluoro)compounds (e.g. (hydro)(fluoro)alkanes or (hydro)(fluoro)alkenes) known to be used in heat transfer compositions. The term "consist of" is included within the meaning of "consist essentially of".

[0026] For the avoidance of doubt, it is to be understood that the stated upper and lower values for ranges of amounts of components in the compositions of the invention described herein may be interchanged in any way, provided that the resulting ranges fall within the broadest scope of the invention.

[0027] The refrigerant compositions will typically be combined with a lubricant when used in a heat pump or combined heat pump and air-conditioning system. Suitable lubricants include polyol esters, such as neopentyl polyol esters, and polyalkylene glycols, preferably end capped at one or both ends with an alkyl, e.g. a C_{1-4} alkyl, group.

[0028] The compositions of the invention have zero ozone depletion potential.

[0029] Typically, the compositions of the invention have a GWP of less than about 150, such as less than about 100, for example less than about 50.

[0030] Typically, the compositions of the invention are of reduced flammability hazard when compared to R-1132a.

[0031] Flammability may be determined in accordance with ASHRAE Standard 34 incorporating the ASTM Standard E-681 with test methodology as per Addendum 34p dated 2004, the entire content of which is incorporated herein by reference.

[0032] In one aspect, the compositions have one or more of (a) a higher lower flammable limit; (b) a higher ignition energy (c) a higher auto-ignition temperature; or (d) a lower flame velocity compared to R-1132a alone. Preferably, the compositions of the invention are less flammable compared to R-1132a in one or more of the following respects: lower flammable limit at 23°C; lower flammable limit at 60°C; breadth of flammable range at 23°C or 60°C; auto-ignition temperature (thermal decomposition temperature); minimum ignition energy in dry air, or burning velocity. The flammable limit and burning velocity being determined according to the methods specified in ASHRAE-34 and the auto-ignition temperature being determined in a 500ml glass flask by the method of ASTM E659-78.

[0033] Preferred compositions of the invention are those which have laminar burning velocity less than 10 cm/s, and especially preferred are those where the formulation and the "worst case fractionated formulation" both have burning velocity below 10 cm/s, meaning that they will be classified as "2L" flammable under ASHRAE Standard 34.

[0034] In a preferred embodiment, the compositions of the invention are non-flammable. For example, the compositions of the invention are non-flammable at a test temperature of 60°C using the ASHRAE-34 methodology. Advantageously, the mixtures of vapour that exist in equilibrium with the compositions of the invention at any temperature between about -20°C and 60°C are also non-flammable.

[0035] In some applications it may not be necessary for the formulation to be classed as non-flammable by the ASHRAE-34 methodology. It is possible to develop fluids whose flammability limits will be sufficiently reduced in air to render them safe for use in the application, for example if it is physically not possible to make a flammable mixture by leaking the refrigeration equipment charge into the surrounds.

[0036] In one embodiment, the compositions of the invention have a flammability classifiable as 1 or 2L according to the ASHRAE standard 34 classification method, indicating non-flammability (class 1) or a weakly flammable fluid with flame speed lower than 10 cm/s (class 2L).

[0037] The compositions of the invention preferably have a temperature glide in an evaporator or condenser of less than about 15K, even more preferably less than about 10K, and even more preferably less than about 5K.

[0038] The compositions of the present invention are useful in mobile, e.g. automotive, heat pump applications and also exhibit acceptable performance in mobile air-conditioning applications. The compositions may provide particular benefits where the heat pump and/or air-conditioning system is used in an electric vehicle, whether a purely electric or hybrid vehicle.

[0039] Unless otherwise stated, it is to be understood that the term "electric vehicle" refers to both purely electric vehicles as well as vehicles which use electricity as one of several means of propulsion, such as hybrid vehicles.

[0040] Preferably, in the use of the invention, the refrigerant compositions evaporate at temperatures below about -30°C, thereby enabling heat pump operation at ambient air temperatures as low as -25 to -30°C.

[0041] Accordingly, in a further aspect the present invention provides an electric vehicle with a heat pump and/or air-conditioning system which uses a refrigerant composition of the first aspect of the invention. The refrigerant composition can be as described in any of the embodiments discussed above.

[0042] Accordingly, the invention also provides (i) a method of producing cooling in an electric vehicle which method comprises evaporating a refrigerant composition of the invention in the vicinity of a body to be cooled; and (ii) a method of producing heating in an electric vehicle which method comprises condensing a refrigerant composition of the invention in the vicinity of a body to be heated.

[0043] The invention is illustrated by the following non-limiting examples.

EXAMPLES

[0044] The invention is now illustrated by theoretical cycle modelling of performance of selected compositions of the invention in a heat pump cycle and in an air-conditioning cycle. R-1234yf was chosen as the reference refrigerant for both cycles.

[0045] The modelling was carried out in Microsoft Excel using NIST REFPROP10 as the thermodynamic data source. The phase equilibrium of mixtures of R-1132a with R-32 and R-1234yf was first studied using a constant-volume apparatus to measure the vapour pressure of binary mixtures of R-1132a/R-32 or R-1132a/R-1234yf over a range of temperatures from - 70C to +40C. This data was then regressed to yield binary interaction parameters for use in REFPROP that reproduced the experimental data.

[0046] For the heat pump cycle the following conditions were assumed:

Data Input Section		**R1234yf**
Heating duty	kW	4
Mean condenser temperature	°C	45
Mean evaporator temperature	°C	-20
Condenser subcooling	K	5
Evaporator superheat	K	5
Evaporator pressure drop	bar	0
Suction line pressure drop	bar	0
Condenser pressure drop	bar	0
Compressor suction superheat	K	10
Isentropic efficiency		65%

[0047] The cycle modelled included intermediate pressure vapour injection of refrigerant vapour to improve cycle performance. For each composition the optimum injection pressure was determined so as to maximise the Coefficient of Performance (COP) for heating.

[0048] Results for selected binary and ternary mixtures of the invention are summarised in the following Examples 1-8. It was discovered that incorporation of R-1132a increased the COP (energy efficiency) and increased the evaporation pressure of the refrigerants compared to R-1234yf. It also reduced the volumetric flow of refrigerant that would need to be pumped through the system, indicating that pressure drop losses would be reduced compared to R-1234yf. For comparison, modelled performance data of two commercially available blends (R-454C and R-516A) is also provided in the table below:

Results		**R1234yf**	**R454C**	**R516A**
Heating COP		3.08	3.73	3.13
Heating COP relative to reference		100.0%	120.9%	101.5%
Compressor displacement needed	m^3/hr	11.0	7.4	10.5
Compressor displacement relative to reference		100.0%	67.4%	95.9%
Compressor discharge temperature	°C	45.6	64.5	49.7
Discharge temp. difference from reference	K	0.0	18.9	4.1
Evaporator inlet pressure	bar	1.51	2.34	1.51
Condenser inlet pressure	bar	11.5	17.9	11.8
Evaporator glide (out-in)	K	0.0	6.3	0.0
Condenser glide (in-out)	K	0.0	6.6	0.0

Example 1 (binary compositions of R-1132a and R-1234yf

[0049]

Results		R1234yf	R1132a	0*	2	4	6	8	10	12	14	16	18	20
			R1234yf	100	98	96	94	92	90	88	86	84	82	80
Heating COP		3.08		3.08	3.13	3.18	3.24	3.29	3.35	3.42	3.48	3.55	3.63	3.71
Heating COP relative to reference		100.0%		100.0%	101.6%	103.2%	105.0%	106.8%	108.8%	110.8%	113.0%	115.3%	117.7%	120.2%
Compressor displacement needed	m^3/hr	11.0		11.0	10.6	10.2	9.9	9.6	9.2	8.9	8.6	8.4	8.1	7.9
Compressor displacement relative to reference		100.0%		100.0%	96.5%	93.1%	90.0%	86.9%	84.0%	81.3%	78.7%	76.2%	73.9%	71.7%
Compressor discharge temperature	°C	45.6		45.6	48.2	50.7	53.1	55.4	57.5	59.6	61.5	63.3	65.0	66.6
Discharge temp. difference from reference	K	0.0		0.0	2.6	5.1	7.5	9.8	11.9	14.0	15.9	17.7	19.4	21.0
Evaporator inlet pressure	bar	1.51		1.51	1.56	1.62	1.69	1.76	1.83	1.91	2.00	2.09	2.18	2.29
Condenser inlet pressure	bar	11.5		11.5	12.3	13.1	13.9	14.6	15.4	16.2	17.0	17.7	18.5	19.3
Evaporator glide (out-in)	K	0.0		0.0	0.8	1.7	2.7	3.6	4.6	5.5	6.5	7.5	8.4	9.4
Condenser glide (in-out)	K	0.0		0.0	2.5	4.8	6.7	8.4	9.9	11.2	12.4	13.3	14.1	14.8

*Comparative performance data for a composition comprising 0 weight % R-1132a and 100 weight % R-1234yf (not according to the invention)

Example 2 (ternary compositions of R-1132a, 4 wt% R-32 and R-1234yf)

[0050]

Results		R1234yf	R1132a	0*	2	4	6	8	10	12	14	16	18	20
			R32	4	4	4	4	4	4	4	4	4	4	4
			R1234yf	96	94	92	90	88	86	84	82	80	78	76
Heating COP		3.08		3.20	3.26	3.31	3.37	3.43	3.50	3.57	3.64	3.72	3.80	3.89
Heating COP relative to reference		100.0%		103.9%	105.6%	107.4%	109.4%	111.4%	113.5%	115.8%	118.2%	120.7%	123.3%	126.2%
Displacement needed	m^3/hr	11.0		10.0	9.7	9.4	9.1	8.8	8.5	8.2	8.0	7.7	7.5	7.3
Compressor displacement relative to reference		100.0%		91.2%	88.2%	85.3%	82.6%	79.9%	77.4%	75.0%	72.8%	70.6%	68.6%	66.8%
Compressor discharge temperature	°C	45.6		50.7	53.1	55.3	57.5	59.5	61.5	63.3	65.0	66.6	68.1	69.6
Discharge temp. difference from reference	K	0.0		5.0	7.4	9.7	11.8	13.9	15.8	17.6	19.4	21.0	22.5	23.9
Evaporator inlet pressure	bar	1.51		1.64	1.71	1.78	1.85	1.93	2.02	2.11	2.20	2.30	2.40	2.51
Condenser inlet pressure	bar	11.5		13.0	13.8	14.6	15.3	16.1	16.9	17.6	18.4	19.2	20.0	20.8
Evaporator glide (out-in)	K	0.0		1.8	2.7	3.6	4.5	5.5	6.4	7.3	8.2	9.1	10.0	10.8
Condenser glide (in-out)	K	0.0		3.8	5.8	7.4	8.9	10.2	11.3	12.3	13.1	13.8	14.4	14.8

