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(54) Title: REFRIGERANT COMPOSITIONS

(57) Abstract

Refrigerant compositions are disclosed which comprise: (a) pentafluoroethane, octafluoropropane, trifluoromethoxydifluoromethane or hexafluoro-cyclopropane, or a mixture of two or more thereof, in an amount from 5 to 60 % based on the weight of the composition, (b) pentafluoroethane, 1,1,1,2- or 1,1,2,2-tetrafluoroethane, 1,1-difluoroethane, trifluoromethoxypentafluoroethane, 1,1,1,2,3,3,3-heptafluoropropane or 1,1,1,2,2,3,3-heptafluoropropane, or a mixture of two or more thereof, in an amount from 30 to 94 % by weight based on the weight of the composition and (c) an unsubstituted hydrocarbon of the formula C_nH_m in which n is at least 4 and m is at least 2n-2, other than methyl propane, in an amount from 1 to 10 % by weight based on the weight of the composition.

REFRIGERANT COMPOSITIONS

The present invention relates to refrigerant compositions, particularly for use as replacements in refrigeration equipment currently employing, or designed to employ, the refrigerants R12 and R22.

Refrigerant R12 (CCl_2F_2) has been a commonly used refrigerant especially in domestic refrigerators. However, R12 contains chlorine atoms and has been implicated in environmental damage to the ozone layer. As a result efforts have been made to replace R12 with a refrigerant formulation which does not involve the use of refrigerants such as R12 which contain chlorine atoms. Similar comments apply to R22 which is used principally for air conditioning systems.

Among alternatives, particular attention has been directed at R134a($C_2H_2F_4$;1,1,1,2-tetrafluoroethane) along with pentafluoroethane (R125)(b.pt. -48.6°C). Commercial formulations of these two refrigerants involve the use of a hydrocarbon, namely propane, propylene or isobutane. While these refrigerant formulations are generally effective as replacements for R12 and R22, nevertheless it has been found that their use is not entirely satisfactory.

Difficulty has arisen with the flammability of the fractionated composition, that is to say the vapour above the liquid composition possesses flammability problems. As a result these commercial formulations can produce flammable compositions under some leak scenario conditions. The flammability of these refrigerant compositions resides in their hydrocarbon content. One of the purposes of incorporating the hydrocarbon is so that formulation is compatible with the lubricants ordinarily used in R12 and R22 refrigeration equipment. The specific hydrocarbons have been selected because they possess the correct boiling point in relation to that of the fluorocarbon.

It has now been found, surprisingly, according to the present invention, that if a hydrocarbon with at least 4 carbon atoms other than methyl propane (isobutane) is used instead of

those previously advocated the flammability of the fractionated composition is greatly reduced. This result is very surprising as n-butane, for example, has a significantly higher boiling point (-0.5°) than, say, isobutane (-11.7°C) and is accordingly less volatile. Indeed, the U.S. NIST (National Institute of Standards & Technology) computer programs REFPREP and REFLEAK have predicted that a particularly preferred such n-butane-containing formulation would be flammable when it has been found not to be. Further, although there can be a considerable boiling point range between the lowest boiling point component and the hydrocarbon of the composition the temperature glide of the blend is relatively small. In a particular embodiment, although the boiling point range is 36.2°C, the temperature glide is only 3.9K at the boiling point of -34.6°C at one atmosphere pressure. It is further surprising that such a formulation has a reduced flammability because n-butane, for example, has a larger range of flammability limits as compared with isobutane. Thus n-butane has a flammability range from 1.5 to 10.1% v/v whereas for isobutane it is only 1.7 to 9.7% v/v.

According to the present invention there is provided a refrigerant composition which comprises:

(i) pentafluoroethane (R125), 1,1,1,2- tetrafluoroethane (R134a), 1,1,2,2-tetrafluoroethane (R134), 1,1-difluoroethane (R152a; b.pt. -24.7°C), trifluoromethoxypentafluoroethane (b.pt.-23.3°C), 1,1,1,2,3,3,3-heptafluoropropane (R227ea; b.pt. -18.3°C or 1,1,1,2,2,3,3-heptafluoropropane (R227ca; b.pt. -16.3°C), or a mixture of two or more thereof, in Embodiment A in an amount from 30 to 50% by weight and in Embodiment B in an amount from 50 to 75% by weight, based on the weight of the composition,

(ii) an unsubstituted hydrocarbon of the formula C_nH_m in which n is at least 4 and m is at least 2n-2, other than methyl propane, in an amount from 1 to 4% by weight based on the weight of the composition,

with the remainder, not exceeding 60% by weight based on the weight of the composition being:

(iii) pentafluoroethane (R125), trifluoromethoxydifluoromethane (b.pt. -34.6°C) or hexafluorocyclopropane (b.pt. -31.5°C) , or a mixture of two or more thereof.

