

TITLE OF THE INVENTION

COMPOSITIONS COMPRISING TETRAFLUOROPROPENE AND USES THEREOF

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of priority of U.S. Provisional Application 63/546,461 filed October 30, 2023, the disclosure of which is incorporated herein by reference in its entirety.

FIELD

[0002] The present invention is directed to fluoroolefin refrigerant compositions, methods and systems using the same, and systems containing the E-HFO-1234ze refrigerant compositions.

BACKGROUND

[0003] The fluorocarbon industry has been working for the past few decades to find replacement refrigerants for ozone depleting chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) being phased out as a result of the Montreal Protocol. The solution for many applications has been the commercialization of hydrofluorocarbon (HFC) compounds for use as refrigerants, solvents, fire extinguishing agents, foam blowing agents and propellants. These new compounds, such as HFC-refrigerants, HFC-134a and HFC-125 being the most widely used at this time, have zero ozone depletion potential (ODP) and thus are not affected by the current regulatory phase-out as a result of the Montreal Protocol. In addition to ozone depleting concerns, global warming is another environmental concern in many applications. HFC refrigerants such as HFC-134a and HFC-125 respectively have global warming potentials (GWP) of 1,430 and 3,500 according to the UN's IPCC Fourth Assessment Report (AR4).

[0004] This regulatory landscape is continuously evolving, taking into consideration properties beyond just ODP and GWP. More particularly, there is a need for refrigerants composition that not only meet low ODP standards and have lower (<500 GWP) or low (<150 GWP) global warming potentials, but that also exhibit low or no flammability, provide superior performance in a variety of applications and which meet the standards of evolving regulations.

[0005] There is a need in this art for new refrigerant compositions that meet evolving regulations as well as provide heat transfer and refrigerant characteristics that meet or exceed the effectiveness of conventional refrigerant and refrigerant blends.

[0006] HFO-1234ze(E) (CF₃CH=CHF), like HFO-1234yf, has zero ozone depletion and very low global warming potential, and has thus been identified as a potential useful refrigerant. For example, U.S. Patent No. 7,862,742 discloses compositions comprising HFC-1234ze and HFO-1234yf. U.S. Patent No. 9,302,962 discloses methods for making HFO-1234ze. The disclosures of U.S. Patent No. 7,862,742 and U.S. Patent No. 9,302,962 are hereby incorporated by reference in their entireties. HFO-1234ze(E), which has zero ozone depletion and very low global warming potential and with a boiling point of -19.0 °C possesses physical properties that make it an attractive option for refrigeration, air conditioning, and heat pump applications.

[0007] The present invention solves certain problems associated with conventional refrigerants and provides HFO-1234ze(E)-based compositions which meet the evolving regulatory landscape.

SUMMARY

[0008] HFO-1234ze(E) has been used in refrigerant blends for several years. As a component of blends, it provides the ability to reduce global warming potential and provide environmentally sustainable refrigerant and refrigerant blends to the industry.

[0009] The present disclosure relates to compositions comprising HFO-1234zeE and HFC-152a.

[0010] In one embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E); HFC-152a; and one or more additional compounds or two or more additional compounds or three or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropylene, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a.

[0011] In one embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E); HFC-152a; and one or more additional compounds or two or more additional compounds or three or more additional compounds selected from HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0012] In one aspect of the invention, the compositions include refrigerant blends comprising, consisting of or consisting essentially of one of the following:

- a. HFO-1234ze(E), HFC-152a, HFC-245cb and HFC-161;
- b. HFO-1234ze(E), HFC-152a, HFO-1243zf and HFC-161;
- c. HFO-1234ze(E), HFC-152a, HFO-1243zf and HCO-1140;
- d. HFO-1234ze(E), HFC-152a, HFC-134 and HFC-134a;
- e. HFO-1234ze(E), HFC-152a, HFO-1234yf and HFC-161;
- f. HFO-1234ze(E), HFC-152a, HFO-1234yf and HCC-160;
- g. HFO-1234ze(E), HFC-152a, HFO-1225zc and HFC-161;
- h. HFO-1234ze(E), HFC-152a, HFC-134 and HFC-161;
- i. HFO-1234ze(E), HFC-152a, HFC-134a and HFO-1140;
- j. HFO-1234ze(E), HFC-152a, HCC-40 and HFC-161;
- k. HFO-1234ze(E), HFC-152a, HFO-1225zc and HCO-1140;
- l. HFO-1234ze(E), HFC-152a, HFO-1225zc and HFC-161; or
- m. HFO-1234ze(E), HFC-152a, HFO-1225zc and HCC-160.

[0013] In one aspect of the invention, the compositions include refrigerant blends comprising, consisting of or consisting essentially of one of the following:

- a. HFO-1234ze(E), HFC-152a, HFC-245cb, HFO-1234yf and HFC-161;
- b. HFO-1234ze(E), HFC-152a, HFC-245cb, HFO-1234yf and HCO-1140;
- c. HFO-1234ze(E), HFC-152a, HFC-245cb, HFO-1234yf and HCC-160;
- d. HFO-1234ze(E), HFC-152a, HFC-245cb, HFO-1234yf and HCC-40;
- e. HFO-1234ze(E), HFC-152a, HFC-134, HFC-134a and HFO-1140;
- f. HFO-1234ze(E), HFC-152a, HFO-134, HFC-134a and HFC-161;
- g. HFO-1234ze(E), HFC-152a, HFC-134, HFC-134a and HCO-40;

- h. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1243zf and HFC-161;
- i. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1243zf and HCO-1140; or
- j. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1243zf and HCC-40.

[0014] In some embodiments, the present disclosure relates to compositions comprising HFO-1234ze(E), HFC-152a, and at least one other compound selected from HFC-125, HFC-32, HFC-134, HFC-134a, HFC-227ea, HFO-1336mzz(E), HCFO-1224yd(Z), CO₂, and combinations thereof.

[0015] In one aspect of the invention, the compositions include refrigerant blends comprising, consisting of or consisting essentially of one of the following:

- a. HFO-1234ze(E), HFC-152a, and HFC-227ea;
- b. HFO-1234ze(E), HFC-152a, and HFO-1336mzz(E);
- c. HFO-1234ze(E), HFC-152a, HFO-1336mzz(E), and HFC-227ea;
- d. HFO-1234ze(E), HFC-134, and HFC-152a;
- e. HFO-1234ze(E), HFC-125, and HFC-152a;
- f. HFO-1234ze(E), HFC-32, and HFC-152a;
- g. HFO-1234ze(E), HFC-152a and CO₂;
- h. HFO-1234ze(E), HFC-125, HFC-32, and HFC-152a; and
- i. HFO-1234ze(E), HFC-134a, HCFO-1224yd(Z), and HFC-152a.

[0016] According to any of the foregoing embodiments, also disclosed herein are compositions comprising from about 88 to 91 weight percent HFO-1234ze(E), from about 4 to 9 weight percent HFC-227ea, and from about 3 to 5 weight percent HFC-152a.

[0017] According to any of the foregoing embodiments, also disclosed herein are compositions comprising from about 70 to 80 weight percent HFO-1234ze(E), from about 5 to 20 weight percent HFO-1336mzz(E), and from about 5 to 25 weight percent HFC-152a.

[0018] According to any of the foregoing embodiments, also disclosed herein are compositions comprising from about 70 to 80 weight percent HFO-1234ze(E), from

about 5 to 20 weight percent HFO-1336mzz(E), from about 5 to 25 weight percent HFC-152a, and from about 1 to 3 weight percent HFC-227ea.

[0019] According to any of the foregoing embodiments, also disclosed herein are compositions comprising from about 75 to 85 weight percent HFO-1234ze(E), from about 2 to 8 weight percent HFC-134, and from about 10 to 20 weight percent HFC-152a.

[0020] According to any of the foregoing embodiments, also disclosed herein are compositions comprising from about 75 to 85 weight percent HFO-1234ze(E), from about 3 to 7 weight percent HFC-125, and from about 10 to 20 weight percent HFC-152a.

[0021] According to any of the foregoing embodiments, also disclosed herein are compositions comprising about 60 to 95 weight percent HFO-1234ze(E), about 10 to 30 weight percent HFC-32, and about 5 to 10 weight percent HFC-152a.

[0022] According to any of the foregoing embodiments, also disclosed herein are compositions comprising about 85 to 95 weight percent HFO-1234ze(E), about 10 to 15 weight percent HFC-32, and about 5 to 10 weight percent HFC-152a.

[0023] According to any of the foregoing embodiments, also disclosed herein are compositions comprising about 60 weight percent HFO-1234ze(E), about 30 weight percent HFC-32, and about 10 weight percent HFC-152a.

[0024] According to any of the foregoing embodiments, also disclosed herein are compositions comprising from about 75 to 85 weight percent HFO-1234ze(E), from about 3 to 7 weight percent HFC-125, from about 3 to 7 weight percent HFC-32 and from about 5 to 15 weight percent HFC-152a.

[0025] According to any of the foregoing embodiments, also disclosed herein are compositions comprising from about 75 to 85 weight percent HFO-1234ze(E), from about 3 to 7 weight percent HFC-134a, from about 3 to 7 weight percent HCFO-1224yd(Z), and from about 5 to 15 weight percent HFC-152a.

[0026] According to any of the foregoing embodiments, also disclosed herein are compositions further comprising less than 100 ppm (weight) water, or less than 20 ppm (weight) water, or less than 10 ppm (weight) water.

[0027] According to any of the foregoing embodiments, also disclosed herein are compositions further comprising less than 5 volume percent non-adsorbable gases (NAG) or less than 3 volume percent NAG, or less than 1.5 volume percent NAG.

[0028] According to any of the foregoing embodiments, also disclosed herein are compositions further comprising a stabilizer.

[0029] According to any of the foregoing embodiments, also disclosed herein are compositions further comprising a lubricant selected from polyol ester, polyvinyl ether, and polyalkylene glycol.

[0030] According to any of the foregoing embodiments, also disclosed herein are compositions wherein said composition has global warming potential per IPCC AR4 less than 750, or less than 300, or less than 150.

[0031] According to any of the foregoing embodiments, also disclosed herein are compositions wherein said composition is characterized as flammability class 1 (non-flammable), flammability class 2L (mildly flammable), or flammability class 2. In some embodiments, the compositions disclosed herein are characterized as flammability class 2 or 2L.

[0032] According to any of the foregoing embodiments, also disclosed herein are compositions further comprising additional compounds. In one embodiment, said additional compounds are selected from HFC-23, HFC-32, HFC-125, HFC-143a, HFC-134, HFO-1132a, HFO-1132(E), HFO-1132(Z), HFO-1234ze(Z), HCFO-1233zd(E), HCFO-1233zd(Z), HFC-245fa, HFO-1336mzz(E), HFO-1336mzz(Z), HCC-1130(E), HCC-1130(Z), CFO-1112(E), CFO-1112(Z), HFC-356mcf, HFC-356mff, HFO-1234yf, HFC-227ea, HFO-1225ye(E), HCFO-1224yd(Z), HFC-134a, and combinations thereof.

[0033] According to any of the foregoing embodiments, also disclosed herein are compositions further comprising at least one hydrocarbon selected from propane, propylene, cyclopropane, isobutane, n-butane, isobutene, and combinations thereof.

[0034] According to any of the foregoing embodiments, also disclosed herein are compositions wherein the composition is free of or substantially free of Group A Fluorinated Substances.

[0035] According to any of the foregoing embodiments, also disclosed herein are compositions wherein degradation products of the composition are free of or substantially free of Group A Fluorinated Substances.

[0036] According to any of the foregoing embodiments, also disclosed herein is a process for producing cooling comprising condensing any of the foregoing compositions and thereafter evaporating said composition in the vicinity of a body to be cooled.

[0037] According to any of the foregoing embodiments, also disclosed herein is a process for producing heating comprising evaporating any of the foregoing compositions and thereafter condensing said composition in the vicinity of a body to be heated.

[0038] According to any of the foregoing embodiments, also disclosed herein is a refrigeration, air conditioning, heat pump, or chiller apparatus containing any of the foregoing compositions. The apparatus comprises an evaporator, a compressor, a condenser, and an expansion device. In one embodiment, the apparatus is a chiller. In another embodiment the apparatus is a heat pump. In another embodiment, the heat pump is a high temperature heat pump system. In another embodiment, the apparatus is an air conditioner or air conditioning system. In another embodiment, the apparatus is a medium temperature refrigeration system or a low temperature refrigeration system. In another embodiment, the apparatus is a stand-alone refrigeration system, such as a beverage cooler, vending machine or ice machine.

[0039] According to any of the foregoing embodiments, also disclosed herein are methods of replacing a first refrigerant in a heat transfer system comprising providing any of the foregoing compositions to said heat transfer system, wherein the first refrigerant is selected from HCFC-22, HFC-134a, HFO-1234yf, HFO-1234zeE, R-407C, R-404A, R-410A, R-454A, R-454B, R-454C, R-448A, R-449A, R-449B, R-449C, R-471A, R-476A, R-482A, R-452A, R-452C, R-513A, R-515B, and propane.

[0040] Also disclosed herein is a blowing agent composition comprising HFO-1234ze(E), HFC-152a, and one or more additional compounds selected from the group consisting of HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z),

HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, preferably two or more compounds or preferably three or more compound.

[0041] Also disclosed herein is a blowing agent composition comprising HFO-1234ze(E), HFC-152a, and one or more additional compounds selected from the group consisting of HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160, preferably two or more compounds or preferably three or more compounds.

[0042] Also disclosed herein is either of the above-disclosed blowing agent compositions comprising one of:

- a. HFO-1234ze(E), HFC-152a, HFC-245cb and HFC-161;
- b. HFO-1234ze(E), HFC-152a, HFO-1243zf and HFC-161;
- c. HFO-1234ze(E), HFC-152a, HFO-1243zf and HCO-1140;
- d. HFO-1234ze(E), HFC-152a, HFC-134 and HFC-134a;
- e. HFO-1234ze(E), HFC-152a, HFO-1234yf and HFC-161;
- f. HFO-1234ze(E), HFC-152a, HFO-1234yf and HCC-160;
- g. HFO-1234ze(E), HFC-152a, HFO-1225zc and HFC-161;
- h. HFO-1234ze(E), HFC-152a, HFC-134 and HFC-161;
- i. HFO-1234ze(E), HFC-152a, HFC-134a and HFO-1140;
- j. HFO-1234ze(E), HFC-152a, HCC-40 and HFC-161;
- k. HFO-1234ze(E), HFC-152a, HFO-1225zc and HCO-1140;
- l. HFO-1234ze(E), HFC-152a, HFO-1225zc and HFC-161;
- m. HFO-1234ze(E), HFC-152a, HFO-1225zc and HCC-160
- n. HFO-1234ze(E), HFC-152a, HFO-1225zc and HFO-1243zf;
- o. HFO-1234ze(E), HFC-152a, HFC-245cb and HFO-1234yf;
- p. HFO-1234ze(E), HFC-152a, HFO-1234yf and HFC-134a;
- q. HFO-1234ze(E), HFC-152a, HFO-1234yf and HFC-134;
- r. HFO-1234ze(E), HFC-152a, HFO-1234yf and HFO-1243zf;
- s. HFO-1234ze(E), HFC-152a, HFC-245cb and HFC-134a;

- t. HFO-1234ze(E), HFC-152a, HFC-245cb and HFC-134; or
- u. HFO-1234ze(E), HFC-152a, HFC-245cb and HFO-1243zf.