*Comparative performance data for a composition comprising 0 weight % R-1132a, 4 weight % R-32 and 96 weight % R-1234yf (not according to the invention)

Example 3 (ternary compositions of R-1132a, 12 wt% R-32 and R-1234yf)

[0051]

Results		R1234yf	R1132a	0*	2	4	6	8	10	12	14	16	18	20
			R32	12	12	12	12	12	12	12	12	12	12	12
			R1234yf	88	86	84	82	80	78	76	74	72	70	68
Heating COP		3.08		3.45	3.51	3.58	3.65	3.72	3.80	3.88	3.96	4.06	4.16	4.26
Heating COP relative to reference		100.0%		111.8%	113.9%	116.0%	118.2%	120.6%	123.1%	125.8%	128.6%	131.6%	134.8%	138.2%
Displacement needed	m^3/hr	11.0		8.5	8.3	8.0	7.8	7.6	7.4	7.2	7.0	6.8	6.7	6.5
Compressor displacement relative to reference		100.0%		77.8%	75.5%	73.3%	71.2%	69.3%	67.4%	65.6%	64.0%	62.4%	60.9%	59.5%
Compressor discharge temperature	°C	45.6		58.2	60.2	62.1	64.0	65.7	67.4	68.9	70.4	71.8	73.1	74.4
Discharge temp. difference from reference	K	0.0		12.5	14.6	16.5	18.3	20.1	21.7	23.3	24.8	26.2	27.5	28.8
Evaporator inlet pressure	bar	1.51		1.96	2.04	2.12	2.21	2.31	2.40	2.51	2.62	2.73	2.84	2.97
Condenser inlet pressure	bar	11.5		15.5	16.3	17.0	17.8	18.6	19.3	20.1	20.9	21.7	22.5	23.3
Evaporator glide (out-in)	K	0.0		4.8	5.6	6.4	7.2	8.0	8.8	9.6	10.3	11.0	11.8	12.2
Condenser glide (in-out)	K	0.0		6.7	7.9	9.1	10.0	10.9	11.6	12.2	12.7	13.1	13.4	13.6

*Comparative performance data for a composition comprising 0 weight % R-1132a, 12 weight % R-32 and 88 weight % R-1234yf (not according to the invention)

Example 4 (ternary compositions of R-1132a, 20 wt% R-32 and R-1234yf)

[0052]

Results		R1234yf	R1132a	0*	2	4	6	8	10	12	14	16	18	20
			R32	20	20	20	20	20	20	20	20	20	20	20
			R1234yf	80	78	76	74	72	70	68	66	64	62	60
Heating COP		3.08		3.68	3.76	3.83	3.91	3.99	4.08	4.18	4.28	4.39	4.51	4.64
Heating COP relative to reference		100.0%		119.5%	121.8%	124.3%	126.8%	129.6%	132.5%	135.6%	138.9%	142.5%	146.3%	150.6%
Displacement needed	m^3/hr	11.0		7.5	7.3	7.2	7.0	6.8	6.7	6.6	6.4	6.2	6.1	6.0
Compressor displacement relative to reference		100.0%		68.7%	66.9%	65.3%	63.7%	62.1%	60.7%	59.3%	58.0%	56.8%	55.6%	54.5%
Compressor discharge temperature	°C	45.6		63.6	65.5	67.3	69.0	70.6	72.1	73.5	74.9	76.2	77.4	78.6
Discharge temp. difference from reference	K	0.0		18.0	19.9	21.6	23.3	24.9	26.4	27.9	29.3	30.6	31.8	33.0
Evaporator inlet pressure	bar	1.51		2.28	2.37	2.47	2.57	2.67	2.78	2.89	3.01	3.13	3.25	3.38
Condenser inlet pressure	bar	11.5		17.6	18.4	19.1	19.9	20.7	21.5	22.3	23.1	23.9	24.7	25.5
Evaporator glide (out-in)	K	0.0		6.2	6.9	7.5	8.2	8.8	9.4	10.0	10.5	11.0	11.5	11.9
Condenser glide (in-out)	K	0.0		6.7	7.7	8.5	9.3	9.9	10.4	10.8	11.1	11.4	11.6	11.7

*Comparative performance data for a composition comprising 0 weight % R-1132a, 20 weight % R-32 and 80 weight % R-1234yf (not according to the invention)

Example 5 (binary compositions of R-1132a and R-152a)

[0053]

Results		R1234yf	R1132a	0*	2	4	6	8	10	12	14	16	18	20
			R152a	100	98	96	94	92	90	88	86	84	82	80
Heating COP		3.08		3.02	3.05	3.09	3.13	3.17	3.22	3.27	3.32	3.38	3.44	3.50
Heating COP relative to reference		100.0%		97.9%	99.0%	100.2%	101.5%	102.9%	104.4%	106.0%	107.7%	109.6%	111.6%	113.6%

Compressor displacement needed	m³/hr	11.0		10.8	10.6	10.4	10.2	9.9	9.7	9.4	9.2	8.9	8.7	8.4
Compressor displacement relative to reference		100.0%		98.8%	96.9%	94.9%	92.7%	90.5%	88.2%	85.8%	83.5%	81.1%	78.9%	76.8%
Compressor discharge temperature	°C	45.6		64.5	68.8	73.4	78.0	82.4	86.2	89.5	92.2	94.6	96.1	97.5
Discharge temp. difference from reference	K	0.0		18.9	23.2	27.8	32.3	36.7	40.6	43.9	46.6	48.9	50.5	51.9
Evaporator inlet pressure	bar	1.51		1.21	1.24	1.27	1.31	1.35	1.40	1.46	1.52	1.59	1.66	1.74
Condenser inlet pressure	bar	11.5		10.4	11.2	12.0	12.7	13.5	14.2	14.9	15.6	16.3	17.0	17.7
Evaporator glide (out-in)	K	0.0		0.0	0.7	1.6	2.5	3.5	4.6	5.7	6.9	8.2	9.4	10.7
Condenser glide (in-out)	K	0.0		0.0	4.0	7.6	10.7	13.3	15.6	17.6	19.3	20.7	21.9	22.9

*Comparative performance data for a composition comprising 0 weight % R-1132a and 100 weight % R-152a (not according to the invention)

Example 6 (ternary compositions of R-1132a, 8 wt% R-32 and R-1234yf)

[0054]

			R1132a	0*	2	4	6	8	10	12	14	16	18	20
			R32	8	8	8	8	8	8	8	8	8	8	8
Results		R1234yf	R1234yf	92	90	88	86	84	82	80	78	76	74	72
Heating COP		3.08		3.33	3.38	3.44	3.51	3.58	3.65	3.72	3.80	3.89	3.98	4.07
Heating COP relative to reference		100.0%		107.9%	109.7%	111.7%	113.8%	116.0%	118.3%	120.8%	123.4%	126.1%	129.1%	132.2%
Displacement needed	m³/hr	11.0		9.2	8.9	8.6	8.4	8.1	7.9	7.7	7.5	7.3	7.1	6.9
Compressor displacement relative to reference		100.0%		83.9%	81.3%	78.7%	76.3%	74.0%	71.9%	69.8%	67.9%	66.1%	64.4%	62.8%
Compressor discharge temperature	°C	45.6		54.8	57.0	59.0	61.0	62.9	64.6	66.3	67.9	69.4	70.8	72.1
Discharge temp. difference from reference	K	0.0		9.2	11.3	13.4	15.4	17.2	19.0	20.7	22.2	23.7	25.1	26.5
Evaporator inlet pressure	bar	1.51		1.79	1.87	1.95	2.03	2.12	2.21	2.31	2.41	2.52	2.63	2.74
Condenser inlet pressure	bar	11.5		14.4	15.1	15.9	16.6	17.4	18.2	18.9	19.7	20.5	21.3	22.1
Evaporator glide (out-in)	K	0.0		3.4	4.3	5.2	6.1	7.0	7.8	8.7	9.5	10.3	11.1	11.8
Condenser glide (in-out)	K	0.0		5.8	7.3	8.7	9.9	10.9	11.8	12.5	13.1	13.6	14.0	14.4

*Comparative performance data for a composition comprising 0 weight % R-1132a, 8 weight % R-32 and 92 weight % R-1234yf (not according to the invention)

Example 7 (ternary compositions of R-1132a, 16 wt% R-32 and R-1234yf)

[0055]

			R1132a	0*	2	4	6	8	10	12	14	16	18	20
			R32	16	16	16	16	16	16	16	16	16	16	16
Results		R1234yf	R1234yf	84	82	80	78	76	74	72	70	68	66	64
Heating COP		3.08		3.57	3.63	3.70	3.78	3.86	3.94	4.03	4.12	4.22	4.33	4.45
Heating COP relative to reference		100.0%		115.7%	117.9%	120.2%	122.6%	125.1%	127.8%	130.7%	133.8%	137.0%	140.5%	144.3%
Displacement needed	m³/hr	11.0		8.0	7.8	7.6	7.4	7.2	7.0	6.8	6.7	6.5	6.4	6.2
Compressor displacement relative to reference		100.0%		72.8%	70.8%	68.9%	67.1%	65.4%	63.7%	62.2%	60.7%	59.3%	58.0%	56.8%
Compressor discharge temperature	°C	45.6		61.0	63.0	64.8	66.6	68.2	69.8	71.3	72.7	74.1	75.3	76.6
Discharge temp. difference from reference	K	0.0		15.4	17.3	19.2	20.9	22.6	24.2	25.7	27.1	28.4	29.7	30.9
Evaporator inlet pressure	bar	1.51		2.12	2.21	2.30	2.39	2.49	2.60	2.70	2.82	2.93	3.05	3.18
Condenser inlet pressure	bar	11.5		16.6	17.4	18.1	18.9	19.7	20.5	21.2	22.0	22.8	23.6	24.5
Evaporator glide (out-in)	K	0.0		5.7	6.5	7.2	7.9	8.6	9.3	10.0	10.6	11.2	11.7	12.2
Condenser glide (in-out)	K	0.0		6.9	8.0	8.9	9.8	10.5	11.1	11.6	12.0	12.3	12.5	12.6

*Comparative performance data for a composition comprising 0 weight % R-1132a, 16 weight % R-32 and 92 weight % R-1234yf (not according to the invention)

Example 8 (ternary compositions of R-1132a, 21.5 wt% R-32 and R-1234yf)

[0056]