The present invention also provides, as Embodiment C, a refrigerant composition which comprises:

(i) 1,1,1,2- or 1,1,2,2-tetrafluoroethane, or a mixture of pentafluoroethane and 1,1,1,2- or 1,1,2,2-tetrafluoroethane, in an amount from 30 to 94% by weight based on the weight of the composition,

(ii) an unsubstituted hydrocarbon of the formula C_nH_m in which n is at least and m is at least 2n-2, other than methyl propane, in an amount from 1 to 4% by weight based on the weight of the composition,

(iii) pentafluoroethane in an amount from 5 to 60% by weight based on the weight of the composition with the proviso that the concentration of pentafluoroethane in the composition is not 5 to 20% by weight based on the weight of the composition.

The present invention also provides, as Embodiment Em, a refrigerant composition which comprises:

(a) octafluoropropane and, optionally, pentafluoroethane, trifluoromethoxydifluoromethane or hexafluorocyclopropane, or a mixture of two or more thereof, in an amount from 5 to 60% based on the weight of the composition,

(b) pentafluoroethane, 1,1,1,2- or 1,1,2,2-tetrafluoroethane, 1,1-difluoroethane, trifluoromethoxypentafluoroethane, 1,1,1,2,3,3,3-heptafluororpropane or 1,1,1,2,2,3,3-heptafluoropropane, or a mixture of two or more thereof, in an amount from 50 to 94% by weight based on the weight of the composition,

(c) an unsubstituted hydrocarbon of the formula C_nH_m in which n is at least 4 and m is at least 2n-2, other than methyl propane, in an amount from 1 to 10% by weight based on the weight of the composition.

The present invention also provides a process for producing refrigeration which comprises condensing a composition of the present invention and thereafter evaporating the composition in the vicinity of a body to be cooled. The invention also provides a refrigeration apparatus containing, as refrigerant, a composition of the present invention. The invention further provides the use of a refrigeration composition which comprises:

(i) pentafluoroethane, 1,1,1,2- or 1,1,2,2-tetrafluoroethane, 1,1-difluoroethane, trifluoromethoxypentafluoroethane, 1,1,1,2,3,3,3,-heptafluoropropane or 1,1,1,2,2,3,3,-heptafluoropropane, or a mixture of two or more thereof, in an amount from 30 to 94% by weight based on the weight of the composition,

(ii) an unsubstituted hydrocarbon of the formula C_nH_m in which n is at least 4 and m is at least 2n-2, other than methyl propane, in an amount from 1 to 10% by weight based on the weight of the composition, as a replacement for chlorodifluoromethane, and

(iii) pentafluoroethane in an amount from 5 to 60% by weight based on the weight of the composition, as a replacement for chlorodifluoromethane, as Embodiment D.

Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

Component (ii) or (c) will be present in amount from 1 to 10%, especially 1 to 8%, preferably 2 to 6% and more preferably 2 to 5%, and in particular 3 to 4%, most preferably about 3.5%, by weight of the composition, but only 1 to 4% in Embodiments A, B and C.

It will be appreciated that component (i) and component (iii) can both be R125. In this situation the composition can, therefore, be binary and the amount of R125 will be from 90 to 99% by weight. In all other situations, the composition will be at least ternary.

Among the preferred compositions of the present invention are those which contain one or more of R125, R134a and R218. Thus component (iii) preferably comprises R125 and/or R218 while component (i) or (b) preferably comprises R125 and/or R134a.

