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(54) Title: APPLICATION OF 1-CHLORO-3,3,3-TRIFLUOROPROPENE AND 1,1,1,2,3-PENTAFLUORO- PROPANE MIXTURES IN CHILLERS HAVING A SCREW-TYPE COMPRESSOR

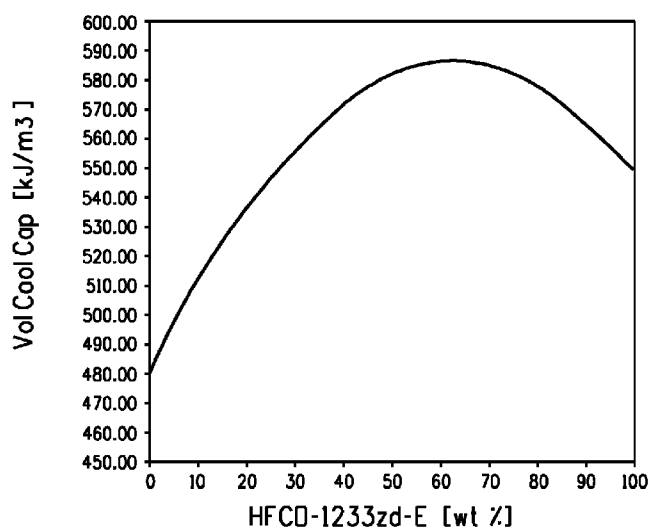


FIG. 1

(57) Abstract: The present invention provides a comprises (a) a process for operating a chiller to provide a cooling effect, comprising compressing a working fluid in a screw type compressor, condensing the compressed working fluid, expanding the condensed working fluid, and evaporating the expanded working fluid to provide said cooling effect, said working fluid comprising a mixture of 1-chloro-3,3,3-trifluoropropene and 1,1,1,2,3-pentafluoro- propane, said mixture exhibiting a volumetric cooling capacity that is at least 2.5% greater than the volumetric cooling capacity of said 1-chloro-3,3,3-trifluoropropene and 1,1,1,2,3-pentafluoropropane by themselves and a temperature glide during at least one of said condensing and said evaporating that is no greater than 0.25°C, and (b) chiller apparatus having the screw type compressor for compressing the working fluid, wherein during the condensation by condensation means and or evaporation of the working fluid during evaporation by evaporation means, the mixture exhibits the same improvement in volumetric cooling capacity and low temperature glide as mentioned under (a).

TITLE OF INVENTION

APPLICATION OF 1-CHLORO-3,3,3-TRIFLUOROPROPENE AND
1,1,1,2,3-PENTAFLUORO- PROPANE MIXTURES IN CHILLERS
HAVING A SCREW-TYPE COMPRESSOR

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FIELD OF THE INVENTION

This invention relates to the advantageous use of certain mixtures of 1-chloro-3,3,3-trifluoropropene and 1,1,1,2,3-pentafluoro- propane as the working fluid in chillers having a screw-type compressor.

BACKGROUND OF THE INVENTION

10 WO 2011/022260 discloses azeotrope and azeotrope-like compositions (mixtures) of 1-chloro-3,3,3-trifluoropropene and 1,1,1,2,3-pentafluoropropane for use in a wide variety of refrigeration systems including air-conditioning, refrigeration, heat-pump, chiller, HVAC systems, and the like (p. 6, second paragraph). This publication also discloses that
15 for the chiller application, those with centrifugal compressors are preferred, and even more preferred, are the chillers with centrifugal compressors and flooded type evaporators, (p. 7, last paragraph). The publication discloses additional applications of the compositions, as follows: propellants, blowing agents, foaming agent, solvents, de-fluxing
20 agents, degreasers, flushing agents, and the like (pp. 8 and 9).