			R1132a	0*	2	4	6	8	10	12	14	16	18	20
			R32	21.5	21.5	21.5	21.5	21.5	21.5	21.5	21.5	21.5	21.5	21.5
Results		R1234yf	R1234yf	78.5	76.5	74.5	72.5	70.5	68.5	66.5	64.5	62.5	60.5	58.5
Heating COP		3.08		3.73	3.80	3.88	3.96	4.05	4.14	4.24	4.34	4.46	4.58	4.71
Heating COP relative to reference		100.0%		120.9%	123.3%	125.8%	128.4%	131.2%	134.2%	137.4%	140.9%	144.6%	148.6%	152.8%
Displacement needed	m³/hr	11.0		7.4	7.2	7.0	6.9	6.7	6.5	6.4	6.3	6.1	6.0	5.9
Compressor displacement relative to reference		100.0%		67.4%	65.7%	64.1%	62.5%	61.1%	59.7%	58.4%	57.1%	55.9%	54.8%	53.8%
Compressor discharge temperature	°C	45.6		64.5	66.4	68.1	69.8	71.4	72.9	74.3	75.7	77.0	78.2	79.3
Discharge temp. difference from reference	K	0.0		18.9	20.7	22.5	24.2	25.8	27.3	28.7	30.0	31.3	32.6	33.7
Evaporator inlet pressure	bar	1.51		2.34	2.43	2.53	2.63	2.73	2.84	2.96	3.08	3.20	3.33	3.46
Condenser inlet pressure	bar	11.5		17.9	18.7	19.5	20.3	21.1	21.9	22.7	23.5	24.3	25.1	25.9
Evaporator glide (out-in)	K	0.0		6.3	6.9	7.6	8.2	8.8	9.3	9.9	10.4	10.9	11.3	11.7
Condenser glide (in-out)	K	0.0		6.6	7.5	8.3	9.0	9.6	10.1	10.5	10.8	11.0	11.2	11.3

*Comparative performance data for a composition comprising 0 weight % R-1132a, 21.5 weight % R-32 and 78.5 weight % R-1234yf (not according to the invention)

[0057] Air-conditioning performance was then assessed (Examples 9 and 10) using the following theoretical cycle modelling conditions representing operating in a high temperature ambient condition:

Data Input Section		R1234yf
Cooling duty	kW	6
Mean condenser temperature	°C	65
Mean evaporator temperature	°C	5
Condenser subcooling	K	5
Evaporator superheat	K	5
Evaporator pressure drop	bar	0
Suction line pressure drop	bar	0
Condenser pressure drop	bar	0
Compressor suction superheat	K	10
Isentropic efficiency		65%

[0058] It was found possible to obtain improved heating mode performance and also to obtain cooling mode performance where the theoretical COP for cooling was within about 10% of that obtained with R-1234yf. The fluids of the invention would operate at higher pressure and reduced mass/volumetric flows compared to R-1234yf meaning that efficiency losses in a real system from pressure drop effects would also be reduced compared to R-1234yf.

Example 9 (binary compositions of R-1132a and R-1234yf)

[0059]

Results		R1132a	0*	2	4	6	8	10	12	14	16	18	20
		R1234yf	100	98	96	94	92	90	88	86	84	82	80
Cooling COP			1.84	1.82	1.81	1.79	1.78	1.76	1.74	1.72	1.70	1.68	1.66
Cooling COP relative to reference			100.0 %	99.3 %	98.5 %	97.6 %	96.7 %	95.8 %	94.8 %	93.8 %	92.7 %	91.5 %	90.3 %
Compressor displacement needed.	m³/hr		13.1	12.5	12.0	11.5	11.1	10.7	10.3	10.0	9.7	9.4	9.1
Compressor displacement relative to reference			100.0 %	95.6 %	91.6 %	88.0 %	84.7 %	81.6 %	78.8 %	76.3 %	73.9 %	71.7 %	69.8 %
Compressor discharge temperature	°C		87.1	89.0	90.8	92.6	94.2	95.7	97.2	98.6	99.9	101.2	102.4
Discharge temp. difference from reference	K		0.0	1.9	3.7	5.4	7.0	8.6	10.1	11.5	12.8	14.1	15.3
Evaporator inlet pressure	bar		3.73	3.90	4.07	4.25	4.44	4.63	4.84	5.04	5.26	5.48	5.71
Condenser inlet pressure	bar		18.3	19.4	20.5	21.6	22.6	23.7	24.8	25.9	27.1	28.2	29.3
Evaporator glide (out-in)	K		0.0	0.7	1.4	2.0	2.7	3.4	4.0	4.6	5.2	5.7	6.2
Condeniser glide (in-out)	K		0.0	1.9	3.6	5.1	6.3	7.4	8.3	9.1	9.7	10.2	10.5

*Comparative performance data for a composition comprising 0 weight % R-1132a and 100 weight % R-1234yf (not according to the invention)

Example 10 (ternary compositions of R-1132a, 8 wt% R-32 and R-1234yf))

[0060]

Results		R1132a	0*	2	4	6	8	10	12	14	16	18	20
		R32	8	8	8	8	8	8	8	8	8	8	8
		R1234yf	92	90	88	86	84	82	80	78	76	74	72
Cooling COP			1.83	1.81	1.80	1.78	1.76	1.74	1.71	1.69	1.67	1.64	1.62
Cooling COP relative to reference			99.8 %	98.8 %	97.8 %	96.7 %	95.7 %	94.5 %	93.3 %	92.1 %	90.8 %	89.5 %	88.1 %
Displacement needed	m3/hr		10.7	10.3	9.9	9.6	9.3	9.1	8.8	8.6	8.4	8.2	8.0
Compressor displacement relative to reference			81.5 %	78.7 %	76.0 %	73.6 %	71.3 %	69.3 %	67.4 %	65.6 %	64.0 %	62.5 %	61.2 %
Compressor discharge temperature	°C		95.7	97.3	98.7	100.1	101.5	102.8	104.0	105.1	106.3	107.3	108.4
Discharge temp. difference from reference	K		8.6	10.1	11.6	13.0	14.3	15.6	16.8	18.0	19.1	20.2	21.2
Evaporator inlet pressure	bar		4.48	4.67	4.87	5.07	5.29	5.50	5.73	5.96	6.20	6.44	6.69
Condenser inlet pressure	bar		22.5	23.6	24.7	25.8	26.9	28.0	29.1	30.2	31.4	32.5	33.7
Evaporator glide (out-in)	K		2.4	3.1	3.7	4.3	4.8	5.4	5.9	6.3	6.7	7.1	7.5
Condenser glide (in-out)	K		4.7	5.8	6.8	7.6	8.2	8.7	9.2	9.5	9.7	9.7	9.7

*Comparative performance data for a composition comprising 0 weight % R-1132a and 8 weight % R-32 and 92 weight % R-1234yf (not according to the invention)

[0061] The performance of selected binary, ternary and quaternary compositions of the present invention in a heat pump cycle is further demonstrated in the Examples 11 to 34 below. Again, R-1234yf was chosen as the reference refrigerant for the cycle.

[0062] The following operating conditions were assumed:

Data Input Section		R-1234yf
Compressor displacement	m3/hr	16.5
Mean condenser temperature	°C	45.0
Mean evaporator temperature	°C	-25.0
Condenser subcooling	K	3.0
Evaporator superheat	K	1.0
Evaporator pressure drop	bar	0.20
Suction line pressure drop	bar	0.10
Condenser pressure drop	bar	0.20
Compressor suction superheat	K	10.0
Isentropic efficiency		65.0%

[0063] In summary, the modelled performance data demonstrates the following advantages of the compositions according to the present invention:

1. (a) Essentially equivalent or improved energy efficiency (COP) in heating mode cycle operation compared to R-1234yf alone
2. (b) Increased evaporation pressure, leading to higher volumetric capacity and better ability to operate at lower external air temperatures

[0064] Furthermore, performance in the air-conditioning cycle of selected binary blends comprising R-1132a and R-32 and ternary blends comprising R-1132a, R-32 and CO_2 is demonstrated in the Examples 35 to 37 below.

Example 11 (binary compositions of R-1132a and R-1234ze(E))

[0065]

			R1132a	4%	6%	8%	10%	12%
			R1234ze(E)	96%	94%	92%	90%	88%
Results		**R1234yf**		**4%/96%**	**6%/94%**	**8%/92%**	**10%/90%**	**12%/88%**
Heating COP		2.39		2.48	2.47	2.45	2.44	2.43
Volumetric heating Capacity	kJ/m3	1108		944	1011	1077	1145	1213
Heating Capacity relative to Reference		100.0%		85.2%	91.2%	97.3%	103.3%	109.5%
Pressure ratio		9.39		12.57	12.98	13.23	13.35	13.38
Compressor discharge temperature	°C	71.6		86.9	90.3	93.3	95.9	98.1
Discharge temp. difference from reference	K	0.0		15.2	18.7	21.7	24.2	26.5
Evaporator inlet pressure	bar	1.23		0.88	0.93	0.99	1.05	1.12
Condenser inlet pressure	bar	11.54		11.03	12.10	13.11	14.08	15.02
Evaporator glide (out-in)	K	0.0		2.0	3.1	4.2	5.4	6.5
Condenser glide (in-out)	K	0.0		12.3	16.5	19.8	22.3	24.2

Example 12 (binary compositions of R-1132a and CF_3I)

[0066]

			R1132a	4%	6%	8%	10%	12%	14%
			CF3I	96%	94%	92%	90%	88%	86%
Results		**R1234yf**		**4%/96%**	**6%/94%**	**8%/92%**	**10%/90%**	**12%/88%**	**14%/86%**
Heating COP		2.39		2.60	2.58	2.56	2.54	2.53	2.52
Volumetric heating Capacity	kJ/m3	1108		1189	1310	1431	1553	1675	1795
Heating Capacity relative to Reference		100.0%		107.3%	118.3%	129.2%	140.2%	151.2%	162.1%
Pressure ratio		9.39		10.25	10.35	10.31	10.20	10.05	9.88
Compressor discharge temperature	°C	71.6		123.2	126.2	128.2	129.6	130.5	131.1
Discharge temp. difference from reference	K	0.0		51.6	54.5	56.5	57.9	58.9	59.5
Evaporator inlet pressure	bar	1.23		1.10	1.22	1.34	1.47	1.61	1.75
Condenser inlet pressure	bar	11.54		11.27	12.59	13.83	15.02	16.17	17.28

Evaporator glide (out-in)	K	0.0	4.6	6.8	9.0	10.9	12.7	14.3
Condenser glide (in-out)	K	0.0	15.2	19.6	22.7	24.9	26.4	27.3

Example 13 (ternary compositions of 4 wt% R-1132a, R-1234yf and CF_3I)

[0067]