[0043] Also disclosed herein is either of the above-disclosed blowing agent compositions comprising one of:

- a. HFO-1234ze(E), HFC-152a, HFC-245cb, HFO-1234yf and HFC-161;
- b. HFO-1234ze(E), HFC-152a, HFC-245cb, HFO-1234yf and HCO-1140;
- c. HFO-1234ze(E), HFC-152a, HFC-245cb, HFO-1234yf and HCC-160;
- d. HFO-1234ze(E), HFC-152a, HFC-245cb, HFO-1234yf and HCC-40;
- e. HFO-1234ze(E), HFC-152a, HFC-134, HFC-134a and HFO-1140;
- f. HFO-1234ze(E), HFC-152a, HFO-134, HFC-134a and HFC-161;
- g. HFO-1234ze(E), HFC-152a, HFC-134, HFC-134a and HCO-40;
- h. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1243zf and HFC-161;
- i. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1243zf and HCO-1140;
- j. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1243zf and HCC-40;
- k. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1243zf and HFO-1234yf;
- l. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1234yf and HFC-134a;
- m. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1234yf and HFC-134;
- n. HFO-1234ze(E), HFC-152a, HFO-1243zf, HFC-245cb and HFO-1234yf;
- o. HFO-1234ze(E), HFC-152a, HFO-1243zf, HFC-134 and HFC-134a;
- p. HFO-1234ze(E), HFC-152a, HFO-1234yf, HFC-134 and HFC-134a;
- q. HFO-1234ze(E), HFC-152a, HFO-1243zf, HFC-245cb and HFC-134a;
- r. HFO-1234ze(E), HFC-152a, HFO-1243zf, HFC-245cb and HFC-134;
- s. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1243zf, HFO-1234yf and HFC-245cb;
- t. HFO-1234ze(E), HFC-152a, HFO-1234yf, HFC-245cb, HFC-134a and HFC-134; or
- u. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1234yf, HFC-134a and HFC-134.

[0044] Also disclosed herein is any embodiment in which any of the above-disclosed blowing agent compositions further comprise less than 100 ppm wt water, preferably less than 20 ppm wt water, and more preferably less than 10 ppm wt water.

[0045] Also disclosed herein is any embodiment in which any of the above-disclosed blowing agent compositions have a ratio of HFO-1234ze(E):HFC-152a of from about 40:60 to about 60:40, preferably about 50:50 ratio, more preferably about 45:55.

[0046] Also disclosed herein is any embodiment in which any of the above-disclosed blowing agent compositions is utilized for making polystyrene foam.

DETAILED DESCRIPTION

[0047] A refrigerant is defined as a heat transfer fluid that undergoes a phase change from liquid to gas and back again during a cycle used to transfer of heat.

[0048] A heat transfer system is the system (or apparatus) used to produce a heating or cooling effect in a particular space. A heat transfer system may be a mobile system or a stationary system.

[0049] Examples of heat transfer systems are any type of refrigeration systems and air conditioning systems including, but are not limited to, stationary heat transfer systems, air conditioners, freezers, refrigerators, heat pumps, flooded evaporator heat pumps, direct expansion chillers heat pumps, chillers, flooded evaporator chillers, direct expansion chillers, walk-in coolers, mobile refrigerators, mobile heat transfer systems, mobile heat pumps, mobile air conditioning units, dehumidifiers, and combinations thereof.

[0050] Volumetric capacity is the amount of heat absorbed or rejected divided by the theoretical compressor displacement. Heat removed or absorbed is the enthalpy difference across a heat exchanger multiplied by the refrigerant mass flowrate. Theoretical compressor displacement is the refrigerant mass flowrate divided by the density of the gas entering the compressor (i.e., compressor suction density). More simply, volumetric capacity is the suction density multiplied by the heat exchanger enthalpy difference. Higher volumetric capacity allows the use of a smaller

compressor for the same heat load. Herein, cooling capacity refers to the volumetric capacity in cooling mode and heating capacity refers to the volumetric capacity in heating mode.

[0051] Coefficient of performance (COP) is the amount of heat absorbed or rejected divided by the required energy input to operate the cycle (approximated by the compressor power). COP is specific to the mode of operation of a heat pump, thus COP for heating or COP for cooling. COP is directly related to the energy efficiency ratio (EER).

[0052] Subcooling refers to the reduction of the temperature of a liquid below that liquid's saturation point for a given pressure. The liquid saturation point is the temperature at which the vapor is completely condensed to a liquid. By cooling a liquid below the saturation temperature (or bubble point temperature), the net refrigeration effect can be increased. Subcooling thereby improves refrigeration capacity and energy efficiency of a system. The subcool amount is the amount of cooling below the saturation temperature (in degrees).

[0053] Superheating refers to the increase of the temperature of a vapor above that vapor's saturation point for a given pressure. The vapor saturation point is the temperature at which the liquid is completely evaporated to a vapor. Superheating continues to heat the vapor to a higher temperature vapor at the given pressure. By heating the vapor above the saturation temperature (or dew point temperature), the net refrigeration effect can be increased. Superheating thereby improves refrigeration capacity and energy efficiency of a system when it occurs in the evaporator. Suction line superheat does not add to the net refrigeration effect and can reduce efficiency and capacity. The superheat amount is the amount of heating above the saturation temperature (in degrees).

[0054] Temperature glide (sometimes referred to simply as "glide") is the absolute value of the difference between the starting and ending temperatures of a phase-change process by a refrigerant within a condenser of a refrigerant system, exclusive of any subcooling or superheating. For an evaporator, the glide is the difference in temperature between the dew point and the evaporator inlet. Glide may be used to describe condensation or evaporation of a near azeotrope or non-azeotropic composition. When referring to the temperature glide of an air conditioning or heat

pump system, it is common to provide the average temperature glide being the average of the temperature glide in the evaporator and the temperature glide in the condenser. Glide is applicable to blend refrigerants, i.e. refrigerants that are composed of at least two components.

[0055] The net refrigeration effect is the quantity of heat that each kilogram of refrigerant absorbs in the evaporator to produce useful cooling.

[0056] The mass flow rate is the quantity of refrigerant in kilograms circulating through the refrigeration, heat pump or air conditioning system over a given period of time.

[0057] As used herein, the term “lubricant” means any material added to a composition or a compressor (and in contact with any heat transfer composition in use within any heat transfer system) that provides hydrodynamic lubrication to the compressor to aid in preventing parts from seizing.

[0058] Flammability is a term used to mean the ability of a composition to ignite and/or propagate a flame. For refrigerants and other heat transfer compositions, the lower flammability limit (“LFL”) is the minimum concentration of the heat transfer composition in air that is capable of propagating a flame through a homogeneous mixture of the composition and air under test conditions specified in ASTM (American Society of Testing and Materials) E681. The upper flammability limit (“UFL”) is the maximum concentration of the heat transfer composition in air that is capable of propagating a flame through a homogeneous mixture of the composition and air under the same test conditions. Determination of whether a refrigerant compound or mixture able to propagate a flame or not is also done by testing under the conditions of ASTM E-681.

[0059] During a refrigerant leak, the more volatile components of a mixture may leak preferentially. Thus, the composition in the system as well as the vapor leaking can vary over the time period of the leak. Thus, a non-flammable mixture may become able to propagate a flame under leakage scenarios. In order to be classified as non-flammable by ASHRAE (American Society of Heating, Refrigeration and Air-conditioning Engineers), a refrigerant or heat transfer composition must be non-flammable as formulated, but also under specified leakage conditions.

[0060] In order for a refrigerant to be classified by ANSI/ASHRAE as low flammability (class 2L), it must: 1) exhibit flame propagation when tested at 140°F (60°C) and 14.7 psia (101.3 kPa); 2) have an LFL >0.0062 lb/ft³ (0.10 kg/m³); 3) have a heat of combustion <8169 Btu/lb (19,000 kJ/kg); and 4) have a maximum burning velocity of ≤3.9 in./s (10 cm/s) when tested at 73.4°F (23.0°C) and 14.7 psia (101.3 kPa) in dry air.

[0061] In order for a refrigerant to be classified by ANSI/ASHRAE as flammable (class 2), it must: 1) exhibit flame propagation when tested at 140°F (60°C) and 14.7 psia (101.3 kPa); 2) have an LFL >0.0062 lb/ft³ (0.10 kg/m³); and 3) have a heat of combustion <8169 Btu/lb (19,000 kJ/kg).

[0062] In order for a refrigerant to be classified by ANSI/ASHRAE standard 34 class 3, refrigerant 1) exhibits flame propagation when tested at 140°F (60°C) and 14.7 psia (101.3 kPa), 2) has an LFL < 0.0062 lb/ft³ (0.10 kg/m³) or 3) has a heat of combustion >8169 Btu/lb (19,000 kJ/kg).

[0063] ASHRAE Standard 34 provides a methodology to calculate the heat of combustion for refrigerant blends using a balanced stoichiometric equation based on the complete combustion of one mole of refrigerant with enough oxygen for a stoichiometric reaction. Global warming potential (GWP) is an index for estimating relative global warming contribution due to atmospheric emission of a kilogram of a particular greenhouse gas compared to emission of a kilogram of carbon dioxide. GWP can be calculated for different time horizons showing the effect of atmospheric lifetime for a given gas. The GWP for the 100-year time horizon is commonly the value referenced. For mixtures, a weighted average can be calculated based on the individual GWPs for each component. Herein, the GWP values are those reported in the International Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) as those are the currently used values for several regulatory bodies

[0064] Ozone depletion potential (ODP) is a number that refers to the amount of ozone depletion caused by a substance. The ODP is the ratio of the impact on ozone of a chemical compared to the impact of a similar mass of CFC-11 (fluorotrichloromethane). Thus, the ODP of CFC-11 is defined to be 1.0. Other CFCs and HCFCs have ODPs that range from 0.01 to 1.0. HFCs and HFOs have

zero ODP because they do not contain chlorine, bromine or other ozone depleting halogens.

[0065] 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.

[0066] 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.

[0067] The transitional phrase “consisting essentially of” is used to define a composition, method or apparatus 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. The term “consisting essentially of” occupies a middle ground between “comprising” and “consisting of”. Typically, components of the refrigerant mixtures and the refrigerant mixtures themselves can contain minor amounts (e.g., less than about 0.5 weight percent total) of impurities and/or byproducts (e.g., from the manufacture of the refrigerant components or reclamation of the refrigerant components from other systems) which do not materially affect the novel and basic characteristics of the refrigerant mixture.

[0068] 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 describe such an invention using the terms “consisting essentially of” or “consisting of.”

[0069] 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

[0070] Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Although methods and materials similar or equivalent to those described herein can be used in the practice or testing of embodiments of the disclosed compositions, suitable methods and materials are described below. All publications, patent applications, patents, and other references mentioned herein are incorporated by reference in their entirety, unless a particular passage is cited. In case of conflict, the present specification, including definitions, will control. In addition, the materials, methods, and examples are illustrative only and not intended to be limiting.

COMPOSITIONS

[0071] In one embodiment, the present disclosure provides compositions comprising HFO-1234zeE and HFC-152a.

[0072] In one embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E); HFC-152a; and one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a.

[0073] In one embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E); HFC-152a; one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb and HFC-134; and one or more additional compounds selected from HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a.

[0074] In one embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E); HFC-152a; and one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0075] In one embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E); HFC-152a; one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1225zc and HFO-1243zf; and one or more additional compounds selected from HFC-161, HCC-40, HCO-1140 and HCC-160.

[0076] In one embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E); HFC-152a; and two or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropylene, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a.

[0077] In one embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E); HFC-152a; and two or more additional compounds selected from HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0078] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and two additional compounds of HFC-245cb and HFC-161. The composition may optionally further comprise one or more additional compounds selected from HFO-1234yf, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropylene, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFO-1234yf, HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HCC-40, HCO-1140 and HCC-160.

[0079] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and two additional compounds of

HFO-1243zf and HFC-161. The composition may optionally further comprise one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFC-263fb, HFC-134, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1225zc, HCC-40, HCO-1140 and HCC-160.

[0080] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and two additional compounds of HFO-1243zf and HCO-1140. The composition may optionally further comprise one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCC-160 and CFC-114a, more preferably selected from HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFC-161, HCC-40 and HCC-160.

[0081] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and two additional compounds of HFC-134 and HFC-134a. The composition may optionally further comprise one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFO-1234yf, HFC-245cb, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0082] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and two additional compounds of HFO-1234yf and HFC-161. The composition may optionally further comprise one or more additional compounds selected from HFC-245cb, HFO-1225ye(E), HFO-

1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HCC-40, HCO-1140 and HCC-160.

[0083] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and two additional compounds of HFO-1234yf and HCC-160. The composition may optionally further comprise one or more additional compounds selected from HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140 and CFC-114a, more preferably selected from HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40 and HCO-1140.

[0084] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and two additional compounds of HFO-1225zc and HFC-161. The composition may optionally further comprise one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1243zf, HCC-40, HCO-1140 and HCC-160.

[0085] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and two additional compounds of HFC-134 and HFC-161. The composition may optionally further comprise one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124,

trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFO-1234yf, HFC-245cb, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HCC-40, HCO-1140 and HCC-160.

[0086] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and two additional compounds of HFC-134a and HCO-1140. The composition may optionally further comprise one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCC-160 and CFC-114a, more preferably selected from HFO-1234yf, HFC-245cb, HFC-134, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40 and HCC-160.

[0087] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and two additional compounds of HCC-40 and HFC-161. The composition may optionally further comprise one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HCO-1140 and HCC-160.

[0088] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and two additional compounds of HFO-1225zc and HCO-1140. The composition may optionally further comprise one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCC-160 and CFC-114a, more preferably selected from HFO-

1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1243zf, HFC-161, HCC-40 and HCC-160.

[0089] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and two additional compounds of HFO-1225zc and HFC-161. The composition may optionally further comprise one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1243zf, HCC-40, HCO-1140 and HCC-160.

[0090] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and two additional compounds of HFO-1225zc and HCC-160. The composition may optionally further comprise one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, and CFC-114a, more preferably selected from HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1243zf, HFC-161, HCC-40 and HCO-1140.

[0091] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and two additional compounds of HFO-1225zc and HFO-1243zf. The composition may optionally further comprise one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0092] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and two additional compounds of HFO-1234yf and HFC-245cb. The composition may optionally further comprise one or more additional compounds selected from HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0093] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and two additional compounds of HFO-1234yf and HFC-134a. The composition may optionally further comprise one or more additional compounds selected from HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFC-245cb, HFC-134, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0094] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and two additional compounds of HFO-1234yf and HFC-134. The composition may optionally further comprise one or more additional compounds selected from HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFC-245cb, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0095] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and two additional compounds of

HFO-1234yf and HFO-1243zf. The composition may optionally further comprise one or more additional compounds selected from HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0096] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and two additional compounds of HFC-245cb and HFC-134a. The composition may optionally further comprise one or more additional compounds selected from HFO-1234yf, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFO-1234yf, HFC-134, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0097] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and two additional compounds of HFC-245cb and HFC-134. The composition may optionally further comprise one or more additional compounds selected from HFO-1234yf, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFO-1234yf, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0098] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and two additional compounds of HFC-245cb and HFO-1243zf. The composition may optionally further comprise one or more additional compounds selected from HFO-1234yf, HFO-1225ye(E), HFO-

1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFO-1234yf, HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0099] In one embodiment, the composition comprise, consist of or consist essentially of HFO-1234ze(E); HFC-152a; and three or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a.