SUMMARY OF THE INVENTION

The present invention involves the discovery of unexpected performance of certain mixtures of 1-chloro-3,3,3-trifluoropropene and 1,1,1,2,3-pentafluoropropane as the working fluid in chillers having a
25 screw-type compressor. Unexpectedly, the performance characteristics of these working fluids are coincident in the same mixtures. Neither these performance characteristics nor the chiller having the screw type compressor chiller are disclosed in WO 2011/022260.

One embodiment of the present invention comprises the process for
30 operating a chiller to provide a cooling effect, comprising compressing a working fluid by reducing its volume, condensing the compressed working

fluid, expanding the condensed working fluid, and evaporating the expanded working fluid to provide said cooling effect, said working fluid comprising a mixture of 1-chloro-3,3,3-trifluoropropene and 1,1,1,2,3-pentafluoropropane, said mixture exhibiting a volumetric cooling capacity
5 that is at least 2.5% greater than the volumetric cooling capacity of said 1-chloro-3,3,3-trifluoropropene and 1,1,1,2,3-pentafluoropropane by themselves and a temperature glide during at least one of said condensing and said evaporating that is no greater than 0.25°C.

The compressing of the working fluid by reducing its volume denotes
10 according to the present invention that compressing is obtained by a screw-type compressor.

Another embodiment of the present invention resides in a chiller comprising a screw-type compressor for compressing a working fluid, means for condensing said compressed working fluid, means for
15 expanding said condensed working fluid, and means for evaporating said expanded working fluid, said working fluid comprising a mixture of 1-chloro-3,3,3-trifluoropropene and 1,1,1,2,3-pentafluoropropane, said mixture exhibiting a volumetric cooling capacity that is at least 2.5% greater than the volumetric cooling capacity of said 1-chloro-3,3,3-
20 trifluoropropene and 1,1,1,2,3-pentafluoropropane by themselves and a temperature glide during at least one of condensation by said condensation means and evaporation by said evaporation means that is no greater than 0.25°C.

In another embodiment of the present invention, the composition of
25 the most preferred mixture used in either the process and apparatus embodiments mentioned above or in both such embodiments comprises 60 to 65 wt% of said 1-chloro-3,3,3-trifluoropropene and 40 to 35 wt% of said 1,1,1,2,3-pentafluoropropane to total 100 wt%.

In each of these embodiments, individually or collectively the
30 improvement in volumetric cooling capacity of the mixture is preferably at least 4.0% greater than the volumetric cooling capacity of said 1-chloro-3,3,3-trifluoropropene and 1,1,1,2,3-pentafluoropropane by themselves.

The temperature glide exhibited by the mixture during at least one of said condensing or condensation and said evaporating or evaporation is preferably no greater than 0.15°C. The amount of temperature glide preferably applies to both condensing (condensation) and evaporating
5 (evaporation).

Notwithstanding that WO 2011/022260 reports in Table 1 a single boiling point for mixtures of 20-90 wt% 1-chloro-3,3,3-trifluoropropene (trans-1233zd) and 80-20 wt% 1,1,1,2,3-pentafluoropropane (245eb), the mixtures have been found by the present invention to exhibit glide, which
10 in many cases is too high for practical utility in the chiller having the screw compressor in that such glide imposes an appreciable penalty to chiller operating efficiency.

In each of these embodiments and the preferences associated therewith, the preferred chiller having a screw-type compressor also has
15 flooded heat exchangers. Thus, in the process of the present invention, the condensing and evaporating steps are carried out using a flooded heat exchanger in at least one of these steps. In the apparatus of the present invention, the means for condensing and the means for evaporating comprise a flooded heat exchanger in at least one of these means.
20 Another embodiment of the present invention is wherein both the condensing and evaporating steps and both the means for condensing and means for evaporating are carried out or comprise flooded heat exchangers.

BRIEF DESCRIPTION OF THE DRAWING

25 Fig.1 is a plot of volumetric cooling capacity vs. composition of the working fluids based on data reported in the Table of the Example below.