			R1132a	4%	4%	4%	4%	4%	4%	4%
			R1234yf	10%	20%	30%	40%	50%	60%	70%
			CF3I	86%	76%	66%	56%	46%	36%	26%
Results		R1234yf								
Heating COP		2.39		2.57	2.54	2.51	2.48	2.45	2.43	2.41
Volumetric heating Capacity	kJ/m3	1108		1248	1288	1312	1322	1320	1308	1290
Heating Capacity relative to Reference		100.0%		112.7%	116.3%	118.4%	119.4%	119.2%	118.1%	116.5%
Pressure ratio		9.39		9.88	9.63	9.47	9.38	9.36	9.39	9.46
Compressor discharge temperature	°C	71.6		111.0	102.0	95.2	89.9	86.0	83.0	80.6
Discharge temp. difference from reference	K	0.0		39.4	30.4	23.5	18.3	14.4	11.3	9.0
Evaporator inlet pressure	bar	1.23		1.20	1.28	1.35	1.39	1.41	1.41	1.40
Condenser inlet pressure	bar	11.54		11.88	12.37	12.75	13.02	13.19	13.27	13.28
Evaporator glide (out-in)	K	0.0		4.5	3.9	3.1	2.4	1.9	1.6	1.5
Condenser glide (in-out)	K	0.0		12.7	10.5	8.6	7.1	6.1	5.5	5.1

Example 14 (ternary compositions of 8 wt% R-1132a, R-1234yf and CF_3I

[0068]

			R1132a	8%	8%	8%	8%	8%	8%
			R1234yf	10%	20%	30%	40%	50%	60%
			CF3I	82%	72%	62%	52%	42%	32%
Results		R1234yf							
Heating COP		2.39		2.53	2.50	2.48	2.45	2.43	2.41
Volumetric heating Capacity	kJ/m3	1108		1467	1488	1496	1491	1476	1452
Heating Capacity relative to Reference		100.0%		132.5%	134.3%	135.0%	134.6%	133.2%	131.1%
Pressure ratio		9.39		9.95	9.72	9.58	9.51	9.51	9.56
Compressor discharge temperature	°C	71.6		115.6	106.3	99.3	93.9	89.8	86.7
Discharge temp. difference from reference	K	0.0		44.0	34.7	27.6	22.3	18.2	15.1
Evaporator inlet pressure	bar	1.23		1.43	1.50	1.55	1.57	1.58	1.57
Condenser inlet pressure	bar	11.54		14.24	14.57	14.82	14.97	15.03	15.02
Evaporator glide (out-in)	K	0.0		7.9	6.5	5.2	4.2	3.5	3.1
Condenser glide (in-out)	K	0.0		18.7	15.5	13.1	11.3	10.1	9.3

Example 15 (ternary compositions of 10 wt% R-1132a, R-1234yf and CF_3I)

[0069]

			R1132a	10%	10%	10%	10%	10%	10%
			R1234yf	10%	20%	30%	40%	50%	60%
			CF3I	80%	70%	60%	50%	40%	30%
Results		R1234yf							
Heating COP		2.39		2.52	2.49	2.46	2.44	2.41	2.40
Volumetric heating Capacity	kJ/m3	1108		1577	1588	1587	1576	1554	1524
Heating Capacity relative to Reference		100.0%		142.4%	143.4%	143.3%	142.2%	140.3%	137.6%
Pressure ratio		9.39		9.89	9.69	9.57	9.52	9.53	9.60
Compressor discharge temperature	°C	71.6		117.2	107.9	100.9	95.5	91.4	88.3
Discharge temp. difference from reference	K	0.0		45.5	36.3	29.2	23.9	19.8	16.7
Evaporator inlet pressure	bar	1.23		1.55	1.61	1.65	1.67	1.67	1.65
Condenser inlet pressure	bar	11.54		15.36	15.63	15.82	15.92	15.93	15.87
Evaporator glide (out-in)	K	0.0		9.3	7.7	6.2	5.0	4.3	3.9
Condenser glide (in-out)	K	0.0		20.6	17.2	14.6	12.8	11.5	10.8

Example 16 (quaternary compositions of 4 wt% R-1132a, 8 wt% R-32, R-1234yf and CF_3I)

[0070]

R1132a			4%	4%	4%	4%	4%
R32			8%	8%	8%	8%	8%
R1234yf			10%	20%	30%	40%	50%
CF3I			78%	68%	58%	48%	38%
Results		R1234yf					
Heating COP		2.39	2.55	2.52	2.49	2.47	2.45
Volumetric heating Capacity	kJ/m3	1108	1747	1740	1724	1700	1667
Heating Capacity relative to Reference		100.0%	157.7%	157.1%	155.7%	153.5%	150.5%
Pressure ratio		9.39	9.36	9.28	9.24	9.24	9.29
Compressor discharge temperature	°C	71.6	122.6	113.0	105.6	100.0	95.7
Discharge temp. difference from reference	K	0.0	50.9	41.4	34.0	28.4	24.1
Evaporator inlet pressure	bar	1.23	1.73	1.77	1.79	1.79	1.78
Condenser inlet pressure	bar	11.54	16.19	16.41	16.55	16.58	16.53
Evaporator glide (out-in)	K	0.0	10.5	8.4	6.6	5.4	4.7
Condenser glide (in-out)	K	0.0	17.5	14.6	12.4	10.9	9.9

Example 17 (ternary compositions of R-1132a, 5 wt% R-32 and R-152a)

[0071]

R1132a			4%	6%	8%	10%	12%
R32			5%	5%	5%	5%	5%
R152a			91%	89%	87%	85%	83%
GWP			147	144	142	139	137
Results		R1234yf					
Heating COP		2.39	2.61	2.60	2.59	2.58	2.56
Volumetric heating Capacity	kJ/m3	1108	1263	1312	1362	1413	1466
Heating Capacity relative to Reference		100.0%	114.0%	118.4%	122.9%	127.6%	132.4%
Pressure ratio		9.39	11.03	11.15	11.24	11.29	11.32
Compressor discharge temperature	°C	71.6	123.5	125.0	126.3	127.5	128.6
Discharge temp. difference from reference	K	0.0	51.8	53.4	54.7	55.9	57.0
Evaporator inlet pressure	bar	1.23	1.12	1.16	1.21	1.26	1.31
Condenser inlet pressure	bar	11.54	12.33	12.95	13.57	14.20	14.82
Evaporator glide (out-in)	K	0.0	2.3	3.1	3.9	4.7	5.5
Condenser glide (in-out)	K	0.0	6.7	8.8	10.7	12.4	13.9

Example 18 (quaternary compositions of 4 wt% R-1132a, 6 wt% R-32, R-1234yf and R-152a)

[0072]

R1132a			4%	4%	4%	4%	4%	4%	4%
R32			6%	6%	6%	6%	6%	6%	6%
R1234yf			80%	70%	60%	50%	40%	30%	20%
R152a			10%	20%	30%	40%	50%	60%	70%
GWP			54	66	78	91	103	115	128
Results		R1234yf							
Heating COP		2.39	2.43	2.46	2.49	2.52	2.54	2.57	2.58
Volumetric heating Capacity	kJ/m3	1108	1444	1436	1419	1398	1375	1351	1326
Heating Capacity relative to Reference		100.0%	130.4%	129.6%	128.1%	126.2%	124.1%	121.9%	119.7%
Pressure ratio		9.39	9.82	9.94	10.09	10.25	10.42	10.58	10.73
Compressor discharge temperature	°C	71.6	88.1	92.6	97.3	102.0	106.6	111.2	115.6
Discharge temp. difference from reference	K	0.0	16.5	21.0	25.7	30.4	35.0	39.6	44.0
Evaporator inlet pressure	bar	1.23	1.52	1.48	1.42	1.37	1.31	1.26	1.22
Condenser inlet pressure	bar	11.54	14.98	14.68	14.35	14.01	13.68	13.36	13.05
Evaporator glide (out-in)	K	0.0	2.8	2.7	2.8	2.8	2.9	2.9	2.8
Condenser glide (in-out)	K	0.0	7.3	6.9	6.7	6.7	6.7	6.8	6.9

Example 19 (quaternary compositions of 4 wt% R-1132a, 12 wt% R-32, R-1234yf and R-152a)

[0073]

R1132a	4%	4%	4%	4%	4%	4%
R32	12%	12%	12%	12%	12%	12%

Results		R1234yf						
R1234yf			80%	70%	60%	50%	40%	30%
R152a			4%	14%	24%	34%	44%	54%
GWP			87	99	111	124	136	148
Heating COP		2.39	2.42	2.45	2.48	2.51	2.54	2.56
Volumetric heating Capacity	kJ/m3	1108	1640	1616	1585	1550	1514	1479
Heating Capacity relative to Reference		100.0%	148.1%	145.9%	143.1%	139.9%	136.7%	133.5%
Pressure ratio		9.39	9.60	9.72	9.88	10.06	10.24	10.41
Compressor discharge temperature	°C	71.6	91.7	96.0	100.7	105.4	110.1	114.7
Discharge temp. difference from reference	K	0.0	20.0	24.4	29.0	33.7	38.4	43.0
Evaporator inlet pressure	bar	1.23	1.75	1.68	1.60	1.53	1.46	1.39
Condenser inlet pressure	bar	11.54	16.85	16.36	15.86	15.38	14.92	14.49
Evaporator glide (out-in)	K	0.0	4.3	3.9	3.9	3.9	3.9	3.9
Condenser glide (in-out)	K	0.0	8.7	8.1	7.8	7.8	7.8	7.9

Example 20 (quaternary compositions of 4 wt% R-1132a, 16 wt% R-32, R-1234yf and R-152a)

[0074]

Results		R1234yf					
R1132a			4%	4%	4%	4%	4%
R32			16%	16%	16%	16%	16%
R1234yf			76%	70%	60%	50%	48%
R152a			4%	10%	20%	30%	32%
GWP			114	121	133	146	148
Heating COP		2.39	2.42	2.45	2.48	2.51	2.51
Volumetric heating Capacity	kJ/m3	1108	1767	1745	1702	1657	1648
Heating Capacity relative to Reference		100.0%	159.5%	157.5%	153.6%	149.6%	148.7%
Pressure ratio		9.39	9.45	9.54	9.72	9.91	9.95
Compressor discharge temperature	°C	71.6	95.4	98.0	102.6	107.4	108.4
Discharge temp. difference from reference	K	0.0	23.7	26.4	31.0	35.8	36.7
Evaporator inlet pressure	bar	1.23	1.89	1.83	1.74	1.65	1.63
Condenser inlet pressure	bar	11.54	17.87	17.50	16.89	16.31	16.20
Evaporator glide (out-in)	K	0.0	4.8	4.6	4.4	4.4	4.4
Condenser glide (in-out)	K	0.0	8.7	8.4	8.1	8.1	8.2

Example 21 (quaternary compositions of 8 wt% R-1132a, 16 wt% R-32, R-1234yf and R-152a)

[0075]