[0100] In one embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E); HFC-152a; and three or more additional compounds selected from HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0101] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and three additional compounds of HFC-245cb, HFO-1234yf and HCO-1140. The composition may optionally further comprise one or more additional compounds selected from HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCC-160 and CFC-114a, more preferably selected from HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40 and HCC-160.

[0102] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and three additional compounds of HFC-245cb, HFO-1234yf and HFC-161. The composition may optionally further comprise one or more additional compounds selected from HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-

1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HCC-40, HCO-1140 and HCC-160.

[0103] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and three additional compounds of HFC-245cb, HFO-1234yf and HCC-160. The composition may optionally further comprise one or more additional compounds selected from HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140 and CFC-114a, more preferably selected from HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140.

[0104] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and three additional compounds of HFC-245cb, HFO-1234yf and HCC-40. The composition may optionally further comprise one or more additional compounds selected from HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCO-1140 and HCC-160.

[0105] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and three additional compounds of HFC-134a, HFC-134 and HCO-1140. The composition may optionally further comprise one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb,

HFC-161, HCC-40, isobutane, HCC-160 and CFC-114a, more preferably selected from HFO-1234yf, HFC-245cb, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40 and HCC-160.

[0106] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and three additional compounds of HFC-134a, HFC-134 and HFC-161. The composition may optionally further comprise one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFO-1234yf, HFC-245cb, HFC-125, HFO-1225zc, HFO-1243zf, HCC-40, HCO-1140 and HCC-160.

[0107] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and three additional compounds of HFC-134a, HFC-134 and HCC-40. The composition may optionally further comprise one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-161, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFO-1234yf, HFC-245cb, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCO-1140 and HCC-160.

[0108] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and three additional compounds of HFO-1225zc, HFO-1243zf and HFC-161. The composition may optionally further comprise one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFC-263fb, HFC-134, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected

from HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HCC-40, HCO-1140 and HCC-160.

[0109] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and three additional compounds of HFO-1225zc, HFO-1243zf and HCO-1140. The composition may optionally further comprise one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCC-160 and CFC-114a, more preferably selected from HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFC-161, HCC-40 and HCC-160.

[0110] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and three additional compounds of HFO-1225zc, HFO-1243zf and HCC-40. The composition may optionally further comprise one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFC-263fb, HFC-134, HFC-161, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFC-161, HCO-1140 and HCC-160.

[0111] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and three additional compounds of HFO-1225zc, HFO-1243zf and HFO-1234yf. The composition may optionally further comprise one or more additional compounds selected from HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFC-245cb, HFC-134, HFC-134a, HFC-125, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0112] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and three additional compounds of HFO-1225zc, HFO-1234yf and HFC-134a. The composition may optionally further comprise one or more additional compounds selected from HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFC-236fa, HFC-143a, HFC-125, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFC-245cb, HFC-134, HFC-125, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0113] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and three additional compounds of HFO-1225zc, HFO-1234yf and HFC-134. The composition may optionally further comprise one or more additional compounds selected from HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFC-245cb, HFC-134a, HFC-125, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0114] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and three additional compounds of HFO-1234yf, HFC-245cb and HFO-1243zf. The composition may optionally further comprise one or more additional compounds selected from HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0115] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and three additional compounds

of HFO-1234yf, HFC-134a and HFC-134. The composition may optionally further comprise one or more additional compounds selected from HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFC-245cb, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0116] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and three additional compounds of HFO-1234yf, HFC-245cb and HFC-134a. The composition may optionally further comprise one or more additional compounds selected from HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFC-134, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0117] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and three additional compounds of HFO-1234yf, HFC-245cb and HFC-134. The composition may optionally further comprise one or more additional compounds selected from HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0118] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and three additional compounds of HFO-1243zf, HFC-134a and HFC-134. The composition may optionally further comprise one or more additional compounds selected from HFO-1234yf, HFC-

245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFC-263fb, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFO-1234yf, HFC-245cb, HFC-125, HFO-1225zc, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0119] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and four additional compounds of HFO-1225zc, HFO-1243zf, HFO-1234yf and HFC-245cb. The composition may optionally further comprise one or more additional compounds selected from HFO-1225ye(E), HFO-1225ye(Z), HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0120] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and four additional compounds of HFO-1234yf, HFC-245cb, HFC-134a and HFC-134. The composition may optionally further comprise one or more additional compounds selected from HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0121] In one exemplary embodiment, the composition comprises, consists of or consists essentially of HFO-1234ze(E), HFC-152a, and four additional compounds of HFO-1225zc, HFO-1243zf, HFC-134a and HFC-134. The composition may optionally further comprise one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFC-236fa, HFC-143a, HFC-125, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFC-263fb, HFC-161,

HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFO-1234yf, HFC-245cb, HFC-125, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0122] In one embodiment, the present disclosure provides compositions comprising HFO-1234zeE, HFC-152a, and at least one compound selected from HFC-23, HFC-32, HFC-125, HFC-143a, HFC-134, HFC-134a, HFC-161, HFC-227ca, HCFC-151a, HCFC-22, HCC-40, CFC-114, CFC-115, HCFC-124, HFO-1132a, HFO-1132(E), HFO-1132(Z), HFO-1234ze(Z), HCFO-1233zd(E), HCFO-1233zd(Z), HFO-1233xf, HFC-245fa, HFO-1336mzz(E), HFO-1336mzz(Z), HCC-1130(E), HCC-1130(Z), CFO-1112(E), CFO-1112(Z), HFC-356mcf, HFC-356mff, HFO-1234yf, HFO-1234zc, HFC-227ea, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFO-1243zf, HCFO-1224yd(Z), HFC-134a, HFC-245cb, HFC-236fa, HFO-2223, HFC-263fb and combinations thereof. The compositions may further comprise one or more additional compounds, two or more additional compounds or three or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropylene, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0123] In one embodiment, the present disclosure provides compositions comprising HFO-1234zeE, HFC-152a, and at least one compound selected from HFC-227ea, HFC-134, HFC-125, HFC-32, HFC-134a, HFO-1336mzz(E), HCFO-1224yd(Z), and combinations thereof. The compositions may further comprise one or more additional compounds, two or more additional compounds or three or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropylene, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0124] The compositions of the present invention provide refrigerant performance that is improved over existing HFC refrigerants and blends and even improved over existing HFO refrigerants and blends. Additionally, the presently disclosed compositions are expected to meet the evolving regulatory landscape in the refrigerants business.

[0125] E-1,3,3,3-Tetrafluoropropene (HFO-1234ze(E) or R-1234zeE) is available commercially from Honeywell (Charlotte, North Carolina, USA). 1,1-difluoroethane (HFC-152a or R-152a), E-1,1,1,4,4,4-hexafluoro-2-butene (HFO-1336mzzE, or R-1336mzzE), 1,1,2,2-tetrafluoroethane (HFC-134, or R-134), 1,1,1,2-tetrafluoroethane (HFC-134a, or R-134a), are available commercially from Chemours™ (Wilmington, DE, USA). Difluoromethane (HFC-32 or R-32), pentafluoroethane (HFC-125, or R-125), 1,1,1,2,3,3,3-heptafluoropropane (HFC-227ea, or R-227ea), Z-1-chloro-2,3,3,3-tetrafluoropropene (HCFO-1224yd(Z), or R-1224yd(Z)) are available commercially from various sources worldwide.

[0126] In another embodiment, the compositions comprise, consist of or consist essentially of:

- a. HFO-1234ze(E), HFC-152a, and HFC-227ea;
- b. HFO-1234ze(E), HFC-152a, and HFO-1336mzz(E);
- c. HFO-1234ze(E), HFC-152a, HFO-1336mzz(E), and HFC-227ea;
- d. HFO-1234ze(E), HFC-152a, and HFC-134;
- e. HFO-1234ze(E), HFC-152a, and HFC-125;
- f. HFO-1234ze(E), HFC-152a and CO₂;
- g. HFO-1234ze(E), HFC-152a and HFC-32;
- h. HFO-1234ze(E), HFC-152a, HFC-125, and HFC-32; or
- f. HFO-1234ze(E), HFC-152a, HCFO-1224yd(Z), and HFC-134a.

[0127] In some embodiments, any of the above compositions (a) to (i) may further comprise one or more additional compounds, two or more additional compounds or three or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropylene, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb,

HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0128] In some embodiments, along with the additional compounds listed above, composition (a) may further comprise one or more additional compounds selected from HFC-23, FC-1216, HFC-143a, HFC-134a, HCFC-22, HCFC-124, FC-218, HFC-236fa and HFO-1225zc.

[0129] In some embodiments, along with the additional compounds listed above, composition (b) may further comprise one or more additional compounds selected from C-30, HCFC-114, HCFC-114a, HCFC-133, HCFC-133a, HFC-245fa, HFC-338mee, HFC-338mf, HFC-347mef, HCO-1140, HCFO-1224 isomers, HCFO-1224yd, HCFO-1224yb, HCFO-1233xf, HCFO-1233zd, HFO-1243zf, HFO-1327mz, HFO-1336ft and HCFO-1326mxz.

[0130] In some embodiments, along with the additional compounds listed above, composition (c) may further comprise one or more additional compounds selected from C-30, HCFC-114, HCFC-114a, HCFC-133, HCFC-133a, HFC-245fa, HFC-338mee, HFC-338mf, HFC-347mef, HCO-1140, HCFO-1224 isomers, HCFO-1224yd, HCFO-1224yb, HCFO-1233xf, HCFO-1233zd, HFO-1243zf, HFO-1327mz, HFO-1336ft, HCFO-1326mxz, HFC-23, FC-1216, HFC-143a, HFC-134a, HCFC-22, HCFC-124, FC-218, HFC-236fa and HFO-1225zc.

[0131] In some embodiments, along with the additional compounds listed above, composition (d) may further comprise one or more additional compounds selected from HFC-134a, HCFC-124, HCFC-124a, HCFO-1122, HFC-143a, HCFC-31, HFC-32, HFC-125, CFC-114, CFC-114a, FCO-1114, HFC-152a, FCO-1318my, HFC-245cb, FC-C318, and HC-161.

[0132] In some embodiments, along with the additional compounds listed above, composition (e) may further comprise one or more additional compounds selected from HFC-23, HFC-32, HFC-143a, HFC-134a, CFC-115, CFCO-1113 and HCC-40.

[0133] In some embodiments, along with the additional compounds listed above, composition (f) may further comprise one or more additional compounds selected from N₂, Ar, CO and O₂.

[0134] In some embodiments, along with the additional compounds listed above, composition (g) may further comprise one or more additional compounds selected from HFC-143a, HFC-41, HFC-134a, HCFC-22, CFC-12 and HCC-40.

[0135] In some embodiments, along with the additional compounds listed above, composition (h) may further comprise one or more additional compounds selected from HFC-143a, HFC-41, HFC-134a, HCFC-22, CFC-12, HCC-40, HFC-23, CFC-115 and CFCO-1113.

[0136] In some embodiments, along with the additional compounds listed above, composition (i) may further comprise one or more additional compounds selected from HFC-143a, HFO-1225zc, HFC-245cb, HFC-134, HFO-1225ye, HFC-161, HCFC-22, HFO-1243zf, CHFC-124, HCC-40, CHFO-1122, HCFC-31, CFC-114, CFC-114a, HCO-1140, HFO-1234yf, HFC-263fb, HFC-254eb, HFO-1215yb, HCFC-244bb, HFO-1224yd(E), HFO-1224 isomer(s), HFO-1112a, HFC-225ca, HFC-225cb and HFC-234bb.

[0137] In another embodiment, disclosed herein are compositions comprising from about 88 to 91 weight percent HFO-1234ze(E), from about 4 to 9 weight percent HFC-227ea, and from about 3 to 5 weight percent HFC-152a. In another embodiment, the compositions comprise from about 88 to 91 weight percent HFO-1234ze(E), from about 4.2 to 9 weight percent HFC-227ea, and from about 3 to 4.8 weight percent HFC-152a.

[0138] In another embodiment, disclosed herein are compositions comprising from about 70 to 80 weight percent HFO-1234ze(E), from about 5 to 20 weight percent HFO-1336mzz(E), and from about 5 to 25 weight percent HFC-152a.

[0139] In another embodiment, disclosed herein are compositions comprising from about 70 to 80 weight percent HFO-1234ze(E), from about 5 to 20 weight percent HFO-1336mzz(E), from about 5 to 25 weight percent HFC-152a, and from about 1 to 3 weight percent HFC-227ea.

[0140] In another embodiment, disclosed herein are compositions comprising from about 75 to 85 weight percent HFO-1234ze(E), from about 2 to 8 weight percent HFC-134, and from about 10 to 20 weight percent HFC-152a.

[0141] In another embodiment, disclosed herein are compositions comprising from about 75 to 85 weight percent HFO-1234ze(E), from about 2 to 8 weight percent HFC-125, and from about 10 to 20 weight percent HFC-152a.

[0142] In another embodiment, disclosed herein are compositions comprising about 60 weight percent HFO-1234ze(E), about 10 weight percent HFC-32, and about 30 weight percent HFC-152a.

[0143] In another embodiment, disclosed herein are compositions comprising from about 75 to 85 weight percent HFO-1234ze(E), from about 3 to 7 weight percent HFC-125, from about 3 to 7 weight percent HFC-32 and from about 5 to 15 weight percent HFC-152a.

[0144] In another embodiment, disclosed herein are compositions comprising from about 75 to 85 weight percent HFO-1234ze(E), from about 3 to 7 weight percent HFC-134a, from about 3 to 7 weight percent HCFO-1224yd(Z), and from about 5 to 15 weight percent HFC-152a.

[0145] In some embodiments, the one or more additional compounds contained in any of the compositions disclosed herein is/are selected from those compounds which increase cooling capacity ("CAP") and/or increase coefficient of performance ("COP") relative to an incumbent composition, and/or reduce flammability of the composition to be, for example, flammability class 2L (mildly flammable), or flammability class 2. In some embodiments, the one or more additional compounds contained in any of the compositions disclosed herein is/are selected from HFO-1234yf, HFO-1243zf, HFO-1225zc, HFC-161, HCC-40, HFC-134, HFC-134a and HFC-245cb.

[0146] In some embodiments, the one or more additional compounds contained in any of the compositions disclosed herein is/are selected from HFO-1234yf, HFO-1243zf, HFO-1225zc, HFC-161, HCC-40, HFC-134 and HFC-134a, as such compounds may increase CAP and/or COP of the composition relative to an incumbent composition.

[0147] In some embodiments, the one or more additional compounds contained in any of the compositions disclosed herein is/are selected from HFO-1225zc,

HFC-134, HFC-134a and HFC-245cb, as such compounds may provide for composition which has a flammability classification of 2L or 2.