In Embodiments A and B component (iii) represents the remainder of the composition (to 100%). Component (iii) is present in Embodiments C and D in an amount from 5 to 60% by weight generally 5 to 50% by weight. If R125 does not form part of component (iii) then the amount will typically be from 5 to 20%, especially 5 to 15% and preferably 7 to 12%, by weight. It will be appreciated that if the composition contains R125, the concentration of R125 can be split between components (iii) and (i). Thus in Embodiment C the concentration of R125 in the composition is not 5 to 20% by weight based on the weight of the composition.

In Embodiment E, preferably component (a) comprises, or is, R128 (b.pt. -36.7°C) and component (b) is R134a. R218 is preferably present in an amount from 5 to 20% by weight, especially 7 to 12% by weight of the composition. Typically the composition comprises 5 to 20% by weight of R125. Component (b) is preferably present in an amount of from 75 to 90% by weight.

The concentration of component (i) is from 30 to 50% by weight in Embodiment A and 50% to 75%, by weight in Embodiment B. In Embodiment C and D the concentration is 30 to 94% by weight, generally 50 to 90% and especially 75 to 90%, by weight.

Typically hydrocarbons which can be employed as component (c), and which may be saturated or unsaturated, include methylenecyclopropane, 1-butene, cis and trans-2-butene, butane, cyclobutane, cyclopentene, cyclopentane, 2-methyl-1-butene, 2-methyl-2-butene, 3-methyl-1-butene, 1-pentene, cis and trans-2-pentene, 2-methylbutane, pentane and mixtures of two or more thereof. The use of n-butane (R600) is particularly preferred.

Specific formulations which have been found to be effective are as follows:

	% by weight		% by weight	
			(a)	(b)
R218	9	R125	46	46.5
R134a	88		50	50
n-butane	3		4	3.5

Worst case fractionation study:

The apparatus used for these determinations consisted of a small stainless steel cylinder (343 cm^3 internal volume) which was charged with the blend under evaluation in various fill ratios and was then placed in a temperature controlled bath brought to the appropriate temperature and allowed to equilibrate for at least 30 minutes. The temperature in the bath was controlled to within 0.1 °C and was monitored with a platinum resistance thermometer. Once equilibrated a 75 cm^3 sample cylinder was attached to the test cylinder using quick connections and the void spaces between the test cylinder and the sample cylinder evacuated with a vacuum pump. The system was left for at least 15 minutes to check for leaks and then vapour from the test cylinder was slowly introduced into the sample cylinder using a metering valve. Once the pressure in the sample cylinder reached 1 atmosphere the introduction was stopped, the two cylinders isolated and then the sample cylinder was removed for analysis by GLC. The GLC was

calibrated using three separate analyses of a standard which were made up in such a way as to be quite close to the vapour composition expected for the test mixture. This sampling was repeated and a duplicate sample analysed on the GLC. This was repeated at various temperatures with various fill ratios and the worst case result was the one with the highest hydrocarbon content.

The results obtained as shown below. The flammability tests, determined using the method detailed in ASTM E 681-85, show that the formulations of Examples 1 and 4 are significantly superior to those of Examples 2, 3 and 5, while possessing good refrigeration performance. It will be noted that the vapour of the composition of Example 1 (and 4) was non-flammable. It is clear that similar comments apply to the composition R125 - 46.5%, R134A - 50% and R600 - 3.5%.

	Liquid Composition % w/w				
	R125	R218	R134a	R600a	R600
Example 1	46	-	50	-	4
Example 2	46	-	50	4	-
Example 3	46.5	-	50	3.5	-
Example 4	-	9	88	-	3
Example 5	-	9	88	3	-

Refrigeration Performance as an alternative to R22

Evaporator Temperature / °C	Refrigeration Effect / kW				Coefficient of Performance			
	R22	Example 1	Example 2	Example 3	R22	Example 1	Example 2	Example 3
-15	0.932	0.855	0.823	0.711	1.269	1.204	1.194	0.966
-10	1.328	1.124	1.133	1.058	1.492	1.443	1.436	1.323
-5	1.723	1.437	1.476	1.413	1.716	1.700	1.695	1.624
0	2.118	1.796	1.852	1.775	1.939	1.976	1.970	1.869
5	2.513	2.200	2.262	2.145	2.163	2.270	2.262	2.058