DESCRIPTION OF PREFERRED EMBODIMENTS

In this **DESCRIPTION** and in the **EXAMPLES**, 1-chloro-3,3,3-trifluoropropene (HCFO-1233zd) and 1,1,1,2,3-pentafluoropropane (HFC-
30 245eb) will be referred to as HCFO-1233zd or simply as 1233zd, and HFC- 245eb or simply as 245eb, respectively. The HCFO-1233zd is the

E-isomer, i.e. E-HCFO-1233zd, sometimes referred to as the trans isomer. The E-isomer is also referred to herein simply as 1-chloro-3,3,3-trifluoropropene or as 1233zd.

Certain mixtures of 1233zd and 245eb exhibit exemplary cooling performance in chillers having the screw type compressor. This exemplary performance manifests itself as exhibiting the combination of volumetric cooling capacity greater than either of the 1233zd and 245eb by itself, and low glide as shown in the Table below. These mixtures are referred to as working fluids in the chiller, and can also be called the refrigerant.

Preferably, the volumetric cooling capacity of the mixtures used in the present invention is at least 5% greater than the volumetric cooling capacity of either of the 1233zd and 245eb components of the mixture by itself, more preferably at least 6% greater. Sample calculation of % improvement in volumetric cooling capacity taken from the values reported for Blend C in the Table is as follows:

$$[(587.02-548.81)/548.81] \times 100 = 6.96\%$$

It is apparent from Fig.1 that the volumetric cooling capacity of 1233zd by itself is much greater than for the 245eb by itself. The improvements in volumetric cooling capacity of mixtures of the present invention described herein are calculated by comparison with the higher volumetric cooling capacity of 1233zd.

Preferably, the glide is no greater than 0.20°C, more preferably no greater than 0.15°C, and most preferably, no greater than 0.10°C. Each of the glides exhibited by mixtures used in the present invention disclosed herein applies to either the glide during the condensation step or the glide during the evaporation step in the chiller operation, and preferably to both steps. Each of these glides also applies to each of the improvements in volumetric cooling capacity disclosed herein.

The mixtures used in the present invention are prepared by mixing together the 1233zd and 245eb in the proportions desired to obtain the

combination of volumetric cooling capacity improvement and low glide desired. Compositions of mixtures used in the present invention include those wherein the minimum amount of 1233zd includes the following: 50 wt%, 55 wt%, and 60 wt% and wherein the maximum amount of 1233zd is 90 wt%, 85 wt%, 80 wt%, 75 wt%, 70 wt% and 65 wt%, with 245eb being present in the mixture in an amount to total 100 wt% for the combination of 1233zd and 245eb in each mixture. Each of these minimum amounts of 1233zd can be combined with any of these maximum amounts of 1233zd to define the 1233zd wt% range in the mixture, the combination of 1233zd and 245eb in each mixture totaling 100 wt%. Of particular utility in the process for operating a chiller are non-flammable mixtures containing more than about 36 wt% E-1233zd. Also of utility are non-flammable mixtures with from about 36 wt% to about 90 wt% E-1233zd and from about 10 wt% to about 64 wt% HFC-245eb; or from about 37 wt% to about 90 wt% E-1233zd and from about 10 wt% to about 63 wt% HFC-245eb; or from about 37 wt% to about 80 wt% E-1233zd and from about 20 wt% to about 63 wt% HFC-245eb; or from about 37 wt% to about 65 wt% E-1233zd and from about 35 wt% to about 63 wt% HFC-245eb.

In the process for operating a chiller, examples of mixture compositions used in the present invention include the following: mixtures comprising 50 to 90 wt% of 1233zd and 50 to 10 wt% of 245eb, to total 100%; mixtures comprising 50 to 80 wt% of 1233zd and 50 to 20 wt% of 245eb, to total 100%; mixtures comprising 55 to 70 wt% of 1233zd and 45 to 30 wt% of 245eb, to total 100%; and the 60-65/40-35 mixture mentioned above. The mixture composition is selected to achieve the improvement in volumetric cooling capacity and low glide desired, whether for the condensation step or the evaporation step or both. Another consideration as discussed in Example 1 is the GWP and ODP desired for the mixture. As the amount of 1233zd increases in the mixture, the GWP becomes smaller as shown in Table 1 in the Examples. The ODP of 1233zd is small, but somewhat greater than the zero ODP of 245eb, whereby the

increasing amount of 1233zd in the mixture results in a positive value for ODP as disclosed in the Examples.