[0148] The amount of additional compounds present in any of the compositions disclosed herein can be greater than 0 ppm and less than 5,000 ppm and, in particular, can range from about 5 to about 1,000 ppm, about 5 to about 500 ppm and about 1 to about 100 ppm, based on the total weight of the composition.

[0149] In one embodiment, the amount of additional compounds present in any of the compositions disclosed herein can be greater than 0 and less than 1 wt%, preferably less than 0.5 weight percent, or more preferably less than 0.1 weight percent, based on the total weight of the composition.

[0150] In one embodiment, the compositions as disclosed herein may further comprise at least one hydrocarbon selected from the group consisting of propane, propylene, cyclopropane, isobutane, n-butane, isobutene, and combinations thereof.

[0151] In some embodiments, the compositions comprising, consisting essentially of, or consisting of HFO-1234ze(E), HFC-152a, and at least one compound selected from HFC-227ea, HFO-1336mzz(E), HFC-134, HFC-125, HFC-32, HFC-134a, HCFO-1224yd(Z), and combinations thereof, according to the present invention, and the degradation products thereof are preferably free of or substantially free of Group A Fluorinated Substances.

[0152] In one embodiment, as used herein, " Group A Fluorinated Substances" includes any substance that (i) contains at least one fully fluorinated methyl ($-\text{CF}_3$) or methylene ($-\text{CF}_2-$) carbon atom (without any H/Cl/Br/I attached to it); and (ii) meets the criterion for persistence in soil/sediment and water established in Annex XIII (Section 1.1.1) of the European Union's REACH Regulation (<https://reachonline.eu/reach/en/annex-xiii-1-1.1-1.1.1.html> as accessed on May 2, 2023) and referenced in the Annex XV Restriction Report dated March 22, 2023, the disclosure of which is hereby incorporated by reference (<https://echa.europa.eu/documents/10162/f605d4b5-7c17-7414-8823-b49b9fd43aea> as accessed on May 2, 2023). In one embodiment, Group A Fluorinated Substances include, but are not limited to, trifluoroacetic acid (TFA).

[0153] In another embodiment, as used herein, "Group A Fluorinated Substances" includes any substance that has a Henry's Law constant $\leq 250 \text{ Pa}\cdot\text{m}^3/\text{mol}$ and contains at least one fully fluorinated methyl ($-\text{CF}_3$) or methylene ($-\text{CF}_2-$) carbon atom (without any H/Cl/Br/I attached to it). In one embodiment, Group A Fluorinated Substances include, but are not limited to, TFA.

[0154] Thus, according to some embodiments, compositions of the present invention comprise HFO-1234ze(E), as a single fluid or blend, and are free of or substantially free of Group A Fluorinated Substances, such as TFA. In one embodiment, the phrase "free of" as used herein with respect to the presence of Group A Fluorinated Substances in the present compositions means that the amount of such substances in the compositions is sufficiently low so as to not be detectable, including but not limited to 0%, when measured by gas chromatography with a flame ionization detector, gas chromatography with a mass detector by analysis of a gas sample or liquid sample, and/or ion chromatography by analysis of a water sample after bubbling the thermal fluid through water. Such methodologies are well known to those skilled in the art. In one embodiment, the phrase "substantially free of" as used herein with respect to the presence of Group A Fluorinated Substances in the present compositions means that the amount of such substances in the compositions is $> 0 \text{ wt.}\%$ and $\leq 15 \text{ wt.}\%$, $> 0 \text{ wt.}\%$ and $\leq 10 \text{ wt.}\%$, or $> 0 \text{ wt.}\%$ and $\leq 5 \text{ wt.}\%$, or $> 0 \text{ wt.}\%$ and $\leq 4 \text{ wt.}\%$, or $> 0 \text{ wt.}\%$ and $\leq 3 \text{ wt.}\%$, or $> 0 \text{ wt.}\%$ and $\leq 2 \text{ wt.}\%$, or $> 0 \text{ wt.}\%$ and $\leq 1 \text{ wt.}\%$, and all values and ranges therebetween, when measured by gas chromatographic (GC) techniques, for example gas chromatography (GC) with a flame ionization or electron-capture detector, or GC coupled with a mass detector (gas chromatography/mass spectral (GC/MS) method), by ion chromatograph(IC) or ion chromatography mass spectrometry (IC-MS) techniques, or by high-performance liquid chromatography (HPLC) or high-performance liquid chromatography mass spectrometry (HPLC-MS) techniques. The TFA analytical standard may be used in either gas chromatography or ion chromatography and is available from, for example, Sigma Aldrich.

[0155] Further, in some embodiments, degradation products of such compositions of the present invention which comprise HFO-1234ze(E), as a single fluid or blend, are free of or substantially free of Group A Fluorinated Substances, such as TFA. In one embodiment, the phrase "free of" as used herein with respect to the formation of

Group A Fluorinated Substances by the present compositions means that the theoretical molar yield of such substances in environmental compartments of air, soil/sediment and water produced during tropospheric degradation of the compositions is sufficiently low so as to not be detectable, including but not limited to 0%, when measured by GC techniques, for example GC with a flame ionization or electron-capture detector or GC/MS method, by IC or IC-MS techniques, or by HPLC or HPLC-MS techniques. In one embodiment, the phrase "substantially free of" as used herein with respect to the formation of Group A Fluorinated Substances by the present compositions means that the theoretical molar yield of such substances in environmental compartments of air, soil/sediment and water produced during tropospheric degradation of the compositions is $> 0\%$ and $\leq 5\%$, or $> 0\%$ and $\leq 4\%$, or $> 0\%$ and $\leq 3\%$, or $> 0\%$ and $\leq 2\%$, or $> 0\%$ and $\leq 1\%$, and all values and ranges therebetween, when measured by GC techniques, for example GC with a flame ionization or electron-capture detector or GC/MS method, by IC or IC-MS techniques, or by HPLC or HPLC-MS techniques.

[0156] The presently disclosed compositions will perform more consistently and be more stable with only minor amounts of water present. Thus, the presently claimed compositions may further comprise less than 100 ppm (by weight) water, preferably less than 20 ppm (by weight) water, and even more preferably less than 10 ppm (by weight) water.

[0157] Additionally, the presently disclosed compositions will perform more consistently and be more stable with only minor amounts of oxygen or air present. Therefore, the presently claimed compositions may further comprise less than about 5 volume percent non-adsorbable gases (NAG), preferably less than 3 volume percent NAG, and more preferably less than 1.5 volume percent NAG. Further, the presently claimed compositions, due to the presence of air or NAG, will contain less than 1 volume percent oxygen, preferably less than 0.5 volume percent oxygen, and more preferably less than 0.3 volume percent oxygen.

[0158] In another embodiment, the presently disclosed compositions may contain a stabilizer. Such stabilizer compounds are intended to be present in a small amount and prevent decomposition due to the presence of water, air, NAG, or oxygen in a system while in use or while the composition is stored. HFO type

refrigerants, due to the presence of a double bond, may be subject to thermal instability and decompose under extreme use, handling or storage situations also. Therefore, there may be advantages to adding stabilizers to HFO type refrigerants. Stabilizers may notably include nitromethane, ascorbic acid, terephthalic acid, azoles such as toluotriazole or benzotriazole, phenolic compounds such as tocopherol, hydroquinone, t-butyl hydroquinone, 2,6-di-tertbutyl-4-methylphenol, epoxides (possibly fluorinated or perfluorinated alkyl epoxides or alkenyl or aromatic epoxides) such as n-butyl glycidyl ether, hexanediol diglycidyl ether, allyl glycidyl ether, butylphenylglycidyl ether, cyclic monoterpenes, terpenes, such as d-limonene, α -terpinene, β -terpinene, γ -terpinene, α -pinene, or β -pinene, phosphites, phosphates, phosphonates, thiols and lactones. Examples of suitable stabilizers are disclosed in WO2019213004, WO2020222864, and WO2020222865; the disclosures of which are hereby incorporated by reference.

[0159] Blends may or may not include stabilizers depending on the requirements of the system being used. If the refrigerant blend does include a stabilizer, it may include any amount from 0.001 wt% up to 1 wt%, preferably from about 0.01 to about 0.5 weight percent, more preferably, from about 0.01 to about 0.3 weight percent of any of the stabilizers listed above.

[0160] In another embodiment of the present disclosure, the compositions further comprise at least one lubricant. Lubricants may be selected from polyol ester, polyvinyl ether, and polyalkylene glycol. Lubricants may also comprise those commonly known as "mineral oils" in the field of compression refrigeration lubrication. Mineral oils comprise paraffins (i.e. straight-chain and branched-carbon-chain, saturated hydrocarbons), naphthenes (i.e. cyclic or ring structure saturated hydrocarbons, which may be paraffins) and aromatics (i.e. unsaturated, cyclic hydrocarbons containing one or more rings characterized by alternating double bonds). Lubricants of the present invention further comprise those commonly known as "synthetic oils" in the field of compression refrigeration lubrication. Synthetic oils comprise alkylaryls (i.e. linear and branched alkyl alkylbenzenes), synthetic paraffins and naphthenes, silicones, and polyalphaolefins. Representative conventional lubricants of the present invention are the commercially available BVM 100 N (paraffinic mineral oil sold by BVA Oils), naphthenic mineral oil commercially available under the trademark from Suniso® 3GS and Suniso® 5GS by Crompton Co.,

naphthenic mineral oil commercially available from Pennzoil under the trademark Sontex® 372LT, naphthenic mineral oil commercially available from Calumet Lubricants under the trademark Calumet® RO-30, linear alkylbenzenes commercially available from Shrieve Chemicals under the trademarks Zerol® 75, Zerol® 150 and Zerol® 500 and branched alkylbenzene, sold by Nippon Oil as HAB 22.

[0161] Lubricants of the present invention further comprise those which have been designed for use with hydrofluorocarbon refrigerants and are miscible with refrigerants of the present invention under compression refrigeration and air-conditioning apparatus' operating conditions. Lubricants include, but are not limited to, polyol esters (POEs) such as Castrol® 100 (Castrol, United Kingdom), polyalkylene glycols (PAGs) such as RL-488A from Dow (Dow Chemical, Midland, Mich.), and polyvinyl ethers (PVEs) such as PVE-FVC68D.

[0162] In one particular embodiment, the foregoing refrigerant compositions are combined with a PAG lubricant or a PVE lubricant or a POE lubricant for usage in an automotive A/C system having an internal combustion engine or an electric or hybrid electric drive train.

[0163] In the compositions of the present invention including a lubricant, the lubricant may be present in an amount of less than 80 weight percent of the total composition. The lubricant may further be present in an amount of less than 60 weight percent of the total composition. In other embodiments, the amount of lubricant may be between about 0.1 and 50 weight percent of the total composition. The lubricant may also be between about 0.1 and 20 weight percent of the total composition. The lubricant may also be between about 0.1 and 5 weight percent of the total composition.

[0164] In one aspect of the invention, the inventive refrigerant composition is used to introduce lubricant into the A/C system as well as or alternatively other additives, such as a) acid scavengers, b) performance enhancers, and c) flame suppressants. In one preferred embodiment, the present compositions comprise an acid scavenger.

[0165] Examples of the acid scavengers that may be included in the present compositions include, but are not limited, the stabilizers and/or the epoxide component of the stabilizers disclosed in U.S. Patent No. 8,535,555 and the acid

scavengers disclosed in International Application Publication No. WO 2020/222864, the disclosure of each of which is incorporated herein by reference in its entirety.

[0166] In some embodiments, an acid scavenger may comprise one or more epoxides, one or more amines and/or one or more hindered amines, such as, for example but not limited to, epoxybutane.

[0167] The acid scavenger (e.g., the activated aromatic compound, the siloxane, or both) may be present in any concentration that results in a relatively low total acid number, a relatively low total halides concentration, a relatively low total organic acid concentration, or any combination thereof.

[0168] Preferably the acid scavenger is present at a concentration greater than about 0.0050 wt%, more preferably greater than about 0.05 wt% and even more preferably greater than about 0.1 wt% (e.g. greater than about 0.5 wt%) based on the total weight of the refrigerant composition. The acid scavenger preferably is present in a concentration less than about 5 wt%, less than about 4 wt%, less than about 3 wt%, more preferably less than about 2.5 wt% and most preferably greater than about 2 wt% (e. g. less than about 1.8 wt%) based on the total weight of the refrigerant composition.

[0169] Preferred additives include those described in U.S. Pat. Nos. 5,152,926; 4,755,316, which are hereby incorporated by reference. In particular, the preferred extreme pressure additives include mixtures of (A) tolyltriazole or substituted derivatives thereof, (B) an amine (e.g. Jeffamine M-600) and (C) a third component which is (i) an ethoxylated phosphate ester (e.g. Antara LP-700 type), or (ii) a phosphate alcohol (e.g. ZELEC 3337 type), or (iii) a Zinc dialkyldithiophosphate (e.g. Lubrizol 5139, 5604, 5178, or 5186 type), or (iv) a mercaptobenzothiazole, or (v) a 2,5-dimercapto-1,3,4-triadiazole derivative (e. g. Curvan 826) or a mixture thereof. Additional examples of additives which may be used are given in U.S. Pat. No. 5,976,399 (Schnur, 5:12-6:51, hereby incorporated by reference).

[0170] Acid number is measured according to ASTM D664-01 in units of mg KOH/g. The total halides concentration, the fluorine ion concentration, and the total organic acid concentration is measured by ion chromatography. Chemical stability of the refrigerant system is measured according to ASHRAE 97: 2007 (RA 2017) "Sealed Glass Tube Method to Test the Chemical Stability of Materials for Use within

Refrigerant Systems”. The viscosity of the lubricant is tested at 40°C according to ASTM D-7042.

[0171] Mouli et al. (WO 2008/027595 and WO 2009/042847) teach the use of alkyl silanes as a stabilizer in refrigerant compositions containing fluoroolefins. Phosphates, phosphites, epoxides, and phenolic additives also have been employed in certain refrigerant compositions. These are described for example by Kaneko (U.S. patent application Ser. No. 11/575,256, published as U.S. Publication 2007/0290164) and Singh et al. (U.S. patent application Ser. No. 11/250,219, published as U.S. Publication 2006/0116310). All of these aforementioned applications are expressly incorporated herein by reference.

[0172] Preferred flame suppressants include the flame retardants described in patent application “Refrigerant compositions containing fluorine substituted olefins CA 2557873 A1” and incorporated by reference, as well as fluorinated products such as HFC-125, HFC-227ea, HFC-236fa, and/or Krytox® lubricants, also incorporated by reference and described in patent application “Refrigerant compositions comprising fluoroolefins and uses thereof WO 2009/018117A1.”

[0173] Additionally, the present compositions may further comprise at least one tracer compound or mixture of tracer compounds. Tracers may be used to identify the process by which a refrigerant, or refrigerant mixture is produced. The tracer compounds may be specific to the manner of production or may be added as a single tracer or mixture of tracers in particular amounts in order to detect dilution, adulteration, contamination, or other unauthorized practices.