Results		R1234yf						
R1132a			8%	8%	8%	8%	8%	8%
R32			16%	16%	16%	16%	16%	16%
R1234yf			72%	70%	60%	50%	48%	44%
R152a			4%	6%	16%	26%	28%	32%
GWP			114	116	129	141	143	148
Heating COP		2.39	2.40	2.41	2.45	2.48	2.48	2.49
Volumetric heating Capacity	kJ/m3	1108	1908	1900	1852	1800	1790	1769
Heating Capacity relative to Reference		100.0%	172.3%	171.5%	167.2%	162.5%	161.6%	159.7%
Pressure ratio		9.39	9.42	9.45	9.65	9.87	9.91	10.00
Compressor discharge temperature	°C	71.6	98.4	99.3	104.0	108.9	109.9	111.8
Discharge temp. difference from reference	K	0.0	26.7	27.6	32.3	37.3	38.2	40.2
Evaporator inlet pressure	bar	1.23	2.06	2.04	1.92	1.82	1.79	1.75
Condenser inlet pressure	bar	11.54	19.39	19.25	18.57	17.91	17.78	17.54
Evaporator glide (out-in)	K	0.0	5.9	5.8	5.7	5.7	5.7	5.8
Condenser glide (in-out)	K	0.0	10.3	10.2	10.2	10.4	10.4	10.6

Example 22 (ternary compositions of R-1132a, 10 wt% R-32 and R-1234ze(E) and R-1132a, 21 wt% R-32 and R-1234ze(E))

[0076]

Results		R1234yf										
R1132a			4%	6%	8%	10%	12%	4%	6%	8%	10%	12%
R32			10%	10%	10%	10%	10%	21%	21%	21%	21%	21%
R1234ze(E)			86%	84%	82%	80%	78%	75%	73%	71%	69%	67%
Heating COP		2.39	2.50	2.49	2.47	2.46	2.44	2.51	2.50	2.48	2.47	2.45
Volumetric heating Capacity	kJ/m3	1108	1227	1302	1377	1453	1530	1550	1631	1713	1796	1880
Heating Capacity relative to												

Heating Capacity relative to Reference		100.0%	110.8%	117.5%	124.3%	131.2%	138.2%	139.9%	147.2%	154.6%	162.2%	169.8%
Pressure ratio		9.39	11.98	12.11	12.15	12.14	12.07	11.09	11.12	11.10	11.05	10.97
Compressor discharge temperature	°C	71.6	98.6	101.2	103.5	105.5	107.3	109.1	111.2	113.0	114.7	116.2
Discharge temp. difference from reference	K	0.0	27.0	29.6	31.9	33.9	35.7	37.5	39.6	41.4	43.1	44.5
Evaporator inlet pressure	bar	1.23	1.14	1.21	1.29	1.37	1.45	1.46	1.55	1.64	1.73	1.83
Condenser inlet pressure	bar	11.54	13.69	14.68	15.65	16.59	17.50	16.25	17.22	18.17	19.11	20.03
Evaporator glide (out-in)	K	0.0	5.7	6.8	7.9	8.9	10.0	8.4	9.3	10.1	11.0	11.8
Condenser glide (in-out)	K	0.0	15.3	17.9	19.9	21.4	22.5	14.9	16.5	17.8	18.7	19.4

Example 23 (quaternary compositions of 3 wt% R-1132a, 3 wt% CO_2, R-32 and R-1234yf)

[0077]

R1132a	3%	3%	3%	3%	3%	3%
R744	3%	3%	3%	3%	3%	3%
R32	4%	8%	12%	16%	20%	21%
R1234yf	90%	86%	82%	78%	74%	73%
GWP	28	55	82	109	136	143

Results		R1234yf						
Heating COP		2.39	2.39	2.39	2.40	2.40	2.40	2.40
Volumetric heating Capacity	kJ/m3	1108	1548	1686	1823	1956	2084	2115
Heating Capacity relative to Reference		100.0%	139.7%	152.2%	164.6%	176.6%	188.1%	191.0%
Pressure ratio		9.39	10.39	10.13	9.86	9.62	9.41	9.36
Compressor discharge temperature	°C	71.6	88.7	92.4	95.9	99.2	102.3	103.1
Discharge temp. difference from reference	K	0.0	17.0	20.8	24.3	27.5	30.7	31.5
Evaporator inlet pressure	bar	1.23	1.63	1.79	1.94	2.10	2.24	2.28
Condenser inlet pressure	bar	11.54	16.96	18.11	19.17	20.16	21.09	21.32
Evaporator glide (out-in)	K	0.0	4.2	5.2	6.0	6.5	6.6	6.6
Condenser glide (in-out)	K	0.0	14.3	14.0	13.4	12.5	11.5	11.3

Example 24 (quaternary compositions of 4 wt% R-1132a, 4 wt% CO_2, R-32 and R-1234yf)

[0078]

R1132a	4%	4%	4%	4%	4%	4%
R744	4%	4%	4%	4%	4%	4%
R32	4%	8%	12%	16%	20%	21%
R1234yf	88%	84%	80%	76%	72%	71%
GWP	28	55	82	109	136	143

Results		R1234yf						
Heating COP		2.39	2.38	2.38	2.39	2.39	2.39	2.39
Volumetric heating Capacity	kJ/m3	1108	1652	1793	1931	2065	2193	2225
Heating Capacity relative to Reference		100.0%	149.1%	161.8%	174.3%	186.4%	198.0%	200.9%
Pressure ratio		9.39	10.49	10.18	9.89	9.63	9.41	9.37
Compressor discharge temperature	°C	71.6	91.8	95.3	98.6	101.8	104.8	105.6
Discharge temp. difference from reference	K	0.0	20.2	23.7	27.0	30.1	33.2	33.9
Evaporator inlet pressure	bar	1.23	1.74	1.90	2.06	2.22	2.36	2.40
Condenser inlet pressure	bar	11.54	18.23	19.33	20.37	21.34	22.26	22.48
Evaporator glide (out-in)	K	0.0	5.2	6.2	6.9	7.3	7.3	7.3
Condenser glide (in-out)	K	0.0	16.6	15.8	14.9	13.7	12.6	12.3

Example 25 (quaternary compositions of 4 wt% R-1132, 2 wt% CO_2, R-32 and R-1234yf)

[0079]

R1132a	4%	4%	4%	4%	4%	4%
R744	2%	2%	2%	2%	2%	2%
R32	4%	8%	12%	16%	20%	21%
R1234yf	90%	86%	82%	78%	74%	73%
GWP	28	55	82	109	136	143

Results		R1234yf						
Heating COP		2.39	2.39	2.39	2.40	2.40	2.40	2.40
Volumetric heating Capacity	kJ/m3	1108	1511	1650	1788	1922	2051	2082
Heating Capacity relative to Reference		100.0%	136.4%	149.0%	161.4%	173.5%	185.1%	188.0%
Pressure ratio		9.39	10.23	10.01	9.77	9.55	9.35	9.31

Pressure ratio		9.39	10.23	10.01	9.77	[illegible]	[illegible]	[illegible]
Compressor discharge temperature	°C	71.6	87.0	90.9	94.5	97.9	101.1	101.9
Discharge temp. difference from reference	K	0.0	15.4	19.3	22.9	26.2	29.5	30.3
Evaporator inlet pressure	bar	1.23	1.61	1.76	1.92	2.07	2.21	2.25
Condenser inlet pressure	bar	11.54	16.43	17.63	18.73	19.75	20.71	20.94
Evaporator glide (out-in)	K	0.0	3.8	4.9	5.7	6.2	6.4	6.4
Condenser glide (in-out)	K	0.0	12.7	12.8	12.4	11.7	10.8	10.6

Example 26 (quaternary compositions of 5 wt% R-1132a, 3 wt% CO_2, R-32 and R-1234yf)

[0080]

R1132a			5%	5%	5%	5%	5%	5%
R744			3%	3%	3%	3%	3%	3%
R32			4%	8%	12%	16%	20%	21%
R1234yf			88%	84%	80%	76%	72%	71%
GWP			28	55	82	109	136	143
Results		R1234yf						
Heating COP		2.39	2.38	2.38	2.39	2.39	2.39	2.39
Volumetric heating Capacity	kJ/m3	1108	1615	1756	1895	2030	2160	2191
Heating Capacity relative to Reference		100.0%	145.8%	158.6%	171.1%	183.3%	195.0%	197.8%
Pressure ratio		9.39	10.36	10.09	9.82	9.57	9.37	9.32
Compressor discharge temperature	°C	71.6	90.3	93.9	97.3	100.5	103.6	104.4
Discharge temp. difference from reference	K	0.0	18.6	22.3	25.7	28.9	32.0	32.8
Evaporator inlet pressure	bar	1.23	1.71	1.87	2.03	2.19	2.34	2.37
Condenser inlet pressure	bar	11.54	17.72	18.87	19.94	20.94	21.88	22.11
Evaporator glide (out-in)	K	0.0	4.9	5.9	6.6	7.0	7.1	7.1
Condenser glide (in-out)	K	0.0	15.2	14.8	14.0	13.0	12.0	11.7

Example 27 (ternary compositions of 4 wt% R-1132a, R-1123 and R-1234yf)

[0081]

R1132a			4%	4%	4%	4%	4%	4%	4%
R1123			4%	8%	12%	16%	20%	24%	28%
R1234yf			92%	88%	84%	80%	76%	72%	68%
Results		R1234yf							
Heating COP		2.39	2.38	2.38	2.38	2.38	2.38	2.37	2.37
Volumetric heating Capacity	kJ/m3	1108	1303	1380	1460	1543	1627	1714	1803
Heating Capacity relative to Reference		100.0%	117.6%	124.6%	131.8%	139.3%	146.9%	154.7%	162.7%
Pressure ratio		9.39	9.73	9.70	9.66	9.59	9.50	9.40	9.30
Compressor discharge temperature	°C	71.6	78.8	81.2	83.5	85.7	87.9	90.0	92.0
Discharge temp. difference from reference	K	0.0	7.1	9.5	11.8	14.1	16.2	18.3	20.4
Evaporator inlet pressure	bar	1.23	1.43	1.51	1.60	1.70	1.80	1.90	2.01
Condenser inlet pressure	bar	11.54	13.87	14.66	15.46	16.26	17.06	17.87	18.69
Evaporator glide (out-in)	K	0.0	1.9	2.5	3.1	3.7	4.3	4.8	5.2
Condenser glide (in-out)	K	0.0	6.1	7.2	8.0	8.7	9.1	9.4	9.5

Example 28 (ternary compositions of 6 wt% R-1132a, R-1123 and R-1234yf)

[0082]