Of particular utility in the process for operating a chiller of the present invention are non-flammable mixtures containing more than about 36 wt% E-1233zd and less than about 64 wt% HFC-245eb. Also of utility are non-flammable mixtures with from about 36 wt% to about 90 wt% E-1233zd and from about 10 wt% to about 64 wt% HFC-245eb; or from about 37 wt% to about 90 wt% E-1233zd and from about 10 wt% to about 63 wt% HFC-245eb; or from about 37 wt% to about 80 wt% E-1233zd and from about 20 wt% to about 63 wt% HFC-245eb; or from about 37 wt% to about 65 wt% E-1233zd and from about 35 wt% to about 63 wt% HFC-245eb.

The 1233zd and 245eb are the essential components of the mixture used as the working fluid in the present invention. Other ingredients can be present in the mixture such as one or more lubricants, compatibilizers, UV dyes, solubilizing agents, tracers, free-radical scavengers, or antioxidants.

The chillers used in the present invention include the conventional process steps and equipment means to accomplish compression, condensation, expansion and evaporation of the working fluid, with the proviso that the compression is accomplished by using a screw type compressor. Screw type compressors useful in the present invention are disclosed in the book entitled 2008 ASHRAE Handbook, HVAC Systems and Equipment, S I Edition, Published by the American Society of Heating, Refrigeration, and Air Conditioning Engineers, Inc. (2008) on pp 37.18 to 37.19. These compressors include compressors wherein the volume reduction and accompanying compression of the working fluid are accomplished by a single screw compressor or a twin screw compressor. In both compressors, the working fluid as a vapor is drawn into the screw(s) of the compressor for compression by volume reduction produced by the reduction in volume of the space available within the grooves of the screw(s) as the vapor passes through the compressor to the discharge port of the compressor.

The evaporation of the working fluid in the evaporator of the chiller cools a heat transfer medium, and the cooled heat transfer medium is transported out of the evaporator to the body to be cooled, whereby the chiller communicates its cooling effect to the environment. Typically, the heat transfer medium is water.

In the chiller of the present invention, examples of working fluids include the following: mixtures comprising 50 to 90 wt% of 1233zd and 50 to 10 wt% of 245eb, to total 100%; mixtures comprising 50 to 80 wt% of 1233zd and 50 to 20 wt% of 245eb, to total 100%; mixtures comprising 55 to 70 wt% of 1233zd and 45 to 30 wt% of 245eb, to total 100%; and the 60-65/40-35 mixture mentioned above.

Of particular utility in the chiller of the present invention are non-flammable mixtures containing more than about 36 wt% E-1233zd and less than about 64 wt% HFC-245eb. Also of utility are non-flammable mixtures with from about 36 wt% to about 90 wt% E-1233zd and from about 10 wt% to about 64 wt% HFC-245eb; or from about 37 wt% to about 90 wt% E-1233zd and from about 10 wt% to about 63 wt% HFC-245eb; or from about 37 wt% to about 80 wt% E-1233zd and from about 20 wt% to about 63 wt% HFC-245eb; or from about 37 wt% to about 65 wt% E-1233zd and from about 35 wt% to about 63 wt% HFC-245eb.

As used herein, the terms “comprises,” “comprising,” “includes,” “including,” “has,” “having” or any other variation thereof, are intended to cover a non-exclusive inclusion. For example, a composition, process, method, article, or apparatus that comprises a list of elements is not necessarily limited to only those elements but may include other elements not expressly listed or inherent to such composition, process, method, article, or apparatus. Further, unless expressly stated to the contrary, “or” refers to an inclusive or and not to an exclusive or. For example, a condition A or B is satisfied by any one of the following: A is true (or present) and B is false (or not present), A is false (or not present) and B is true (or present), and both A and B are true (or present).