Refrigeration Performance as an alternative to R12

Evaporator Temperature / °C	Refrigeration Effect / kW			Coefficient of Performance		
	R12	Example 4	Example 5	R12	Example 4	Example 5
-15	0.585	0.706	0.738	0.942	1.002	1.036
-10	0.786	0.877	0.889	1.227	1.312	1.314
-5	1.018	1.119	1.128	1.513	1.623	1.591
0	1.281	1.434	1.453	1.799	1.933	1.869
5	1.575	1.820	1.865	2.085	2.244	2.146

Fractionation and Flammability test results

	Fractionated Vapour Composition / % w/w					Lower Flammable
Blend	R125	R218	R134a	R600a	R600	Limit % v/v in Air
Example 1	60.7	-	34.6	-	4.7	Non Flammable
Example 2	64.4	-	29.1	6.5	-	12
Example 3	64.7	-	29.8	5.5	-	15
Example 4	-	22.9	72.5	-	4.6	Non Flammable
Example 5	-	21.5	72.5	6	-	9

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A refrigerant composition which comprises:

(i) pentafluoroethane, 1,1,1,2- or 1,1,2,2-tetrafluoroethane, 1,1-difluoroethane, trifluoromethoxypentafluoroethane, 1,1,1,2,3,3,3-heptafluoropropane or 1,1,1,2,2,3,3-heptafluoropropane, or a mixture of two or more thereof, in an amount from 30 to 50% by weight based on the weight of the composition,

(ii) an unsubstituted hydrocarbon of the formula C_nH_m in which n is at least 4 and m is at least 2n-2, other than methyl propane, in an amount from 1 to 4% by weight based on the weight of the composition,

with the remainder, not exceeding 60% by weight based on the weight of the composition being:

(iii) pentafluoroethane, trifluoromethoxydifluoromethane or hexafluorocyclopropane, or a mixture of two or more thereof.

2. A composition according to claim 1 wherein component (i) is present in an amount of 50% by weight based on the weight of the composition.

3. A composition according to claim 1 or 2 wherein component (i) is 1,1,1,2-tetrafluoroethane or a mixture of said ethane with pentafluoroethane.

4. A refrigerant composition which comprises:

(i) pentafluoroethane, 1,1,1,2- or 1,1,2,2-tetrafluoroethane, 1,1-difluoroethane, trifluoromethoxypentafluoroethane, 1,1,1,2,3,3,3-heptafluoropropane or 1,1,1,2,2,3,3-heptafluoropropane, or a mixture of two or more thereof, in an amount from 50 to 75% by weight based on the weight of the composition,

(ii) an unsubstituted hydrocarbon of the formula C_nH_m in which n is at least 4 and m is at least 2n-2, other than methyl propane, in an amount

from 1 to 4% by weight based on the weight of the composition; with the remainder being,

(iii) pentafluoroethane, trifluoromethoxydifluoromethane or hexafluorocyclopropane, or a mixture of two or more thereof.

5. A composition according to claim 4 wherein component (i) is 1,1,1,2-tetrafluoroethane or a mixture of said ethane with pentafluoroethane.

6. A refrigerant composition which comprises:-

(i) 1,1,1,2- or 1,1,2,2-tetrafluoroethane, or a mixture of pentafluoroethane and 1,1,1,2- or 1,1,2,2- tetrafluoroethane, in an amount from 30 to 94% by weight based on the weight of the composition,

(ii) an unsubstituted hydrocarbon of the formula C_nH_m in which n is at least and m is at least 2n-2, other than methyl propane, in an amount from 1 to 4% by weight based on the weight of the composition,

(iii) pentafluoroethane in an amount from 5 to 60% by weight based on the weight of the composition with the proviso that the concentration of pentafluoro-ethane in the composition is not 5 to 20% by weight based on the weight of the composition.

7. A composition according to any one of the preceding claims wherein component (ii) is present in an amount from 2 to 4% by weight based on the weight of the composition.

8. A composition according to claim 7 wherein component (ii) is present in an amount from 3 to 4% by weight based on the weight of the composition.

9. A composition according to any one of the preceding claims wherein component (ii) is a mixture of said hydrocarbons.

10. A composition according to any one of the preceding claims wherein component (ii) comprises a hydrocarbon which possesses 4 or 5 carbon atoms.

11. A composition according to claim 10 wherein component (ii) comprises a hydrocarbon which is n-butane.

12. A composition according to claim 11 which comprises:

(a) 46 to 46.5% by weight of pentafluoroethane

(b) 50% by weight of 1,1,1,3-tetrafluoroethane and

(c) 4 to 3.5% by weight, respectively, of n-butane.