[0174] The tracer may be a single compound or two or more tracer compounds from the same class of compounds or from different classes of compounds. In some embodiments, the tracer is present in the compositions at a total concentration of about 1 part per million by weight (ppm) to about 5000 ppm, based on the weight of the total composition. In other embodiments, the tracer is present at a total concentration of about 1 ppm to about 1000 ppm. In other embodiments, the tracer is present at a total concentration of about 2 ppm to about 500 ppm. Alternatively, the tracer is present at a total concentration of about 10 ppm to about 300 ppm.

[0175] The tracer compound or compounds in amounts up to 100 ppm, 200 ppm, 300, ppm, 400 ppm, 500 ppm, 600 ppm, 700 ppm, 800 ppm and 900 ppm may be

selected from hydrofluorocarbons, hydrofluoroolefins, hydrochlorocarbons, hydrochloroolefins, hydrochlorofluorocarbons, hydrochlorofluoroolefins, hydrochlorocarbons, hydrochloroolefins, chlorofluorocarbons, chlorofluoroolefins, hydrocarbons, perfluorocarbons, perfluoroolefins, and combinations thereof. In particular, the tracers may include, but are not limited to compounds selected from HFC-23 (trifluoromethane), HCFC-31 (chlorofluoromethane), HFC-41 (fluoromethane), HFC-161 (fluoroethane), HFC-152a (1,1-difluoromethane), HFC-143a (1,1,1-trifluoroethane), HFC-227ca (1,1,1,2,2,3,3-heptafluoropropane), HFC-227ea (1,1,1,2,3,3,3-heptafluoropropane), HFC-236fa (1,1,1,3,3,3-hexafluoropropane), HFC-236cb (1,1,1,2,2,3-hexafluoropropane), HFC-236ea (1,1,1,2,3,3-hexafluoropropane), HFC-245cb (1,1,1,2,2-pentafluoropropane), HFC-245fa (1,1,1,3,3-pentafluoropropane), HFC-245eb (1,1,1,2,3-pentafluoropropane), HFC-254eb (1,1,1,2-tetrafluoropropane), HFC-263fb (1,1,1-trifluoropropane), HFC-272ca (2,2-difluoropropane), HFC-281ea (2-fluoropropane), HFC-281fa (1-fluoropropane), HFC-329p (1,1,1,2,2,3,3,4,4-nonafluorobutane), HFC-329mmz (2-trifluoromethyl-1,1,1,3,3,3-hexafluoropropane), HFC-338mf (1,1,1,2,2,4,4,4-octafluorobutane), HFC-338pcc (1,1,2,2,3,3,4,4-octafluorobutane), CFC-12 (dichlorodifluoromethane), CFC-11 (trichlorofluoromethane), CFC-114 (1,2-dichloro-1,1,2,2-tetrafluoroethane), CFC-114a (2,2-dichloro-1,1,1,2-tetrafluoroethane), CFC-115 (chloropentafluoroethane), HCFC-22 (chlorodifluoromethane), HCFC-123 (2,2-dichloro-1,1,1-trifluoroethane), HCFC-124 (2-chloro-1,1,1,2-tetrafluoroethane), HCFC-124a (1-chloro-1,1,2,2-tetrafluoroethane), HCFC-141b (1,1-dichloro-1-fluoroethane), HCFC-142b (1-chloro-1,1-difluoroethane), HCFC-151a (1-chloro-1-fluoroethane), HCFC-244bb (2-chloro-1,1,1,2-tetrafluoropropane), HCC-40 (chloromethane), HFO-1141 (fluoroethylene), HCO-1130 (1,2-dichloroethylene, E- and/or Z-isomer), HCO-1130a (1,1-dichloroethylene), HCFO-1131 (1-chloro-2-fluoroethylene, E- and/or Z-isomer), HCFO-1131a (1-chloro-1-fluoroethylene), HCFO-1122 (2-chloro-1,1-difluoroethylene), HFO-1123 (trifluoroethylene), HFO-1234ye (1,2,3,3-tetrafluoropropene), HFO-1243zf (3,3,3-trifluoropropene), HFO-1225yeZ (1,2,3,3,3-pentafluoropropene), HFO-1225zc (1,1,3,3,3-pentafluoropropene), PFC-116 (hexafluoroethane), PFC-C216 (hexafluorocyclopropane), PFC-218 (octafluoropropane), PFC-C318 (octafluorocyclobutane), PFC-1216 (hexafluoropropene), PFC-31-10mc (decafluorobutane), PFC-31-10my (2-trifluoromethyl-1,1,1,2,3,3,3-

heptafluoropropane), 2-chloro-1,1,2-trifluoroethylene (CFO-1113), 1,1,1,3,3-pentafluorobutane (HFC-365mfc), 1,1,1,2,3,4,4,5,5,5-decafluoropentane (HFC-43-10mee), 1,1,1,2,2,3,4,5,5,6,6,7,7,7-tetradecafluoroheptane, hexafluorobutadiene, 3,3,3-trifluoropropyne, deuterated hydrocarbons, deuterated hydrofluorocarbons, perfluorocarbons, fluoroethers, and mixtures thereof.

[0176] In some embodiments, the tracer is a blend containing two or more hydrofluorocarbons, or one hydrofluorocarbon in combination with one or more perfluorocarbons. In other embodiments, the tracer is a blend of at least one CFC and at least one HCFC, HFC, or PFC.

[0177] Additionally, the present compositions may further comprise at least one inhibitor, and more particularly an effective amount of at least one inhibitor, and more particularly a polymerization inhibitor. More particularly, when the composition comprises a fluoroolefin, the composition preferably also comprises an effective amount of at least one inhibitor compound that inhibits, if not eliminates, the fluoroolefin from interacting with another compound and forming dimers, oligomers, homopolymers or polymeric products.

[0178] As described herein, the phrase “effective amount” refers to an amount of inhibitor of the present invention which, when added to a composition comprising at least one fluoroolefin, results in a composition wherein the fluoroolefin will not interact with an initiator, and/or degrade to produce as great a reduction in performance, for example, when in use in a cooling apparatus as compared to the composition without an inhibitor. For a cooling apparatus, such effective amounts of inhibitor may be determined by way of testing under the conditions of standard test ASHRAE 97-2007 (RA 2017). In a certain embodiment of the present invention, an effective amount may be said to be that amount of inhibitor which when combined with a composition comprising at least one fluoroolefin allows a cooling apparatus utilizing said composition comprising at least one fluoroolefin to perform at a comparable level of refrigeration performance and cooling capacity as if a composition comprising 1,1,1,2-tetrafluoroethane (R-134a), or other standard refrigerant (R-12, R-22, R-502, R-507A, R-508, R401A, R401B, R402A, R402B, R408, R-410A, R-404A, R407C, R-413A, R-417A, R-422A, R-422B, R-422C, R-422D, R-423, R-114, R-11, R-113, R-123, R-124, R236fa, or R-245fa) depending

upon what refrigerant may have been used in a similar system in the past, were being utilized as the working fluid.

[0179] The instant invention employs effective amounts of at least one of the foregoing inhibitors. While any suitable effective amount can be employed, effective amounts of the at least one inhibitor comprise from about 0.001 weight percent to about 10 weight percent, about 0.01 weight percent to about 5 weight percent, about 0.3 weight percent to about 4 weight percent, about 0.3 weight percent to about 1 weight percent, based on the total weight of compositions comprising at least one fluoroolefin as described herein. In one embodiment, an effective amount comprises about 1 to about 3,000 ppm by weight, or about 1 to about 2,000 ppm by weight, or about 10 to about 3,000 ppm by weight, or about 10 to about 2,000 ppm by weight, or about 30 ppm to about 3,000 ppm by weight, or about 30 ppm to about 2,000 ppm by weight, or about 5 to about 1,000 ppm and in some cases about 10 to about 500 ppm of at least one inhibitor based on the total weight of the composition. The amount of the inhibitor in the total composition can be reduced if an additional component which is added to an HFO-1234yf blend does not contain an inhibitor.

[0180] In one embodiment of the invention, the inventive compositions are substantially free of oligomeric products and polymeric products derived from a hydrofluoroolefin, such as HFO-1234yf, including but not limited to, oligomers and homopolymers. By "substantially free" it is meant that the composition contains less than about 1 wt.%, less than about 0.07 wt.%, less than about 0.03 wt.% and in some cases about 0 ppm of such products when measured by IR or NMR.

[0181] In some embodiments, the at least one inhibitor is selected from hydrocarbons such as cyclic monoterpenes (e.g., limonene, pinene, α -pinene, β -pinene, and terpinene); lipophilic organic compounds such as tocopherols (e.g., α -tocopherol) or butylated hydroxytoluene (BHT); phenols or aromatic organic compounds having at least one chemical moiety -C₆H₄(OH) (e.g., benzene-1,4-diol, 4-methoxyphenol); and mixtures thereof. Specific examples of inhibitor compounds may include at least one member selected from limonene (particularly D-limonene), α -terpinene, pinene, α -pinene, β -pinene, α -tocopherol, butylated hydroxytoluene (BHT), 4-methoxyphenol, benzene-1,4-diol, and mixtures thereof. In one embodiment, the inhibitor is limonene, particularly D-limonene.

[0182] Additional details regarding properties of suitable inhibitors can be found in International Application Nos. WO 2019/213004, WO 2020/222864 and WO2023/141098, the entire disclosure of each of which is incorporated herein in its entirety.

[0183] The compositions of the present invention may be prepared by any convenient method to combine the desired amount of the individual components. A preferred method is to weigh the desired component amounts and thereafter combine the components in an appropriate vessel. Agitation may be used, if desired. In one embodiment, the composition according to the present invention can be prepared by blending HFO-1234zeE and HFC-152a, and, in some cases, at least one of the additional compounds. In another embodiment, any of the foregoing refrigerant compositions can be prepared by blending HFO-1234zeE, HFC-152a, at least one compound selected from HFC-227ea, HFO-1336mzz(E), HFC-134, HFC-125, HFC-32, HFC-134a, HCFO-1224yd(Z), and, in some cases, at least one of the additional compounds. Further, any of the above-mentioned additives, such as stabilizers, acid scavengers, flame suppressants, tracers and the like, may be blended with the HFO-1234zeE and HFC-152a containing compositions.

[0184] In a further embodiment, the compositions may be prepared from recycled or reclaimed refrigerant. One or more of the components may be recycled or reclaimed by means of removing contaminants, such as air, water, or residue, which may include lubricant or particulate residue from system components. The means of removing the contaminants may vary widely, but can include distillation, decantation, filtration, and/or drying by use of molecular sieves or other absorbents. Then the recycled or reclaimed component(s) may be combined with the other component(s) as describe above.

METHODS, APPARATUS AND SYSTEMS

[0185] The disclosure herein regarding methods, apparatus, and/or systems utilizing compositions of the present invention relate to any of the compositions disclosed herein. For example, the composition utilized in the method, apparatus and/or system may be a composition comprising, consisting of, or consisting essentially of (i) HFO-1234ze(E) and HFC-152a; or (ii) HFO-1234ze(E), HFC-152a, and one or more additional compounds selected from HFO-1234yf, HFC-245cb,

HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160; or (iii) HFO-1234ze(E), HFC-152a and at least one compound selected from HFC-227ea, HFO-1336mzz(E), HFC-134, HFC-125, HFC-32, HFC-134a, HCFO-1224yd(Z); or (iv) HFO-1234ze(E), HFC-152a, at least one compound selected from HFC-227ea, HFO-1336mzz(E), HFC-134, HFC-125, HFC-32, HFC-134a, HCFO-1224yd(Z), and one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, more preferably selected from HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160. Such a composition is sometimes referred to herein as “the inventive composition”.

Heat Transfer Methods, Apparatus and Systems

[0186] The compositions disclosed herein are useful in numerous methods and systems that provide cooling (e.g. air-conditioning or refrigeration) and heating.

[0187] In one embodiment, provided is a method of cooling comprising evaporating the inventive composition in the vicinity of a body to be cooled and thereafter condensing said composition, wherein said cooling is provided by a refrigeration system, air-conditioner, heat pump, or chiller.

[0188] In one embodiment, the refrigeration system may be a residential, commercial, or industrial refrigeration system. These may include, but are not limited to, supermarket and convenience store refrigerated cases for beverages, dairy, and produce and prepared foods. In one embodiment, the refrigeration system is a low or medium temperature refrigeration system, including supermarket and convenience store refrigerator and freezer cabinets and displays, ice machines, self-contained coolers and freezers, such as beverage coolers, walk-in and reach-in

coolers and freezers, supermarket rack and distributed systems, and refrigerated or frozen food transport.

[0189] In one embodiment, the air conditioner may be a residential, commercial, or industrial air-conditioning system. These may include, but are not limited to, window, ducted, ductless, packaged terminal, and those exterior to, but connected to the building, such as rooftop systems. These may also include residential heat pumps that provide comfort air-conditioning and heating.

[0190] In another embodiment, the cooling may be performed in a chiller. Chillers, including both flooded evaporator and direct expansion chillers, may be coupled with an air handling and distribution system to provide comfort air conditioning (cooling and dehumidifying the air) to large commercial buildings, including hotels, office buildings, hospitals, universities and the like. In another embodiment, chillers, most likely air-cooled direct expansion chillers, have found additional utility in naval submarines and surface vessels.

[0191] Chillers may be characterized by the compressor used. In one embodiment, the chiller may comprise a centrifugal compressor. In another embodiment, the chiller may comprise a scroll compressor. In another embodiment the chiller may comprise a screw compressor. In yet another embodiment, the chiller may comprise a reciprocating compressor.

[0192] The present method for cooling may be particularly useful in high ambient temperature regions, due to the high critical temperature of blends comprising, consisting of, or consisting essentially of HFO-1234zeE, HFC-152a, and at least one compound selected from the group consisting of HFC-227ea, HFO-1336mzz(E), HFC-134, HFC-125, HFC-32, HFC-134a, HCFO-1224yd(Z).

[0193] In another embodiment, the method for producing cooling is particularly useful in regions where the ambient temperature can exceed at least 35°C.

[0194] In geographic areas with high ambient temperatures, where air conditioning becomes essential, refrigerant compositions with high critical temperatures and high thermal stability are desirable. Currently available hydrofluorocarbon (HFC) refrigerants such as R-410A, R-407C or R-32 have relatively low critical temperatures. As a consequence, these refrigerants do not perform well in extreme

hot environments. The energy efficiency of a refrigerant generally decreases as the condensing temperature approaches the refrigerant critical temperature during operation at high ambient temperatures. In hot climates, R-22 has remained the refrigerant of choice for much air conditioning and refrigeration applications as it is not flammable and has a higher critical temperature so that it delivers higher cooling capacity and higher energy efficiency in hot climates as compared to R-410A or R-32. However, R-22 is an ozone depleting substance in the Montreal Protocol to reduce ozone depletion. As such, R-22 has been mandated and legislated for phase out for manufacture for and use in air conditioning and refrigeration. There is interest in finding a refrigerant with the lowest possible direct GWP and also that performs well in hot climate (or high ambient) temperature regions.

[0195] In the method for producing cooling the body to be cooled may be defined as any space, location, object, or body for which it is desirable to provide cooling. Examples include spaces, open or enclosed, that require cooling such as a residence, such as an apartment or apartment building, university dormitory, townhouse or other attached house, or a single-family home; or the body to be cooled may be any other building, such as an office building, supermarket, college or university classroom or administration buildings.