The transitional phrase "consisting of" excludes any element, step, or ingredient not specified. If in the claim, such would close the claim to the inclusion of materials other than those recited except for impurities ordinarily associated therewith. When the phrase "consists of" appears in a clause of the body of a claim, rather than immediately following the preamble, it limits only the element set forth in that clause; other elements are not excluded from the claim as a whole. The transitional phrase "consisting essentially of" is used to define a composition, method that includes materials, steps, features, components, or elements, in addition to those literally disclosed provided that these additional included materials, steps, features, components, or elements do not materially affect the basic and novel characteristic(s) of the claimed invention, especially the mode of action to achieve the desired result of any of the processes of the present invention. The term 'consisting essentially of' occupies a middle ground between "comprising" and 'consisting of'.

Where applicants have defined an invention or a portion thereof with an open-ended term such as "comprising," it should be readily understood that (unless otherwise stated) the description should be interpreted to also include such an invention using the terms "consisting essentially of" or "consisting of."

Also, use of "a" or "an" are employed to describe elements and components described herein. This is done merely for convenience and to give a general sense of the scope of the invention. This description should be read to include one or at least one and the singular also includes the plural unless it is obvious that it is meant otherwise.

EXAMPLES**EXAMPLE 1**

The following chiller operating conditions using a screw type compressor exist for all the experiments on compositions in the Table:

T_{cond}	°C	37.78
T_{evap}	°C	4.44
Subcooling	°C	0
Superheat	°C	0
Compressor Efficiency		0.7

5 The screw type compressor operates using a twin screw.

The performance of the screw type compressor using various blends (mixtures) comprising HCFO-1233zd-E and HFC-245eb as working fluids is compared in the Table. The volumetric cooling capacity of the working fluids in Table 1 is also plotted in Fig 1.

10 Table 1 – Performance of the chiller using E-HCFO-1233zd/HFC-245eb blends as working fluids

		HFC-245eb	Blend A	Blend B	Blend BC	Blend C	Blend CD	Blend D	E-HCFO-1233zd
E-HCFO-1233zd	wt%	0	20	40	55	60	65	80	100
HFC-245eb	wt%	100	80	60	45	40	35	20	0
GWP		286	230	174	133	119	105	63	7
P_{evap}	MPa	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06
P_{cond}	MPa	0.18	0.20	0.21	0.21	0.21	0.21	0.21	0.20
PR		3.82	3.68	3.57	3.50	3.49	3.48	3.46	3.45
COP_{cool}		5.163	5.146	5.136	5.141	5.144	5.147	5.156	5.17
COP_{cool} vs E-HCFO-1233zd neat	%	-0.14	-0.46	-0.66	-0.56	-0.50	-0.44	-0.27	
CAP_{cool}	kJ/m^3	480.52	537.13	572.70	585.7	587.02	586.8	577.78	548.81
CAP_{cool} vs E-HCFO-1233zd neat	%	-12.44	-2.13	4.35	6.72	6.96	6.92	5.28	
Temp Glide-Cond	°C	0.00	0.81	0.28	0.01	0.00	0.02	0.19	0.00
Temp Glide-Evap	°C	0.00	1.07	0.55	0.09	0.02	0.00	0.10	0.00

In Table 1:

PR is the ratio of the absolute discharge pressure to the absolute inlet pressure for the twin screw compressor.

COP_{cool} is the coefficient of performance for cooling, i.e. the amount of heat received by the working fluid divided by the energy required to operate the screw type compressor.

Vol Cool Cap is the volumetric cooling capacity.

Glide-Cond is the glide occurring during condensation of the working fluid and Glide-Evap is the glide occurring during evaporation of the working fluid. Glide, whether during condensation or during evaporation, is the absolute value of the temperature difference between the starting and ending temperatures of the phase-change step by the working fluid.