R1132a			6%	6%	6%	6%	6%	6%	6%
R1123			4%	8%	12%	16%	20%	24%	28%
R1234yf			90%	86%	82%	78%	74%	70%	66%
Results		R1234yf							
Heating COP		2.39	2.37	2.37	2.37	2.37	2.37	2.36	2.35
Volumetric heating Capacity	kJ/m3	1108	1368	1448	1530	1615	1702	1792	1883
Heating Capacity relative to Reference		100.0%	123.5%	130.7%	138.1%	145.8%	153.7%	161.8%	170.0%
Pressure ratio		9.39	9.81	9.77	9.70	9.62	9.52	9.41	9.30
Compressor discharge temperature	°C	71.6	80.8	83.1	85.4	87.6	89.7	91.7	93.7
Discharge temp. difference from reference	K	0.0	9.2	11.5	13.8	15.9	18.1	20.1	22.1
Evaporator inlet pressure	bar	1.23	1.49	1.58	1.68	1.78	1.88	1.99	2.11
Condenser inlet pressure	bar	11.54	14.66	15.47	16.29	17.10	17.93	18.76	19.61
Evaporator glide (out-in)	K	0.0	2.6	3.2	3.8	4.4	4.9	5.4	5.8
Condenser glide (in-out)	K	0.0	7.9	8.8	9.5	10.0	10.3	10.5	10.5

Example 29 (ternary compositions of 8 wt% R-1132a, R-1123 and R-1234yf)

[0083]

Results		R1234yf							
R1132a			8%	8%	8%	8%	8%	8%	8%
R1123			4%	8%	12%	16%	20%	24%	28%
R1234yf			88%	84%	80%	76%	72%	68%	64%
Heating COP		2.39	2.37	2.37	2.36	2.36	2.35	2.35	2.34
Volumetric heating Capacity	kJ/m3	1108	1434	1516	1602	1689	1779	1871	1965
Heating Capacity relative to Reference		100.0%	129.4%	136.9%	144.6%	152.5%	160.6%	168.9%	177.4%
Pressure ratio		9.39	9.86	9.80	9.72	9.62	9.52	9.40	9.28
Compressor discharge temperature	°C	71.6	82.7	85.0	87.2	89.3	91.4	93.4	95.3
Discharge temp. difference from reference	K	0.0	11.1	13.4	15.6	17.7	19.8	21.8	23.7
Evaporator inlet pressure	bar	1.23	1.57	1.66	1.76	1.87	1.98	2.09	2.21
Condenser inlet pressure	bar	11.54	15.45	16.28	17.12	17.95	18.80	19.66	20.53
Evaporator glide (out-in)	K	0.0	3.2	3.9	4.5	5.1	5.6	6.0	6.4
Condenser glide (in-out)	K	0.0	9.5	10.2	10.8	11.1	11.3	11.4	11.3

Example 30 (ternary compositions of 10 wt% R-1132a, R-1123 and R-1234yf)

[0084]

Results		R1234yf							
R1132a			10%	10%	10%	10%	10%	10%	10%
R1123			4%	8%	12%	16%	20%	24%	28%
R1234yf			86%	82%	78%	74%	70%	66%	62%
Heating COP		2.39	2.36	2.36	2.35	2.35	2.34	2.34	2.33
Volumetric heating Capacity	kJ/m3	1108	1501	1586	1674	1764	1857	1952	2048
Heating Capacity relative to Reference		100.0%	135.5%	143.2%	151.1%	159.3%	167.6%	176.2%	184.9%
Pressure ratio		9.39	9.89	9.82	9.72	9.61	9.50	9.37	9.25
Compressor discharge temperature	°C	71.6	84.6	86.8	88.9	91.0	93.0	95.0	96.9
Discharge temp. difference from reference	K	0.0	12.9	15.2	17.3	19.4	21.4	23.3	25.2
Evaporator inlet pressure	bar	1.23	1.64	1.74	1.85	1.96	2.07	2.19	2.32
Condenser inlet pressure	bar	11.54	16.24	17.09	17.95	18.81	19.68	20.56	21.45
Evaporator glide (out-in)	K	0.0	3.9	4.5	5.1	5.7	6.2	6.6	7.0
Condenser glide (in-out)	K	0.0	10.8	11.4	11.8	12.1	12.2	12.1	11.9

Example 31 (ternary compositions of 4 weight % R-1132a, R-152a and R-1234yf)

[0085]

Results		R1234yf											
R1132a			4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
R1234yf			5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	92%
R152a			91%	86%	76%	66%	56%	46%	36%	26%	16%	6%	4%
Heating COP		2.39	2.61	2.61	2.59	2.57	2.55	2.53	2.50	2.47	2.44	2.40	2.40
Volumetric heating Capacity	kJ/m3	1108	1190	1198	1214	1230	1245	1257	1266	1269	1264	1246	1241
Heating Capacity relative to Reference		100.0%	107.4 %	108.2 %	109.6 %	111.1 %	112.4 %	113.5 %	114.3 %	114.6 %	114.1 %	112.5 %	112.0 %
Pressure ratio		9.39	11.04	10.97	10.83	10.68	10.52	10.36	10.19	10.02	9.88	9.76	9.74
Compressor discharge temperature	°C	71.6	118.2	116.1	111.8	107.4	102.8	98.1	93.4	88.6	83.8	79.1	78.1
Discharge temp. difference from reference	K	0.0	46.6	44.5	40.2	35.8	31.2	26.5	21.7	16.9	12.1	7.4	6.5
Evaporator inlet pressure	bar	1.23	1.06	1.08	1.11	1.15	1.18	1.22	1.26	1.30	1.33	1.35	1.35
Condenser inlet pressure	bar	11.54	11.69	11.80	12.02	12.24	12.45	12.66	12.86	13.01	13.12	13.13	13.12
Evaporator glide (out-in)	K	0.0	1.5	1.6	1.7	1.7	1.7	1.6	1.5	1.4	1.3	1.2	1.2
Condenser glide (in-out)	K	0.0	5.3	5.3	5.2	5.1	4.9	4.8	4.6	4.5	4.5	4.6	4.7

Example 32 (ternary compositions of 6 weight % R-1132a, R-152a and R-1234yf)

[0086]

R1132a	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%
R1234yf	4%	10%	20%	30%	40%	50%	60%	70%	80%	90%
R152a	90%	84%	74%	64%	54%	44%	34%	24%	14%	4%

Results		R1234yf										
Heating COP		2.39	2.60	2.59	2.58	2.56	2.54	2.51	2.49	2.46	2.43	2.39
Volumetric heating Capacity	kJ/m3	1108	1235	1245	1263	1281	1297	1311	1321	1325	1320	1302
Heating Capacity relative to Reference		100.0%	111.5%	112.4%	114.0%	115.6%	117.1%	118.3%	119.2%	119.6%	119.2%	117.5%
Pressure ratio		9.39	11.20	11.11	10.95	10.79	10.62	10.44	10.26	10.10	9.95	9.85
Compressor discharge temperature	°C	71.6	120.2	117.7	113.3	108.8	104.1	99.4	94.5	89.7	84.9	80.2
Discharge temp. difference from reference	K	0.0	48.6	46.0	41.6	37.1	32.5	27.7	22.9	18.1	13.3	8.6
Evaporator inlet pressure	bar	1.23	1.10	1.12	1.15	1.19	1.24	1.28	1.32	1.36	1.39	1.41
Condenser inlet pressure	bar	11.54	12.29	12.42	12.65	12.89	13.12	13.35	13.56	13.73	13.85	13.88
Evaporator glide (out-in)	K	0.0	2.2	2.3	2.4	2.4	2.4	2.3	2.2	2.0	1.9	1.9
Condenser glide (in-out)	K	0.0	7.6	7.5	7.4	7.2	6.9	6.7	6.5	6.3	6.4	6.6

Example 33 (ternary compositions of 8 weight % R-1132a, R-152a and R-1234yf)

[0087]

		R1132a	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%
		R1234yf	4%	10%	20%	30%	40%	50%	60%	70%	80%	88%
		R152a	88%	82%	72%	62%	52%	42%	32%	22%	12%	4%
Results		R1234yf										
Heating COP		2.39	2.59	2.58	2.56	2.54	2.52	2.50	2.47	2.44	2.41	2.38
Volumetric heating Capacity	kJ/m3	1108	1282	1294	1313	1332	1350	1366	1378	1383	1378	1364
Heating Capacity relative to Reference		100.0%	115.8%	116.8%	118.6%	120.3%	121.9%	123.3%	124.4%	124.8%	124.4%	123.2%
Pressure ratio		9.39	11.31	11.21	11.04	10.87	10.68	10.50	10.31	10.14	10.00	9.92
Compressor discharge temperature	°C	71.6	121.7	119.0	114.6	110.0	105.3	100.5	95.6	90.7	85.9	82.2
Discharge temp. difference from reference	K	0.0	50.0	47.4	42.9	38.4	33.6	28.8	24.0	19.1	14.3	10.6
Evaporator inlet pressure	bar	1.23	1.14	1.16	1.20	1.25	1.29	1.34	1.38	1.43	1.46	1.47
Condenser inlet pressure	bar	11.54	12.90	13.04	13.29	13.54	13.79	14.03	14.26	14.46	14.59	14.63
Evaporator glide (out-in)	K	0.0	3.0	3.1	3.2	3.2	3.1	3.0	2.8	2.7	2.6	2.5
Condenser glide (in-out)	K	0.0	9.6	9.5	9.3	9.0	8.7	8.4	8.1	8.0	8.0	8.3

Example 34 (ternary compositions of 10 weight % R-1132a, R-152a and R-1234yf)

[0088]

		R1132a	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
		R1234yf	4%	10%	20%	30%	40%	50%	60%	70%	80%	86%
		R152a	86%	80%	70%	60%	50%	40%	30%	20%	10%	4%
Results		R1234yf										
Heating COP		2.39	2.57	2.57	2.55	2.53	2.51	2.49	2.46	2.43	2.40	2.38
Volumetric heating Capacity	kJ/m3	1108	1331	1344	1365	1386	1406	1423	1436	1442	1438	1428
Heating Capacity relative to Reference		100.0%	120.2%	121.3%	123.2%	125.1%	126.9%	128.5%	129.7%	130.2%	129.8%	128.9%
Pressure ratio		9.39	11.38	11.28	11.10	10.91	10.72	10.52	10.33	10.16	10.02	9.97
Compressor discharge temperature	°C	71.6	122.9	120.3	115.7	111.1	106.3	101.4	96.5	91.6	86.8	84.1
Discharge temp. difference from reference	K	0.0	51.3	48.6	44.1	39.4	34.7	29.8	24.9	20.0	15.2	12.4
Evaporator inlet pressure	bar	1.23	1.19	1.21	1.25	1.30	1.35	1.40	1.45	1.50	1.53	1.54
Condenser inlet pressure	bar	11.54	13.51	13.66	13.92	14.19	14.46	14.73	14.98	15.19	15.34	15.39
Evaporator glide (out-in)	K	0.0	3.8	3.8	3.9	3.9	3.8	3.7	3.5	3.3	3.2	3.2
Condenser glide (in-out)	K	0.0	11.5	11.3	11.0	10.6	10.3	9.9	9.6	9.5	9.5	9.7