[0196] In another embodiment, a method for producing air conditioning in high ambient temperatures is provided. The method comprises evaporating the inventive composition and thereafter condensing said composition. The method is particularly useful in regions where ambient temperatures can exceed 35°C or more.

[0197] In another embodiment, a method is provided for replacing HCFC-22 in high ambient air conditioning apparatus comprising providing the inventive composition to said apparatus. The method of replacing HCFC-22 is particularly useful in regions where ambient temperatures can exceed 35°C or more.

[0198] Similarly, in some industrial air conditioning applications heat must be released in high ambient temperature environments. HCFC-124 has been used as the working fluid in such applications. HCFC-124 is also controlled under the Montreal protocol as an ozone depleting substance and more environmentally sustainable replacements are desirable. Thus, a method is provided for replacing HCFC-124 in industrial air conditioning apparatus, comprising providing the inventive

composition to said apparatus. The method of replacing HCFC-124 is particularly useful in regions where ambient temperatures can exceed 35°C or more.

[0199] In another embodiment, the method for producing cooling and method for replacing HCFC-22 or HCFC-124 are useful for systems operating in ambient temperatures of 40°C or higher. In another embodiment, the method for producing cooling is useful for systems operating in ambient temperatures of 45°C or higher. In another embodiment, the method for producing cooling is useful for systems operating in ambient temperatures of 50°C or higher. In another embodiment, the method for producing cooling is useful for systems operating in ambient temperatures of 55°C or higher. In another embodiment, the method for producing cooling is useful for systems operating in ambient temperatures of 60°C or higher. In another embodiment, the method for producing cooling is useful for systems operating in ambient temperatures from 35-50°C. In another embodiment, the method for producing cooling is useful for systems operating in ambient temperatures from 35-60°C. In another embodiment, the method for producing cooling is useful for systems operating in ambient temperatures from 40- 60°C. In another embodiment, the method for producing cooling is useful for systems operating in ambient temperatures from 45-60°C. In another embodiment, the method for producing cooling is useful for systems operating in ambient temperatures from 50-60°C.

[0200] In another embodiment, provided is a method of heating comprising evaporating the inventive composition and thereafter condensing said composition in the vicinity of a body to be heated.

[0201] In one embodiment, the heating is accomplished by a heat pump, which may be a residential, light commercial, commercial, or industrial heat pump system. These may include, but are not limited to, residential heat pumps that provide comfort air-conditioning and heating, hot water heat pumps for heating air (by secondary loop) or for heating water for residential or commercial use, heat pumps for heating manufacturing process equipment, and high temperature heat pumps (with condensing temperature of 50 deg C or higher).

[0202] Due to the high critical temperature of the inventive composition, and more particularly of blends comprising, consisting of, or consisting essentially of HFO-

1234zeE, HFC-152a, and at least one compound selected from HFC-227ea, HFO-1336mzz(E), HFC-134, HFC-125, HFC-32, HFC-134a, and HCFO-1224yd(Z), it is possible to heat water to higher temperatures than propane or R-454C.

[0203] In another embodiment, is provided a system for cooling or heating comprising the inventive composition. The system comprises an evaporator, compressor, condenser, and expansion device, each operably connected to perform a vapor compression cycle. In another embodiment, the system may further comprise a lubricant. The lubricant may be selected from the group consisting of polyalkylene glycol, polyol ester, poly- α -olefin, and polyvinyl ether. In another embodiment, the lubricant is selected from POE or PVE.

[0204] The system for cooling or heating may be a refrigeration system, air-conditioner, heat pump, or chiller.

[0205] In one embodiment, the refrigeration system may be a residential, commercial, or industrial refrigeration system. These may include, but are not limited to, supermarket and convenience store refrigerated cases for beverages, dairy, and produce and prepared foods. In one embodiment, the refrigeration system is a low or medium temperature refrigeration system, including supermarket and convenience store refrigerator and freezer cabinets and displays, ice machines, self-contained coolers and freezers, such as beverage coolers, walk-in and reach-in coolers and freezers, supermarket rack and distributed systems, and refrigerated or frozen food transport.

[0206] In one embodiment, the air conditioner may be a residential, commercial, or industrial air-conditioning system. These may include, but are not limited to, window, ducted, ductless, packaged terminal, and those exterior to, but connected to the building, such as rooftop systems. These may also include residential heat pumps that provide comfort air-conditioning and heating.

[0207] In one embodiment, the system is a heat pump, which may be a residential, light commercial, commercial, or industrial heat pump system. These may include, but are not limited to, residential heat pumps that provide comfort air-conditioning and heating, hot water heat pumps for heating air (by secondary loop) or for heating water for residential or commercial use, heat pumps for heating manufacturing

process equipment, and high temperature heat pumps (with condensing temperature of 50 deg C or higher).

[0208] In another embodiment, the system is a chiller. Chillers, including both flooded evaporator and direct expansion chillers, may be coupled with an air handling and distribution system to provide comfort air conditioning (cooling and dehumidifying the air) to large commercial buildings, including hotels, office buildings, hospitals, universities and the like. In another embodiment, chillers, most likely air-cooled direct expansion chillers, have found additional utility in naval submarines and surface vessels.

[0209] Chillers may be characterized by the compressor used. In one embodiment, the chiller may comprise a centrifugal compressor. In another embodiment, the chiller may comprise a scroll compressor. In another embodiment the chiller may comprise a screw compressor. In yet another embodiment, the chiller may comprise a reciprocating compressor. When replacing a refrigerant in a chiller, the compressor, often designed for the refrigerant to be used, may need modification. Therefore, for centrifugal chillers, the impeller diameter or impeller tip speed for the new refrigerant must be similar or match that for the original refrigerant to be used as a drop-in replacement.

[0210] In another embodiment, the system containing the inventive composition may be an automobile heat pump for cooling and heating the passenger compartment of an electric or hybrid vehicle. Electric or hybrid vehicles include automobiles with no internal combustion engine (ICE) or those that maintain an ICE but also use electric power and are therefore hybrid electric vehicles (HEV) or plug-in hybrid electric vehicles (PHEV) or mild hybrid electric vehicles (MHEV). Additionally, electric or hybrid vehicles include full electric vehicles (EV), such as battery electric vehicles (BEV). All of these electric or hybrid vehicles use at least one electric motor, wherein the electric motor provides some form of propulsion for the vehicles normally provided by the ICE found in gasoline/diesel powered vehicles.

[0211] In one embodiment, the automobile heat pump is a secondary loop system. The secondary loop allows the separation of a flammable refrigerant from the passenger compartment, using a heat transfer fluid to produce cooling or heating in the passenger compartment.

[0212] In another embodiment, the automobile heat pump does not include a positive temperature coefficient (PTC) heater. The PTC heater often used in electric vehicles is needed in the absence of an ICE to provide adequate heating to the passenger compartment.

[0213] In another embodiment, the inventive composition may be used in a method of replacing at least one of R-22, HFC-134a, propane, HFO-1234yf, R-407C, R-404A, R-410A, R-513A, R-454A, R-454B, R-454C, R-448A, R-449A, R-449B, R-449C, R-1234zeE, R-515B, R471A, R-476A, R-482A, R-452A, or R-452C, in refrigeration, air-conditioning, heat pump, or chiller systems comprising providing any of the compositions disclosed herein to the system in place of R-22, HFC-134a, propane, HFO-1234yf, R-407C, R-404A, R-410A, R-513A, R-454A, R-454B, R-454C, R-448A, R-449A, R-449B, R-449C, R-1234zeE, R-515B, R471A, R-476A, R-482A, R-452A, or R-452C.

[0214] In one embodiment, the method for replacement may be a retrofit for existing equipment. Therefore, the method is specific to replacing a refrigerant in equipment that was designed for, or originally contained R-22, HFC-134a, propane, HFO-1234yf, R-407C, R-404A, R-410A, R-513A, R-454A, R-454B, R-454C, R-448A, R-449A, R-449B, R-449C, R-452A, or R-452C. In another embodiment, the replacement is simply providing a new refrigerant for an application or use, wherein the new refrigerant can provide improved performance, or meet regulatory requirements that are not met by the incumbent refrigerant.

[0215] The inventive compositions, and particularly the compositions comprising, consisting of, or consisting essentially of HFO-1234zeE, HFC-152a, and at least one compound selected from HFC-227ea, HFO-1336mzz(E), HFC-134, HFC-125, HFC-32, HFC-134a, and HCFO-1224yd(Z), and optionally one or more additional compounds, provide performance that would allow replacement of R-22, HFC-134a, propane, HFO-1234yf, R-407C, R-404A, R-410A, R-513A, R-454A, R-454B, R-454C, R-448A, R-449A, R-449B, R-449C, R-1234zeE, R-515B, R471A, R-476A, R-482A, R-452A, or R-452C.

[0216] In another embodiment, the inventive compositions provide performance that enables the use as refrigerant in refrigeration, air-conditioning, heat pump, or chiller systems. In particular, the refrigeration, air-conditioning, heat pump, or chiller

systems comprise mobile or stationary air conditioning, mobile or stationary heat pumps, residential, light commercial, commercial, or industrial air-conditioner, residential, light commercial, commercial, or industrial heat pump, centrifugal chiller, screw chiller, scroll chiller, flooded evaporator chiller, direct expansion chiller, medium or low temperature refrigeration system, beverage cooler, supermarket display case, ice machine, or transport refrigeration or freezer system. Additionally, the compositions are useful wherein the system is an automobile heat pump for cooling and heating the passenger compartment of an electric or hybrid vehicle. Further, the compositions may be useful in replacing refrigerants such as R-22, HFC-134a, propane, HFO-1234yf, R-407C, R-404A, R-410A, R-513A, R-454A, R-454B, R-454C, R-448A, R-449A, R-449B, R-449C, R-1234zeE, R-515B, R471A, R-476A, R-482A, R-452A, or R-452C.

[0217] The compositions disclosed herein may be useful in air conditioning, heat pumps, chillers, and refrigeration systems. In particular, the compositions may be used in residential air conditioning, industrial air conditioning, residential heat pumps, industrial heat pumps, water heating heat pumps, high temperature heat pumps (with condenser temperature above about 55 degrees C), flooded evaporator chillers, screw chillers, scroll chillers, centrifugal chillers, residential refrigerators, supermarket refrigeration systems, ice machines, beverage coolers, vending machines, medium temperature refrigeration, low temperature refrigeration, transport refrigeration, among others.

[0218] The compositions disclosed herein may also be useful in methods for replacing existing or conventional refrigerants that for reasons of environmental concern are in need of replacement. The replacement may mean that the composition of the present invention is used in place of the existing refrigerant in new equipment for a specific application or use. The replacement may also mean that the composition of the invention is used in existing equipment after the original refrigerant is removed. This type of replacement may be referred to as drop-in replacement or retrofit. In some embodiments, the retrofit may require adjustment of existing equipment or even changing out certain pieces of equipment to allow use of the new refrigerant.

[0219] The compositions disclosed herein are useful in methods of replacing R-134a, R-1234zeE, R-515B, R471A, R-476A, R-482A, R-454C, R-404A, and R-449A. The method comprises providing the composition of the present invention comprising, consisting essentially of, or consisting of HFO-1234zeE and HFC-152a; or HFO-1234zeE, HFC-152a and one or more additional compounds as disclosed above; or HFO-1234zeE, HFC-152a, and at least one compound selected from HFC-227ea, HFO-1336mzz(E), HFC-134, HFC-125, HFC-32, HFC-134a, and HCFO-1224yd(Z); or HFO-1234zeE, HFC-152a, at least one compound selected from HFC-227ea, HFO-1336mzz(E), HFC-134, HFC-125, HFC-32, HFC-134a, and HCFO-1224yd(Z), and one or more additional compounds as disclosed above, in place of the refrigerant to be replaced. The method may also comprise, first removing the refrigerant in need of replacement from existing equipment, then charging the composition of the present invention.

Blowing Agent – Methods, Apparatus and Systems

[0220] In some embodiments, the present invention includes methods and systems which include using the inventive composition as a blowing agent, optionally with one or more of the additional compounds which include, but are not limited to, other compounds which also act as blowing agents (hereinafter referred to for convenience but not by way of limitation as co-blowing agents), and optionally with one or more additives such as surfactants, polyols, catalysts, flame retardants, polymer modifiers, colorants, dyes, solubility enhancers, rheology modifiers, plasticizing agents, fillers, nucleating agents, viscosity reduction agents, vapor pressure modifiers, stabilizers, and the like. Preferred blends for blowing agents used for foams, especially spray foams and panel foams include blends of HFO-1234ze(E) and HFC-152a, more preferably HFO-1234ze(E), HFC-152a and one or more additional compounds or two or more additional compounds or three or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropylene, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a. Such blends are particularly useful for formation of polystyrene foam.

[0221] In one embodiment, blowing agent compositions according to the present invention comprise from about 70 wt% to 30 wt% HFO-1234ze(E) and from about 30 wt.% to 70 wt% HFC-152a. The blowing agent composition may optionally contain one or more of the additional compounds in an amount greater than 0 ppm and less than 5,000 ppm, or from about 5 to about 1,000 ppm, or from about 5 to about 500 ppm, or from about 1 to about 100 ppm, based on the total weight of the composition.

[0222] In one embodiment, blowing agent compositions according to the present invention comprise from about 60 wt% to 40 wt% HFO-1234ze(E) and from about 40 wt.% to 60 wt% HFC-152a. The blowing agent composition may optionally contain one or more of the additional compounds in an amount greater than 0 ppm and less than 5,000 ppm, or from about 5 to about 1,000 ppm, or from about 5 to about 500 ppm, or from about 1 to about 100 ppm, based on the total weight of the composition.

[0223] In one embodiment, blowing agent compositions according to the present invention comprise about 50 wt% HFO-1234ze(E) and about 50 wt% HFC-152a. The blowing agent composition may optionally contain one or more of the additional compounds in an amount greater than 0 ppm and less than 5,000 ppm, or from about 5 to about 1,000 ppm, or from about 5 to about 500 ppm, or from about 1 to about 100 ppm, based on the total weight of the composition.

[0224] In certain preferred embodiments, dispersing agents, cell stabilizers, surfactants and other additives may also be incorporated into the blowing agent compositions of the present invention. Certain surfactants are optionally but preferably added to serve as cell stabilizers. Some representative materials are sold under the names of DC-193, B-8404, and L-5340 which are, generally, polysiloxane polyoxyalkylene block co-polymers such as those disclosed in U.S. Pat. Nos. 2,834,748, 2,917,480, and 2,846,458, each of which is incorporated herein by reference. Other optional additives for the blowing agent mixture may include flame retardants such as tris(2-chloroethyl)phosphate, tris(2-chloropropyl)phosphate, tris(2,3-dibromopropyl)-phosphate, tris(1,3-dichloro-propyl)phosphate, diammonium phosphate, various halogenated aromatic compounds, antimony oxide, aluminum trihydrate, polyvinyl chloride, and the like. With respect to nucleating agents, all

known compounds and materials having nucleating functionality are available for use in the present invention, including particularly talc.