The determination of these performance characteristics reported in Table 1 is well known in the art.

As shown in Table 1, HCFO-1233zd/HFC-245eb Blends and Fig. 1, have significantly higher volumetric cooling capacity than either HCFO-1233zd or HFC-245eb used as single components. The coefficient of performance only varies slightly with Blend composition. Nonflammable Blend C offers about 7% higher volumetric cooling capacity than neat HCFO-1233zd with negligible temperature glide in both the evaporator and the condenser and with a low GWP of 119, calculation as follows:

$$((60 \times 7) + (40 \times 286)) / 100.$$

Nonflammable Blend B offers 4.35% higher volumetric cooling capacity than neat HCFO-1233zd, but with glide values that would be considered excessively high for chillers, especially using flooded heat exchangers. Based on the excessive glide obtained for Blend B, the minimum amount of 1233zd in the Blend is preferably at least 50 wt%.

In another experiment, wherein the non-flammable blend (mixture) contains 90 wt% 1233zd and 10 wt% 245eb, the volumetric cooling capacity exceeds that of 100 wt% 1233zd, and the glide-Cond is 0.14°C and the glide-Evap is 0.22°C.

Surprisingly, the peak volumetric cooling capacity of 6.96% resides in the same Blend (Blend C) as the smallest glide temperatures for the Blends. According to the curve in Fig. 1, the peak volumetric cooling capacity of the mixture occurs at 62-63 wt% 1233zd, the remainder to total 100 wt% being 38-37 wt% 245eb.

The ODP for the mixtures used in the present invention is also low. The ODP for 245eb is 0, while for 1233zd, it has been reported to be 0.00034. Thus, for Blend C, the ODP is 0.00020 (calculation: $(60 \times 0.00034)/100$).

10

EXAMPLE 2

Compositions for use in the processes and chillers according to the present invention were tested according to ASTM E681 to determine flammability. The test procedure was run at a temperature of 60°C and 50.0% relative humidity in a 12 liter flask with standard ignition (IE tungsten electrodes offset from center with a 0.25 inch gap, 15 kv with a 0.4 second duration. For those compositions that were found to be flammable, the lower flammability limit (LFL) and upper flammability limit (UFL) are indicated in Table 2.

Table 2: Flammability of HCFO-1233zd-E/HFC-245eb blends

HFC-245eb (wt%)	E-HCFO-1233zd (wt%)	Flammability	LFL	UFL
74.84	25.16	Flammable	7.75	10.25
64.86	35.14	Flammable	8.25	8.5
62.5	37.5	Not flammable	NA	NA
50.0	50.0	Not flammable	NA	NA
45.0	55.0	Not flammable	NA	NA
42.0	58.0	Not flammable	NA	NA
40.5	59.5	Not flammable	NA	NA

Compositions with more than about 36 wt% E-1233zd will be non-flammable. The data indicates that compositions from Example 1 including B, BC, C, CD and D will be non-flammable.

CLAIMS

What is claimed is:

1. Process for operating a chiller to provide a cooling effect, comprising
compressing a working fluid by reducing its volume, condensing the
compressed working fluid, expanding the condensed working fluid,
and evaporating the expanded working fluid to provide said cooling
effect, said working fluid comprising a mixture of 1-chloro-3,3,3-
trifluoropropene and 1,1,1,2,3-pentafluoropropane, said mixture
exhibiting a volumetric cooling capacity that is at least 2.5% greater
than the volumetric cooling capacity of said 1-chloro-3,3,3-
trifluoropropene and 1,1,1,2,3-pentafluoropropane by themselves
and a temperature glide during at least one of said condensing and
said evaporating that is no greater than 0.25°C.
2. The process of claim 1 wherein said compressing is obtained by a
screw-type compressor.
3. The process of claim 2, wherein at least one of said condensing and
said evaporating are carried out in a flooded heat exchanger.
4. The process of claim 1 wherein said mixture comprises 50 to 90 wt%
of said 1-chloro-3,3,3-trifluoropropene and 50 to 10 wt% of said
1,1,1,2,3-pentafluoropropane to total 100%.
5. The process of claim 4 wherein said mixture comprises 50 to 80 wt%
of said 1-chloro-3,3,3-trifluoropropene and 50 to 20 wt% of said
1,1,1,2,3-pentafluoropropane to total 100%.
6. The process of claim 4 wherein said mixture comprises 55 to 70 wt%
of said 1-chloro-3,3,3-trifluoropropene and 45 to 30 wt% of said
1,1,1,2,3-pentafluoropropane to total 100%.
7. The process of claim 4 wherein said mixture comprises 60 to 65 wt%
of said 1-chloro-3,3,3-trifluoropropene and 40 to 35 wt% of said
1,1,1,2,3-pentafluoropropane to total 100 wt%.

8. The process of claim 1 wherein said volumetric cooling capacity that is at least 4% greater than the volumetric cooling capacity of said 1-chloro-3,3,3-trifluoropropene and 1,1,1,2,3-pentafluoropropane by themselves by themselves.
- 5 9. The process of claim 1 and communicating said cooling effect to the environment.
- 10 10. In a chiller comprising a screw-type compressor for compressing a working fluid, means for condensing said compressed working fluid, means for expanding said condensed working fluid, and means for evaporating said expanded working fluid, said working fluid comprising a mixture of 1-chloro-3,3,3-trifluoropropene and 1,1,1,2,3-pentafluoropropane, said mixture exhibiting a volumetric cooling capacity that is at least 2.5% greater than the volumetric cooling capacity of said 1-chloro-3,3,3-trifluoropropene and 1,1,1,2,3-pentafluoropropane by themselves and a temperature glide during at least one of condensation by said condensation means and evaporation by said evaporation means that is no greater than 0.25°C.
- 15 11. In the chiller of claim 10 wherein said mixture exhibits a volumetric cooling capacity that is at least 4% greater than the volumetric cooling capacity of said 1-chloro-3,3,3-trifluoropropene and 1,1,1,2,3-pentafluoropropane by themselves.
- 20 12. In the chiller of claim 10, wherein said temperature glide is no greater than 0.15°C.
- 25 13. In the chiller of claim 10, wherein at least one of said means for condensing and said means for evaporating comprise a flooded heat exchanger.
- 30 14. In the chiller of claim 10, wherein said mixture contains 50 to 90 wt% of said 1-chloro-3,3,3-trifluoropropene and 50 to 10 wt% of said 1,1,1,2,3-pentafluoropropane to total 100 wt%.

15. The process of claim 1, wherein said working fluid comprises a non-flammable mixture containing more than about 36 wt% E-1-chloro-3,3,3-trifluoropropene.
 16. In the chiller of claim 10, wherein said mixture comprises a non-flammable mixture containing more than about 36 wt% E-1-chloro-3,3,3-trifluoropropene.
- 5