Example 35 (ternary compositions of 4 wt% R-1132a, R-32 and CO_2 and ternary compositions comprising 8 wt% R-1132a, R-32 and CO_2)

[0089]

		CO2	92%	88%	84%	80%	76%	72%	68%	64%
		R1132a	4%	4%	4%	4%	4%	4%	4%	4%
		R32	4%	8%	12%	16%	20%	24%	28%	32%
Coefficient of Performance (COP)			2.73	2.80	2.87	2.97	307	3.17	3.24	3.29
Volumetric cooling capacity	kJ/m^3		13948	13584	13213	12840	12500	12472	12323	12092
Compressor discharge temperature	°C		102.6	103.4	103.9	103.9	103.7	105.6	107.3	108.9
Evaporator pressure	bar		39.5	37.5	35.5	33.6	31.8	30.2	28.6	27.1

		CO2	92%	88%	84%	80%	76%	72%	68%	64%
		R1132a	4%	4%	4%	4%	4%	4%	4%	4%
		R32	4%	8%	12%	16%	20%	24%	28%	32%
Gas cooler pressure	bar		85.6	81.4	77.2	72.9	68.7	66.2	63.7	61.3
Evaporator temperature glide	K		1.1	2.3	3.3	4.4	5.3	6.4	7.3	8.1
RESULTS										
		CO2	88%	84%	80%	76%	72%	68%	64%	60%
		R1132a	8%	8%	8%	8%	8%	8%	8%	8%
		R32	4%	8%	12%	16%	20%	24%	28%	32%
Coefficient of Performance (COP)			2.71	2.77	2.85	2.94	304	3.15	3.23	3.28
Volumetric cooling capacity	kJ/m^3		13729	13375	13014	12648	12285	12214	12094	11878
Compressor discharge temperature	°C		101.8	102.6	103.1	103.2	102.8	104.1	105.8	107.3
Evaporator pressure	bar		39.2	37.2	35.3	33.4	31.6	30.0	28.4	26.9
Gas cooler pressure	bar		85.2	81.0	76.9	72.6	68.3	65.5	63.0	60.6
Evaporator temperature glide	K		1.1	2.2	3.3	4.3	5.3	6.2	7.1	7.9

Example 36 (ternary compositions of 10 wt% R-1132a, R-32 and CO_2 and ternary compositions comprising 14 wt% R-1132a, R-32 and CO_2)

[0090]

		CO2	88%	84%	80%	76%	72%	69%	64%	60%
		R1132a	10%	10%	10%	10%	10%	10%	10%	10%
		R32	2%	6%	10%	14%	18%	21%	26%	30%
Coefficient of Performance (COP)			2.66	2.73	2.79	2.87	2.97	3.05	3.18	3.25
Volumetric cooling capacity	kJ/m^3		13789	13446	13077	12717	12359	12084	12028	11875
Compressor discharge temperature	°C		100.8	101.8	102.5	102.9	102.8	102.4	104.3	105.9
Evaporator pressure	bar		40.2	38.1	36.0	34.1	32.3	31.0	29.0	27.5
Gas cooler pressure	bar		87.0	82.9	78.8	74.6	70.3	67.1	63.8	61.4
Evaporator temperature glide	K		0.6	1.7	2.7	3.8	4.8	5.4	6.6	7.5
RESULTS										
		CO2	82%	78%	74%	70%	65%	60%	56%	
		R1132a	14%	14%	14%	14%	14%	14%	14%	
		R32	4%	8%	12%	16%	21%	26%	30%	
Coefficient of Performance (COP)			2.67	2.73	2.81	2.89	3.02	3.16	3.24	
Volumetric cooling capacity	kJ/m^3		13383	13045	12696	12347	11903	11784	11654	
Compressor discharge temperature	°C		100.6	101.4	101.9	102.1	101.6	102.9	104.4	
Evaporator pressure	bar		38.8	36.8	34.8	33.0	30.8	28.7	27.2	
Gas cooler pressure	bar		84.4	80.4	76.2	72.1	66.8	63.1	60.6	

RESULTS										
		CO2	82%	78%	74%	70%	65%	60%	56%	
		R1132a	14%	14%	14%	14%	14%	14%	14%	
		R32	4%	8%	12%	16%	21%	26%	30%	
Evaporator temperature glide	K		1.1	2.2	3.2	4.2	5.4	6.5	7.3	

Example 37 (binary compositions of R-1132a and R-32)

[0091]

RESULTS										
		R1132a	100%	96%	92%	88%	84%	80%	76%	72%
		R32	0%	4%	8%	12%	16%	20%	24%	28%
Coefficient of Performance (COP)			2.75	2.81	2.89	2.97	3.06	3.17	3.30	3.45
Volumetric cooling capacity	kJ/m^3		8680	8708	8723	8724	8712	8679	8633	8709
Compressor discharge temperature	°C		80.9	81.2	81.5	81.7	81.9	81.9	81.6	82.2
Evaporator pressure	bar		26.5	25.9	25.4	24.7	24.1	23.4	22.6	21.9
Gas cooler pressure	bar		56.7	55.5	54.2	52.7	51.0	49.1	47.0	45.3
Evaporator temperature glide	K		0.0	0.1	0.4	0.7	1.0	1.5	2.0	2.7

[0092] Example 38 illustrates the performance data of a ternary composition comprising 8 weight % R-1132a, 11 weight % R-32 and 81 weight % R-1234yf in a mobile heat pump/air-conditioner system for use in an electric car.

[0093] The system performance was run in cooling mode (air-conditioning) according to SAE Standard J2765 at three test conditions, using the same charge size of refrigerant for the blend as for R-1234yf. The compressor speed was reduced for the blend to achieve the same cooling capacity as R-1234yf at each test point, in accordance with the standard practice for comparison of different refrigerants.

[0094] The results are shown below and illustrated in Figures 2 and 3. The tested composition was consistently able to deliver improved energy efficiency at each test point, with the Coefficient of Performance (COP) varying from 110% to 125% of the R-1234yf value.

Example 38 (ternary composition of 8 weight % R-1132a, 11 weight % R-32 and 81 weight % R-1234yf)

[0095]

			Condenser		Evaporator			
Test Name	**Ambient Temperature**	**Compressor speed**	**Air on temperature**	**Air face velocity**	**Air on temperature**	**relative humidity**	**Air mass flow**	**Target air off temperature**
	(°C)	(rpm)	(°C)	(m/s)	(°C)	(%)	(kg/min)	(°C)
I35a	35	900	35	1.5	35	40	9	3
M35a	35	2500	35	3	35	40	9	3
H35a	35	4000	35	4	35	40	9	3

	R1234yf performance data							
	Cooling capacity (kW)	**COP**	**Compressor work (kW)**					
I35a	5.12	1.68	3.05					
M35a	5.74	2.00	2.87					

	R1234yf performance data							
	Cooling capacity (kW)	COP	Compressor work (kW)					
H35a	5.88	2.08	2.83					
	R-1132a/R-32/R-1234yf (8/11/81%) performance data							
	Cooling capacity (kW)	COP	Compressor work (kW)					
I35a	5.14	1.85	2.78					
M35a	5.75	2.47	2.33					
H35a	5.85	2.61	2.24					
								COP of blend relative to R-1234yf
I35a								110%
M35a								123%
H35a								126%
COP = coefficient of performance								

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- US2017335159A [0003]

KØLEMIDDELSAMMENSÆTNING OG ANVENDELSE DERAF

PATENTKRAV:

1. Anvendelse som et kølemiddel i et varmepumpesystem i et elektrisk køretøj af en sammensætning, der omfatter fra 3 til 30 vægtprocent 1,1-difluorethylen (R-1132a) baseret på sammensætningens samlede vægt, og mindst én fluorcarbon-kølemiddelforbindelse, der er valgt fra gruppen bestående af 2,3,3,3-tetrafluorpropen (R-1234yf), difluormethan (R-32), 1,3,3,3-tetrafluorpropen (R-1234ze(E)) og 1,1-difluorethan (R-152a).

2. Anvendelsen ifølge krav 1, hvor kølemiddelsammensætningen endvidere omfatter mindst én af trifluorethylen (R-1123), trifluoriodmethan (CF_3I), carbondioxid (R-744, CO_2) og 1,1,1,2-tetrafluorethan (R-134a).

3. Anvendelse som et kølemiddel i et varmepumpesystem i et elektrisk køretøj af en sammensætning, der omfatter fra 3 til 30 vægtprocent 1,1-difluorethylen (R-1132a) baseret på sammensætningens samlede vægt og trifluoriodmethan (CF_3I).

4. Anvendelsen ifølge krav 1, hvor kølemiddelsammensætningen omfatter fra 3 til 30 vægtprocent R-1132a, R-152a og R-1234yf, såsom fra 4 til 10 vægtprocent R-1132a, fra 2 til 30 vægtprocent R-152a og fra 60 til 94 vægtprocent R-1234yf.

5. Anvendelsen ifølge krav 1, hvor kølemiddelsammensætningen omfatter fra 3 til 30 vægtprocent R-1132a, mindst én tetrafluorpropen-kølemiddelforbindelse, der er valgt fra gruppen bestående af R-1234yf og R-1234ze(E), og eventuelt difluormethan (R-32), såsom hvor R-32 er til stede i en mængde på fra 1 til 21 vægtprocent baseret på kølemiddelsammensætningens samlede vægt.

6. Anvendelsen ifølge et hvilket som helst af kravene 1 til 5, hvor R-1132a er til stede i en mængde på fra 3 til 20 vægtprocent, såsom fra ca. 3 til ca. 15 vægtprocent, baseret på kølemiddelsammensætningens samlede vægt.

7. Anvendelsen ifølge krav 5 eller 6, hvor kølemiddelsammensætningen endvidere omfatter CF_3I, fortrinsvis hvor CF_3I er til stede i en mængde, der er mindre end R-1234yf eller R-1234ze(E), og/eller hvor kølemiddelsammensætningen omfatter fra 3 til 30 vægtprocent R-1132a, R-32, R-1234yf og CF_3I.

8. Anvendelsen ifølge krav 5 eller 6, hvor kølemiddelsammensætningen endvidere omfatter CO_2 (R-744), fortrinsvis hvor det kombinerede CO_2- og R-1132a-indhold er mindre end

ca. 30 vægtprocent, såsom mindre end ca. 20 vægtprocent, og/eller hvor kølemiddelsammensætningen omfatter fra 3 til 30 vægtprocent R-1132a, R-32, R-1234yf og CO_2.