[0225] The co-blowing agent in accordance with the present invention can comprise a physical blowing agent, a chemical blowing agent (which preferably in certain embodiments comprises water) or a blowing agent having a combination of physical and chemical blowing agent properties.

[0226] Although it is contemplated that a wide range of co-blowing agents may be used in accordance with the present invention, in certain embodiments it is preferred that the blowing agent compositions of the present invention include one or more HFCs as co-blowing agents, more preferably one or more C1-C4 HFCs, and/or one or more hydrocarbons, more preferably C4-C6 hydrocarbons. For example, with respect to HFCs, the present blowing agent compositions may include one or more of 1,1-difluoroethane (HFC-152a), difluoromethane (HFC-32), fluoroethane (HFC-161), difluoroethane (HFC-152), trifluoroethane (HFC-143), tetrafluoroethane (HFC-134), pentafluoroethane (HFC-125), pentafluoropropane (HFC-245), hexafluoropropane (HFC-236), heptafluoropropane (HFC-227), pentafluorobutane (HFC-365), hexafluorobutane (HFC-356) and all isomers of all such HFCs.

[0227] With respect to hydrocarbons, the present blowing agent compositions may include in certain preferred embodiments, for example, iso, normal and/or cyclopentane for thermoset foams and butane or isobutane for thermoplastic foams. Of course other materials, such as water, CO₂, CFCs (such as trichlorofluoromethane (CFC-11) and dichlorodifluoromethane (CFC-12), hydrochlorocarbons (HCCs such as dichloroethylene (preferably trans-1,2-dichloroethylene), ethyl chloride and chloropropane), HCFCs, C1-C5 alcohols (such as, for example, ethanol and/or propanol and/or butanol), C1-C4 aldehydes, C1-C4 ketones, C1-C4 ethers (including ethers (such as dimethyl ether and diethyl ether), diethers (such as dimethoxy methane and diethoxy methane), and methyl formate including combinations of any of these may be included, although such components are contemplated to be not preferred in many embodiments due to negative environmental impact.

[0228] The relative amount of any of the above noted additional co-blowing agents, as well as any additional components which may be included in present

compositions, can vary widely within the general broad scope of the present invention according to the particular application for the composition, and all such relative amounts are considered to be within the scope hereof.

[0229] In certain embodiments, it is preferred that the blowing agent compositions of the present invention comprise at least one co-blowing agent and an amount of HFO-1234ze(E) and HFC-152a sufficient to produce a blowing agent composition which is overall nonflammable.

[0230] For compositions which include HFC co-blowing agents, the HFC co-blowing agent (preferably C2, C3, C4 and/or C5 HFC), and even more preferably difluoroethane (HFC-152a being particularly preferred for extruded thermoplastics) and/or pentafluoropropane (HFC-245)), is preferably present in the composition in amounts of from about 5% by weight to about 80% by weight of the total blowing agent composition, more preferably from about 10% by weight to about 75% by weight, and even more preferably of from about 25% to about 75% by weight of the total blowing agent. Furthermore, in such embodiments, the HFC is preferably C2-C4 HFC, and even more preferably C3 HFC, with penta-fluorinated C3 HFC, such as HFC-245fa, being highly preferred in certain embodiments.

[0231] One embodiment of the present invention provides foamable compositions. As is known to those skilled in the art, foamable compositions generally include one or more components capable of forming foam. As used herein, the term "foam foaming agent" is used to refer to a component, or a combination of components, which are capable of forming a foam structure, preferably a generally cellular foam structure. The foamable compositions of the present invention include such component(s) and the blowing agent composition of the present invention (e.g., composition comprising at least HFO-1234ze(E) and HFC-152a).

[0232] In certain embodiments, the one or more components capable of forming foam comprise a thermosetting composition capable of forming foam and/or foamable compositions. Examples of thermosetting compositions include polyurethane and polyisocyanurate foam compositions, and also phenolic foam compositions. This reaction and foaming process may be enhanced through the use of various additives such as catalysts and surfactant materials that serve to control and adjust cell size and to stabilize the foam structure during formation. Furthermore,

it is contemplated that any one or more of the additional components described above with respect to the blowing agent compositions of the present invention could be incorporated into the foamable composition of the present invention. In such thermosetting foam embodiments, one or more of the present compositions are included as or part of a blowing agent in a foamable composition, or as a part of a two or more part foamable composition, which preferably includes one or more of the components capable of reacting and/or foaming under the proper conditions to form a foam or cellular structure.

[0233] In certain other embodiments of the present invention, the one or more components capable of foaming comprise thermoplastic materials, particularly thermoplastic polymers and/or resins. Examples of thermoplastic foam components include polyolefins, such as for example monovinyl aromatic compounds of the formula $\text{Ar}-\text{CH}=\text{CH}_2$ wherein Ar is an aromatic hydrocarbon radical of the benzene series such as polystyrene (PS). Other examples of suitable polyolefin resins in accordance with the invention include the various ethylene resins including the ethylene homopolymers such as polyethylene and ethylene copolymers, polypropylene (PP) and polyethylene-terephthalate (PET). In certain embodiments, the thermoplastic foamable composition is an extrudable composition.

[0234] It is contemplated that all presently known and available methods and systems for forming foam are readily adaptable for use in connection with the present invention. For example, the methods of the present invention generally require incorporating a blowing agent in accordance with the present invention into a foamable or foam forming composition and then foaming the composition, preferably by a step or series of steps which include causing volumetric expansion of the blowing agent in accordance with the present invention.

[0235] In general, it is contemplated that the presently used systems and devices for incorporation of blowing agent and for foaming are readily adaptable for use in accordance with the present invention. In fact, it is believed that one advantage of the present invention is the provision of an improved blowing agent which is generally compatible with existing foaming methods and systems.

[0236] Thus, it will be appreciated by those skilled in the art that the present invention comprises methods and systems for foaming all types of foams, including

thermosetting foams, thermoplastic foams and formed-in-place foams. Thus, one aspect of the present invention is the use of the present blowing agents in connection with conventional foaming equipment, such as polyurethane foaming equipment, at conventional processing conditions. The present methods therefore include polyol premix type operations, blending type operations, third stream blowing agent addition, and blowing agent addition at the foam head.

[0237] With respect to thermoplastic foams, the preferred methods generally comprise introducing a blowing agent in accordance with the present invention into a thermoplastic material, preferably thermoplastic polymer such as polyolefin, and then subjecting the thermoplastic material to conditions effective to cause foaming. For example, the step of introducing the blowing agent into the thermoplastic material may comprise introducing the blowing agent into a screw extruder containing the thermoplastic, and the step of causing foaming may comprise lowering the pressure on the thermoplastic material and thereby causing expansion of the blowing agent and contributing to the foaming of the material.

[0238] One embodiment of the present invention relates to methods of forming foams, especially panel foams and spray foams, and preferably such foams made from polyurethane and polyisocyanurate. The methods generally comprise providing a blowing agent composition of the present inventions, adding (directly or indirectly) the blowing agent composition to a foamable composition, and reacting the foamable composition under the conditions effective to form a foam or cellular structure, as is well known in the art. Any of the methods well known in the art, such as those described in "Polyurethanes Chemistry and Technology," Volumes I and II, Saunders and Frisch, 1962, John Wiley and Sons, New York, N.Y., which is incorporated herein by reference, may be used or adapted for use in accordance with the foam embodiments of the present invention.

[0239] In general, such preferred methods comprise preparing polyurethane or polyisocyanurate foams by combining an isocyanate, a polyol or mixture of polyols, a blowing agent or mixture of blowing agents comprising one or more of the present compositions, and other materials such as catalysts, surfactants, and optionally, flame retardants, colorants, or other additives.

[0240] It is convenient in many applications to provide the components for polyurethane or polyisocyanurate foams in pre-blended formulations. Most typically, the foam formulation is pre-blended into two components. The isocyanate and optionally certain surfactants and blowing agents comprise the first component, commonly referred to as the "A" component. The polyol or polyol mixture, surfactant, catalysts, blowing agents, flame retardant, and other isocyanate reactive components comprise the second component, commonly referred to as the "B" component. Accordingly, polyurethane or polyisocyanurate foams are readily prepared by bringing together the A and B side components either by hand mix for small preparations and, preferably, machine mix techniques to form blocks, slabs, laminates, pour-in-place panels and other items, spray applied foams, froths, and the like. Optionally, other ingredients such as fire retardants, colorants, auxiliary blowing agents, and even other polyols can be added as one or more additional streams to the mix head or reaction site. Most preferably, however, they are all incorporated into one B-component as described above.

[0241] The present methods and systems also include forming a one component foam, preferably polyurethane foam, containing a blowing agent in accordance with the present invention. In certain preferably embodiments, a portion of the blowing agent is contained in the foam forming agent, preferably by being dissolved in a foam forming agent which is liquid at the pressure within the container, a second portion of the blowing agent is present as a separate gas phase. In such systems, the contained/dissolved blowing agent performs, in large part, to cause the expansion of the foam, and the separate gas phase operates to impart propulsive force to the foam forming agent.

[0242] Such one component systems are typically and preferably packaged in a container, such as an aerosol type can, and the blowing agent of the present invention thus preferably provides for expansion of the foam and/or the energy to transport the foam/foamable material from the package, and preferably both. In certain embodiments, such systems and methods comprise charging the package with a fully formulated system (preferably isocyanate/polyol system) and incorporating a gaseous blowing agent in accordance with the present invention into the package, preferably an aerosol type can.

[0243] It is contemplated also that in certain embodiments it may be desirable to utilize the present compositions when in the supercritical or near supercritical state as a blowing agent.

[0244] The present invention also relates to all foams, including but not limited to closed cell foam, open cell foam, spray foams, panel foams, rigid foam, flexible foam, integral skin and the like, prepared from a polymer foam formulation containing a blowing agent composition, such as a composition comprising HFO-1234ze(E) and HFC-152a, either alone or in combination with one or more other compounds.

EXAMPLES

Example 1

[0245] Refrigerant performance of compositions of the present invention were calculated using conditions for a heat pump in cooling mode. Compositions containing HFO-1234zeE, HFC-227ea, and HFC-152a were compared to results for R-515A (ASHRAE designation for refrigerant mixtures containing 88 wt% HFO-1234zeE and 12 wt% HFC-227ea) and R-515B (ASHRAE designation for refrigerant mixtures containing 91.1 wt% HFO-1234zeE and 8.9 wt% HFC-227ea). The conditions for the comparisons are as follows:

Temperature of the condenser	65 C
Temperature of the evaporator	-10 to -20 C
Subcool	10.0 K
Superheat	5.0 K
Compressor efficiency	70%

TABLE 1A: Evaporator temperature = -10 C

Composition	GWP	T_disch, C	Avg glide	Capacity, kJ/m3	Cap_cool vs incumbent,%		COP	COP_cool vs incumbent,%	
R-515A	389	80.3	0.0007	813.5	100		1.665	100	
R-515B	289	80.8	0.0004	818.1		100	1.671		100
1234zeE/152a/227ea, wt%*									
88/3/9	294	82.0	0.0676	836.3	102.8	102.2	1.679	100.8	100.5
91/4.8/4.2	148	83.6	0.1018	853.6	104.9	104.3	1.693	101.7	101.3

TABLE 1B: Evaporator temperature = -15 C

Composition	GWP	T _{disch} , C	Avg glide	Capacity, kJ/m ³	Cap_cool vs incumbent, %		COP	COP_cool vs incumbent, %	
R-515A	389	81.7	0.0007	646	100		1.474	100	
R-515B	289	82.3	0.0004	650		100	1.48		100
1234zeE/152a/227ea, wt%*									
88/3/9	294	83.6	0.0665	665.3	103.0	102.4	1.489	101.0	100.6
91/4.8/4.2	148	85.3	0.1002	680	105.3	104.6	1.502	101.9	101.5

TABLE 1C: Evaporator temperature = -20 C

Composition	GWP	T _{disch} , C	Avg glide	Capacity, kJ/m ³	Cap_cool vs incumbent, %		COP	COP_cool vs incumbent, %	
					R- 515A	R- 515B			
R-515A	389	83.3	0.0007	507.9	100		1.308	100	
R-515B	289	84.0	0.0004	511.3		100	1.314		100
1234zeE/152a/227ea wt%*									
88/3/9	294	85.4	0.0654	524	103.2	102.5	1.323	101.1	100.7
91/4.8/4.2	148	87.3	0.0986	536.5	105.6	104.9	1.336	102.1	101.7

[0246] The data demonstrates improved performance for the presently claimed compositions relative to R-515A and R-515B compositions, providing higher capacity and higher COP with essentially equivalent compressor discharge temperature and low average glide.

[0247] *It will be understood by those skilled in the art that weight percentage of each component is approximate such that the total amount of HFO-1234ze(E), HFC-152a and HFC-227ea may be less than 100 wt%, and the ternary composition of HFO-1234ze(E), HFC-152a and HFC-227ea may further comprise one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropylene, HFO-1234ze(Z), HFC-245fa, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160, CFC-114a, HFC-23, FC-1216, HCFC-22 and FC-218, more preferably selected from HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

Example 2

[0248] Refrigerant performance of compositions of the present invention were calculated using conditions for a heat pump in cooling mode. Compositions containing HFO-1234zeE, HFO-1336mzzE, and HFC-152a or HFO-1234zeE, HFO-1336mzzE, HFC-152a, and HFC-227ea or HFO-1234zeE, HFC-134a, and HFC-152a were compared to results for R-471A (ASHRAE designation for refrigerant mixtures containing 78.7 wt% HFO-1234zeE, 17 wt% HFO-1336mzzE, and 4.3 wt% HFC-227ea) and R-476A (ASHRAE designation for refrigerant mixtures containing 78 wt% HFO-1234zeE, 12 wt% HFO-1336mzzE, and 10 wt% HFC-134a). The conditions for the comparisons are as follows:

Temperature of the condenser	65 C
Temperature of the evaporator	-10 to -20 C
Subcool	10.0 K
Superheat	5.0 K
Compressor efficiency	70%

TABLE 2A: Evaporator temperature = -10 C

Composition	GWP	T _{disch} , C	Avg glide	Capacity, kJ/m3	Cap_cool vs incumbent, %		COP	COP_cool vs incumbent, %	
R-471A	144	81.7	2.124	714	100		1.484	100	
R-476A	148	84.2	1.9735	787.3		100	1.495		100
1234zeE / 1336mzzE / 152a, wt%*									
80/9/11	19	87.1	1.4952	835.6	117.0	106.1	1.521	102.5	101.7
75/20/5	12	84.0	2.7843	695.9	97.5	88.4	1.499	101.0	100.3
75/5/20	25	90.1	0.8589	908.7	127.3	115.4	1.542	103.9	103.1
70/5/25	36	91.8	0.8102	932.7	130.6	118.5	1.552	104.6	103.8
1234zeE/1336mzzE/152a/227ea, wt%*									
78/9/10/3	114	86.2	1.4916	825.8	115.7	104.9	1.514	102.0	101.3
1234zeE/134a/152a, wt%*									
75/15/10	231	88.2	0.3221	938.6	131.5	119.2	1.525	102.8	102.0