13. Use as a refrigerant of a composition as claimed in any one of claims 1 to 12.

14. Use according to claim 13 in a refrigeration or airconditioning system designed to use chlorodifluoromethane as refrigerant.

15. Use of a refrigeration composition which comprises:

(i) pentafluoroethane, 1,1,1,2- or 1,1,2,2-tetrafluoroethane, 1,1-difluoroethane, trifluoromethoxypentafluoroethane, 1,1,1,2,3,3,3,-heptafluoropropane or 1,1,1,2,2,3,3,-heptafluoropropane, or a mixture of two or more thereof, in an amount from 30 to 94% by weight based on the weight of the composition,

(ii) an unsubstituted hydrocarbon of the formula C_nH_m in which n is at least 4 and m is at least 2n-2, other than methyl propane, in an amount from 1 to 10% by weight based on the weight of the composition, as a replacement for chlorodifluoromethane, and

(iii) pentafluoroethane in an amount from 5 to 60% by weight based on the weight of the composition, as a replacement for chlorodifluoromethane.

16. Use according to claim 15 wherein the composition is as defined in claim 12.

17. A refrigerant composition which comprises:

(a) octafluoropropane and, optionally, pentafluoroethane, trifluoromethoxydifluoromethane or hexafluorocyclopropane, or a mixture of two or more thereof, in an amount from 5 to 60% based on the weight of the composition,

(b) pentafluoroethane, 1,1,1,2- or 1,1,2,2-tetrafluoroethane, 1,1-difluoroethane, trifluoromethoxypentafluoroethane, 1,1,1,2,3,3,3-heptafluoropropane or 1,1,1,2,2,3,3-heptafluoropropane, or a mixture of two or more thereof, in an amount from 50 to 94% by weight

based on the weight of the composition,

(c) an unsubstituted hydrocarbon of the formula C_nH_m in which n is at least 4 and m is at least 2n-2, other than methyl propane, in an amount from 1 to 10% by weight based on the weight of the composition.

18. A composition according to claim 17 in which component (c) is present in an amount from 2 to 6% by weight based on the weight of the composition.

19. A composition according to claim 17 or 18 in which component (c) is present in an amount from 3 to 4% by weight based on the weight of the composition.

20. A composition according to any one of claims 17 to 19 in which component (b) comprises: pentafluoroethane, 1,1,1,2- tetrafluoroethane.

21. A composition according to any one of claims 17 to 20 in which component (a) comprises octafluoropropane and component (b) is 1,1,1,2-tetrafluoroethane.

22. A composition according to claim 21 in which component (a) is octafluoropropane.

23. A composition according to any one of claims 17 to 22 in which the octafluoropropane is present in an amount from 5 to 20% by weight based on the weight of the composition.

24. A composition according to claim 23 in which the octafluoropropane is present in an amount from 7 to 12% by weight based on the weight of the composition.

25. A composition according to any one of claims 17 to 24 which comprises from 5 to 20% by weight based on the weight of the composition of pentafluoroethane.

26. A composition according to any one of claims 17 to 25 in which component (b) is present in an amount from 75% to 90% by weight based on the weight of the composition.

27. A composition according to any one of claims 17 to 26 in which

component (c) possesses 4 or 5 carbon atoms.

28. A composition according to claim 27 in which component (c) is n-butane.

29. A composition according to claim 17 which comprises about 9% by weight of octafluoropropane, about 88% by weight of 1,1,1,2-tetrafluoroethane and about 3% by weight of n-butane.

30. Use of a refrigerant composition as claimed in any one of claims 17 to 29 as a replacement for dichlorodifluoromethane.

31. A composition according to any one of claims 1, 4, 6, 12 or 17 substantially as hereinbefore described.

32. The process for producing refrigeration which comprises evaporating a composition as claimed in any one of claims 1 to 29 and 31 in the vicinity of a body to be cooled.

33. A refrigeration apparatus containing, as refrigerant, a composition as claimed in any one of claims 1 to 29 and 31.

34. Apparatus according to claim 33 which is designed to use chlorodifluoromethane as refrigerant.

DATED this 8th day of October, 2002

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