9. Anvendelsen ifølge krav 1, 2 eller 6, hvor kølemiddelsammensætningen omfatter fra 3 til 30 vægtprocent R-1132a, R-152a og eventuelt R-32, såsom hvor kølemiddelsammensætningen omfatter fra 3 til 30 vægtprocent R-1132a, R-152a, R-32 og mindst én tetrafluorpropen-kølemiddelforbindelse, der er valgt fra gruppen bestående af R-1234yf og R-1234ze(E).

10. Anvendelsen ifølge et hvilket som helst af kravene 3 til 7 eller 9, hvor kølemiddelsammensætningen endvidere omfatter R-134a, fortrinsvis i en mængde på fra ca. 1 til ca. 10 vægtprocent R-134a.

11. Anvendelsen ifølge krav 2, hvor kølemiddelsammensætningen omfatter fra 3 til 30 vægtprocent R-1132a, R-1123 og R-1234yf, eller hvor kølemiddelsammensætningen omfatter fra 3 til 30 vægtprocent R-1132a, R-152a, R-134a og R-1234yf.

12. Anvendelsen ifølge krav 2, hvor kølemiddelsammensætningen omfatter R-1132a, R-32 og CO_2, fortrinsvis fra ca. 3 til ca. 20 vægtprocent R-1132a, fra ca. 1 til ca. 32 vægtprocent R-32 og fra ca. 50 til ca. 95 vægtprocent CO_2, såsom fra ca. 3 til ca. 15 vægtprocent R-1132a, fra ca. 2 til ca. 32 vægtprocent R-32 og fra ca. 55 til ca. 93 vægtprocent CO_2, fx fra ca. 64 til ca. 93 vægtprocent carbondioxid, fra ca. 2 til ca. 25 vægtprocent difluormethan og fra ca. 3 til ca. 14 vægtprocent R-1132a, fx fra ca. 65 til ca. 93 vægtprocent carbondioxid, fra ca. 2 til ca. 22 vægtprocent difluormethan og fra ca. 3 til ca. 14 vægtprocent R-1132a.

13. Anvendelsen ifølge et hvilket som helst af de foregående krav, hvor kølemiddelsammensætningen har et globalt opvarmningspotentiale (GWP) på under 150.

14. Anvendelsen ifølge et hvilket som helst af de foregående krav, hvor varmepumpesystemet også er indrettet til at udføre luftkonditionering.

15. Anvendelsen ifølge et hvilket som helst af kravene 1 til 14, hvor sammensætningen i det væsentlige består af de angivne bestanddele.

16. Anvendelsen ifølge et hvilket som helst af de foregående krav, hvor kølemiddelsammensætningen er mindre brændbar end R-1132a alene, fortrinsvis hvor kølemiddelsammensætningen har:

a. en højere antændelsesgrænse,

b. en højere antændelsesenergi, og/eller

c. en lavere flammehastighed

sammenlignet med R-1132a alene, fortrinsvis hvor kølemiddelsammensætningen er ikke-brandfarlig, såsom hvor kølemiddelsammensætningen er ikke-brandfarlig ved omgivelsestemperatur, eller hvor sammensætningen er ikke-brandfarlig ved 60 °C.

17. Anvendelsen ifølge et hvilket som helst af de foregående krav, hvor varmepumpesystemet endvidere omfatter et smøremiddel, fortrinsvis et polyolester (POE)- eller polyalkylenglycol (PAG)-smøremiddel.

18. Anvendelsen ifølge et hvilket som helst af de foregående krav, hvor kølemiddelsammensætningen fordamper ved temperaturer på under -30 °C, fortrinsvis hvor kølemiddelsammensætningen også kondenserer ved temperaturer på over 40 °C, og/eller hvor kølemiddelsammensætningen har en temperaturglidning i en fordamper eller kondensator på mindre end ca. 15 K, fortrinsvis mindre end ca. 10 K, såsom mindre end ca. 5 K.

19. Anvendelsen ifølge et hvilket som helst af de foregående krav, hvor kølemiddelsammensætningen kan fungere i varmepumpetilstand ved en omgivelsestemperatur, der er lavere end ca. -15 °C, fortrinsvis lavere end over -20 °C.

20. Et elektrisk køretøj udstyret med et varmepumpesystem og en kølemiddelsammensætning som defineret i et hvilket som helst af kravene 1 til 19.

21. En fremgangsmåde til frembringelse af køling i et elektrisk køretøj, hvilken fremgangsmåde omfatter fordampning af en kølemiddelsammensætning som defineret i et hvilket som helst af kravene 1 til 19 i nærheden af et legeme, der skal afkøles.

22. En fremgangsmåde til frembringelse af opvarmning i et elektrisk køretøj, hvilken fremgangsmåde omfatter kondensering af en kølemiddelsammensætning som defineret i et hvilket som helst af kravene 1 til 19 i nærheden af et legeme, der skal opvarmes.

DRAWINGS

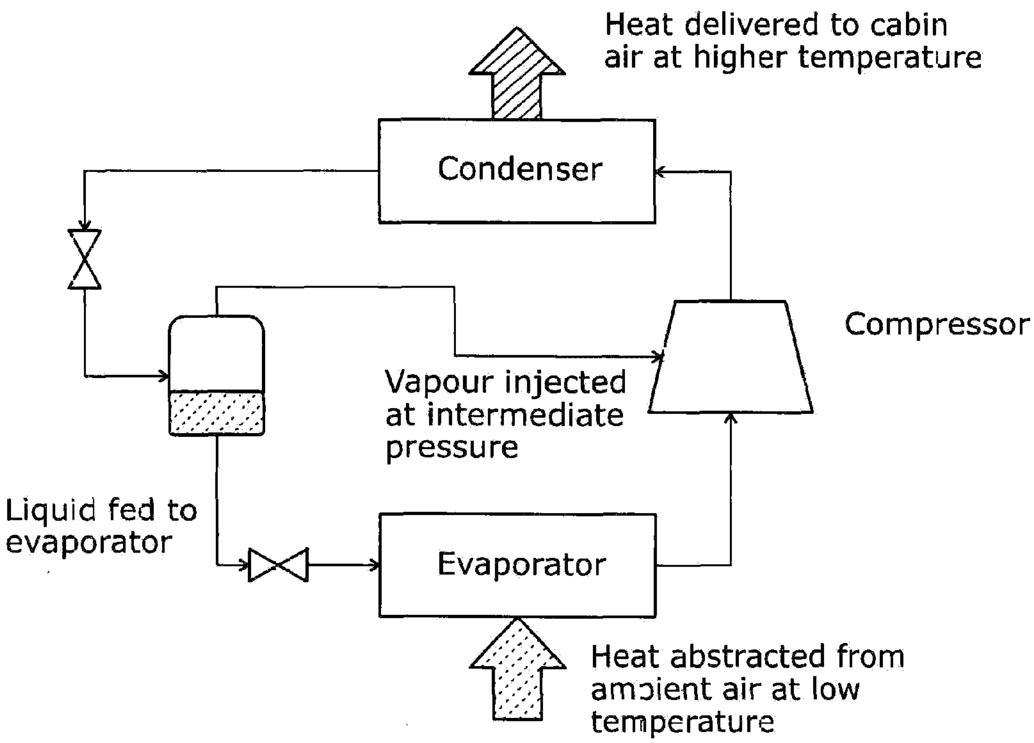

Figure 1

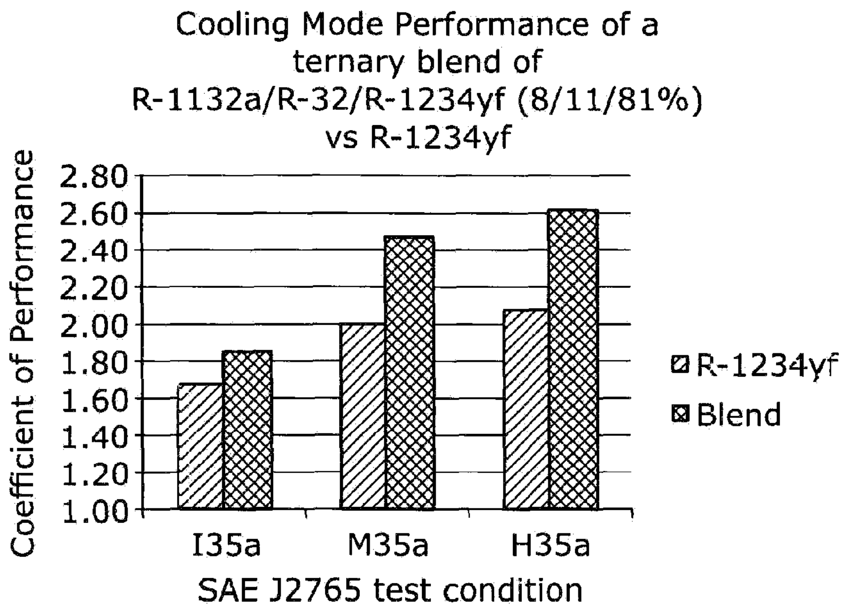

Figure 2

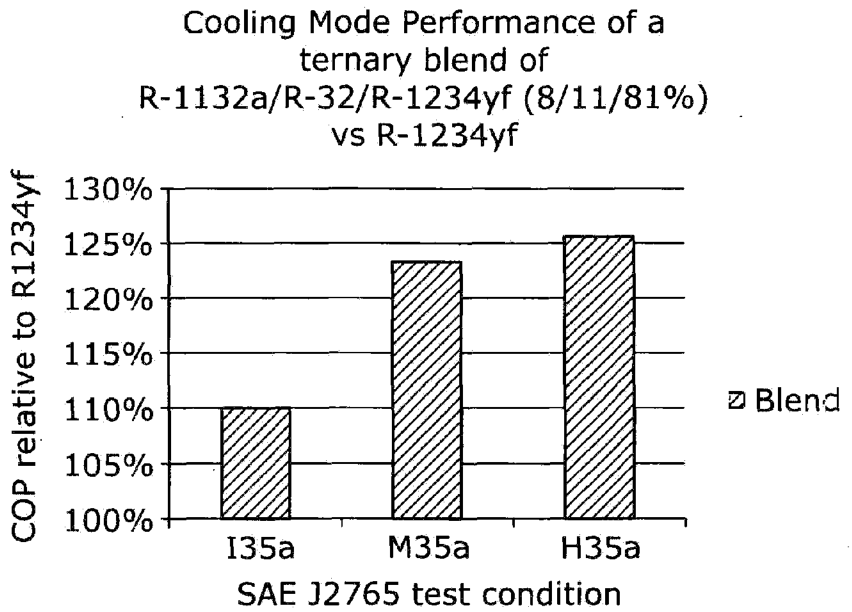

Figure 3