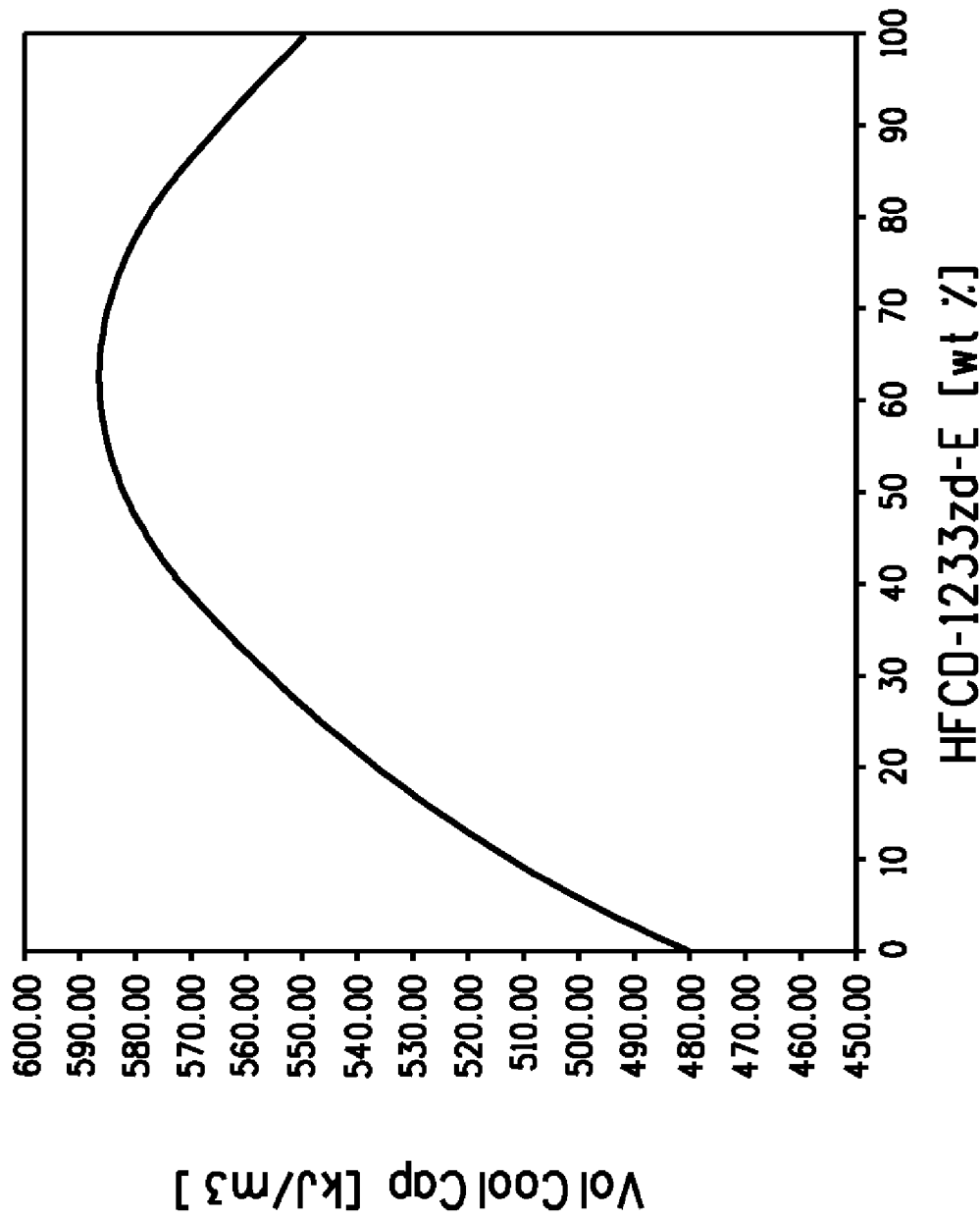


FIG. 1

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/032236

A. CLASSIFICATION OF SUBJECT MATTER
INV. F25B39/02 F25B1/047 F25B9/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F25B

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

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

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2011/022260 A1 (ARKEMA INC [US]; VAN HORN BRETT L [US]; BONNET PHILIPPE [FR]; ABBAS LA) 24 February 2011 (2011-02-24) cited in the application page 1 - page 10; figure 1 -----	1-16
A	WO 2011/130237 A1 (DU PONT [US]; KONTOMARIS KONSTANTINOS [US]; LECK THOMAS J [US]) 20 October 2011 (2011-10-20) page 21, line 1 - line 11; figures 1-3 -----	1-16
A	WO 2009/114398 A1 (ARKEMA INC [US]; VAN HORN BRETT L [US]; BONNET PHILIPPE [US]) 17 September 2009 (2009-09-17) page 1 - page 4; figures 1-9 -----	1-16



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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