TABLE 2B: Evaporator temperature = -15 C

Composition	GWP	T _{disch} , C	Avg glide	Capacity, kJ/m3	Cap_cool vs incumbent, %		COP	COP_cool vs incumbent, %	
R-471A	144	83.3	2.129	562.5	100		1.484	100	
R-476A	148	85.9	1.975	623		100	1.495		100
1234zeE/1336mzzE/152a, wt%*									
80/9/11	19	89.1	1.5049	664.5	118.1	106.7	1.521	102.5	101.7
75/20/5	12	86.0	2.7875	547.6	97.4	87.9	1.499	101.0	100.3
75/5/20	25	92.5	0.8659	726.6	129.2	116.6	1.542	103.9	103.1

Composition	GWP	T _{disch} , C	Avg glide	Capacity, kJ/m3	Cap_cool vs incumbent, %		COP	COP_cool vs incumbent, %	
70/5/25	36	94.3	0.8175	747	132.8	119.9	1.552	104.6	103.8
1234zeE/1336mzzE/152a/227ea, wt%*									
78/9/10/3	114	88.2	1.5008	656.2	116.7	105.3	1.514	102.0	101.3
1234zeE/134a/152a, wt%*									
75/15/10	231	90.3	0.3161	750.8	133.5	120.5	1.525	102.8	102.0

TABLE 2C: Evaporator temperature = -20 C

Composition	GWP	T _{disch} , C	Avg glide	Capacity, kJ/m3	Cap_cool vs incumbent, %		COP	COP_cool vs incumbent, %	
R-471A	144	85.1	2.1345	438.3	100		1.317	100	
R-476A	148	87.9	1.9776	487.8		100	1.328		100
1234zeE/1336mzzE/152a, wt%*									
80/9/11	19	91.4	1.5158	523.2	119.4	107.3	1.354	102.8	102.0
75/20/5	12	88.0	2.7913	426.1	97.2	87.4	1.332	101.1	100.3
75/5/20	25	95.0	0.8739	575.4	131.3	118.0	1.376	104.5	103.6
70/5/25	36	97.1	0.8259	592.7	135.2	121.5	1.387	105.3	104.4
1234zeE/1336mzzE/152a/227ea, wt%*									
78/9/10/3	114	90.3	1.511	516.2	117.8	105.8	1.347	102.3	101.4
1234zeE/134a/152a, wt%*									
75/15/10	231	92.7	0.3103	594.9	135.7	122.0	1.36	103.3	102.4

[0249] The performance of the presently claimed compositions is an improvement over the existing R-471A and R-476A compositions, providing higher capacity in most cases and higher COP with essentially equivalent compressor discharge temperature and average glide.

[0250] *It will be understood by those skilled in the art that weight percentage of each component is approximate such that the total amount of HFO-1234ze(E), HFO-1336mzz(E) and HFC-152a may be less than 100 wt%, and the ternary composition of HFO-1234ze(E), HFO-1336mzz(E) and HFC-152a may further comprise one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropylene, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160, CFC-114a, C-30, HCFC-114a, HCFC-133, HCFC-133a, HFC-338mee, HFC-338mf, HFC-347mef, HCFO-1224 isomers, HCFO-1224yd, HCFO-1224yb, HFO-1327mz, HFO-1336ft and HCFO-1326mxz, more preferably selected from HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0251] *It will be understood by those skilled in the art that weight percentage of each component is approximate such that the total amount of HFO-1234ze(E), HFO-1336mzz(E), HFC-152a and HFC-227ea may be less than 100 wt%, and the quaternary composition of HFO-1234ze(E), HFO-1336mzz(E), HFC-152a and HFC-227ea may further comprise one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160, CFC-114a, C-30, HCFC-133, HCFC-133a, HFC-338mee, HFC-338mf, HFC-347mef, HCFO-1224 isomers, HCFO-1224yd, HCFO-1224yb, HFO-1327mz, HFO-1336ft, HCFO-1326mxz, HFC-23, FC-1216, HCFC-22 and FC-218, more preferably selected from HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

[0252] *It will be understood by those skilled in the art that weight percentage of each component is approximate such that the total amount of HFO-1234ze(E), HFC-134a and HFC-152a may be less than 100 wt%, and the ternary composition of HFO-1234ze(E), HFC-134a and HFC-152a may further comprise one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160, CFC-114a, HCFC-22, HCFO-1122 and HCFC-31, more preferably selected from HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

Example 3

[0253] Refrigerant performance of compositions of the present invention were calculated using conditions for a heat pump in cooling mode. Compositions containing HFO-1234zeE, HFC-134, and HFC-152a were compared to results for a composition containing only HFO-1234zeE and HFC-134. The conditions for the comparisons are as follows:

Temperature of the condenser	65 C
Temperature of the evaporator	-10 to -20 C
Subcool	10.0 K
Superheat	5.0 K
Compressor efficiency	70%

TABLE 3A: Evaporator temperature = -10 C

Composition	GWP	T _{disch} , C	Avg glide	Capacity, kJ/m ³	Cap_cool vs incumbent, %	COP	COP_cool vs incumbent, %
1234zeE/134, wt%							
63/37	522	86.4	0.0585	913.2	100.0	1.721	100.0
1234zeE/134/152a, wt%*							
80/5/15	93	88.7	0.1672	922.9	101.1	1.728	100.4

TABLE 3B: Evaporator temperature = -15 C

Composition	GWP	T _{disch} , C	Avg glide	Capacity, kJ/m ³	Cap_cool vs incumbent, %	COP	COP_cool vs incumbent, %
1234zeE/134, wt%							
63/37	522	88.44	0.0568	728.9	100.0	1.53	100.0
1234zeE/134/152a, wt%*							
80/5/15	93	90.84	0.1651	738.8	101.4	1.538	100.5

TABLE 3C: Evaporator temperature = -20 C

Composition	GWP	T _{disch} , C	Avg glide	Capacity, kJ/m ³	Cap_cool vs incumbent, %	COP	COP_cool vs incumbent, %
1234zeE/134, wt%							
63/37	522	90.7	0.0552	576.2	100.0	1.364	100.0
1234zeE/134/152a, wt%*							
80/5/15	93	93.3	0.1632	585.8	101.7	1.373	100.7

[0254] The performance of the presently claimed compositions is an improvement over the prior art composition containing HFO-1234zeE and HFC-134, providing higher capacity and higher COP with essentially equivalent compressor discharge temperature and average glide.

[0255] *It will be understood by those skilled in the art that weight percentage of each component is approximate such that the total amount of HFO-1234ze(E), HFC-152a and HFC-134 may be less than 100 wt%, and the ternary composition of HFO-1234ze(E), HFC-152a and HFC-134 may further comprise one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-

1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160, CFC-114a, HCFC-124a, HCFO-1122, HCFC-31, HFC-32, FCO-1114, FCO-1318my and FC-C318, more preferably selected from HFO-1234yf, HFC-245cb, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

Example 4

[0256] Refrigerant performance of compositions of the present invention were calculated using conditions for a heat pump in cooling mode. Compositions containing HFO-1234zeE, HFC-125, and HFC-152a were compared to results for a composition containing only HFO-1234zeE and HFC-125. The conditions for the comparisons are as follows:

Temperature of the condenser	65 C
Temperature of the evaporator	-10 to -20 C
Subcool	10.0 K
Superheat	5.0 K
Compressor efficiency	70%

TABLE 4A: Evaporator temperature = -10 C

Composition	GWP	T _{disch} , C	Avg glide	Capacity, kJ/m3	Cap_cool vs incumbent,%	COP	COP_cool vs incumbent,%
1234zeE/125, wt%							
96/4		82.9	0.5032	852.5	100.0	1.679	100.0
43.03/56.97		87.1	4.4412	1233.3	100	1.514	100
1234zeE/125/152a, wt%*							
80/5/15		88.6	0.7142	943	110.6	1.715	102.1

TABLE 4B: Evaporator temperature = -15 C

Composition	GWP	T _{disch} , C	Avg glide	Capacity, kJ/m ³	Cap_cool vs incumbent, %	COP	COP_cool vs incumbent, %
1234zeE/125, wt%							
96/4	146	84.54	0.491	678.2	100.0	1.489	100.0
43.03/56.97	1994	88.68	4.3462	981.1	100	1.334	100
1234zeE/125/152a, wt%*							
80/5/15	198	90.77	0.6999	754.5	111.3	1.525	102.4

TABLE 4C: Evaporator temperature = -20 C

Composition	GWP	T _{disch} , C	Avg glide	Capacity, kJ/m ³	Cap_cool vs incumbent, %	COP	COP_cool vs incumbent, %
1234zeE/125, wt%							
96/4	146	86.38	0.4795	534.2	100.0	1.323	100.0
43.03/56.97	1994	90.44	4.2494	772.7	100	1.177	100
1234zeE/125/152a, wt%*							
80/5/15	198	93.14	0.6862	598	111.9	1.36	102.8

[0257] The performance of the presently claimed compositions is an improvement over the prior art composition containing 96 wt% HFO-1234zeE and 4 wt% HFC-125, providing higher capacity and higher COP with essentially equivalent compressor discharge temperature and average glide. When compared to the 43.03 wt% HFO-1234zeE and 56.97 wt% HFC-125 composition, the capacity is lower, but the GWP is significantly reduced and the COP is also improved making it applicable to certain applications.

[0258] *It will be understood by those skilled in the art that weight percentage of each component is approximate such that the total amount of HFO-1234ze(E), HFC-152a and HFC-125 may be less than 100 wt%, and the ternary composition of HFO-1234ze(E), HFC-152a and HFC-125 may further comprise one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-134a, HFC-134, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160, CFC-114a, HFC-23, HFC-32, CFC-115 and CFCO-1113, more preferably selected from HFO-1234yf, HFC-245cb, HFC-134a, HFC-134, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

Example 5

[0259] Refrigerant performance of compositions of the present invention were calculated using conditions for a heat pump in cooling mode. Compositions containing HFO-1234zeE, HFC-32, HFC-125, and HFC-152a were compared to results for R-447A (ASHRAE designation for refrigerant mixtures containing 28.5 wt% HFO-1234zeE, 68 wt% HFC-32, and 3.5 wt% HFC-125) and R-447B (ASHRAE designation for refrigerant mixtures containing 24 wt% HFO-1234zeE, 68 wt% HFC-32, and 8 wt% HFC-125). The conditions for the comparisons are as follows:

Temperature of the condenser	65 C
Temperature of the evaporator	-10 to -20 C
Subcool	10.0 K
Superheat	5.0 K
Compressor efficiency	70%

TABLE 5A: Evaporator temperature = -10 C

Composition	GWP	T _{disch} , C	Avg glide	Capacity, kJ/m3	Cap_cool vs incumbent, %	COP	COP_cool vs incumbent, %
R-447A	583	137.5	3.1849	2627.5	100.0	1.649	100.0
R-447B	740	137.0	2.6866	2680.7	100	1.639	100
1234zeE/125/152a/32, wt%*							
80/5/10/5	226	92.9	3.17	1043.3	39.71 38.92	1.704	103.3 104.0

TABLE 5B: Evaporator temperature = -15 C

Composition	GWP	T _{disch} , C	Avg glide	Capacity, kJ/m3	Cap_cool vs incumbent, %	COP	COP_cool vs incumbent, %
R-447A	583	144.1	3.1863	2174.8	100.0	1.48	100.0
R-447B	740	143.6	2.6866	2220.6	100	1.471	100
1234zeE/125/152a/32, wt%*							
80/5/10/5	226	95.2	3.0954	834.6	38.38 37.58	1.517	

TABLE 5C: Evaporator temperature = -20 C

Composition	GWP	T _{disch} , C	Avg glide	Capacity, kJ/m3	Cap_cool vs incumbent, %	COP	COP_cool vs incumbent, %
R-447A	583	151.1	3.1891	1786.7	100.0	1.332	100.0
R-447B	740	150.6	2.6877	1825.8	100	1.324	100
1234zeE/125/152a/32, wt%*							
80/5/10/5	226	97.8	3.0245	661.5	37.02 36.23	1.353	

[0260] *It will be understood by those skilled in the art that weight percentage of each component is approximate such that the total amount of HFO-1234ze(E), HFC-152a, HFC-32 and HFC-125 may be less than 100 wt%, and the quaternary composition of HFO-1234ze(E), HFC-152a, HFC-32 and HFC-125 may further comprise one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-134a, HFC-134, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160, CFC-114a, HFC-23, CFC-115, CFCO-1113, HFC-41, HCFC-22 and CFC-12, more preferably selected from HFO-1234yf, HFC-245cb, HFC-134a, HFC-134, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

Example 6

[0261] Refrigerant performance of compositions of the present invention were calculated using conditions for a heat pump in cooling mode. Compositions containing HFO-1234zeE, HCFO-1224ydZ, HFC-134, and HFC-152a were compared to results for R-482A (ASHRAE designation for refrigerant mixtures containing 83.5 wt% HFO-1234zeE, 6.5 wt% HCFO-1224ydZ, and 10 wt% HFC-134a). The conditions for the comparisons are as follows:

Temperature of the condenser	65 C
Temperature of the evaporator	-10 to -20 C
Subcool	10.0 K
Superheat	5.0 K
Compressor efficiency	70%

TABLE 6A: Evaporator temperature = -10 C

Composition	GWP	T_disch, C	Avg glide	Capacity, kJ/m3	Cap_cool vs incumbent,%	COP	COP_cool vs incumbent,%
R-482A	148	85.6	2.2896	808.3	100.0	2.701	100.0
1234zeE/1224ydZ/134/152a, wt%*							
80/5/5/10	87	88.3	1.7169	850.5	105.2	2.725	100.89

TABLE 6B: Evaporator temperature = -15 C

Composition	GWP	T_disch, C	Avg glide	Capacity, kJ/m3	Cap_cool vs incumbent,%	COP	COP_cool vs incumbent,%
R-482A	148	87.5	2.2909	641.2	100.0	1.51	100.0
1234zeE/1224ydZ/134/152a, wt%*							
80/5/5/10	87	90.5	1.7237	677.5	105.66	1.535	101.66

TABLE 6C: Evaporator temperature = -20 C

Composition	GWP	T_disch, C	Avg glide	Capacity, kJ/m3	Cap_cool vs incumbent,%	COP	COP_cool vs incumbent,%
R-482A	148	89.7	2.2925	503.4	100.0	1.344	100.0
1234zeE/1224ydZ/134/152a, wt%*							
80/5/5/10	87	92.9	1.7308	534.4	105.16	1.368	808.3

[0262] The performance of the presently claimed compositions show higher capacity and COP, with lower average glide and similar compressor discharge temperatures as compared to R-482A. These claimed compositions are an improvement over R-482A under these conditions.

[0263] *It will be understood by those skilled in the art that weight percentage of each component is approximate such that the total amount of HFO-1234ze(E), HFC-152a, HFC-134 and HFO-1224yd(Z) may be less than 100 wt%, and the quaternary composition of HFO-1234ze(E), HFC-152a, HFC-134 and HFO-1224yd(Z) may further comprise one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160, CFC-114a, HFC-254eb, HFO-1215yb, HCFC-244bb, HFO-1224yd(E), HFO-1224 isomer(s), HFO-1112a, HFC-225ca, HFC-225cb, HFC-234bb, HCFC-124a, HCFO-1122, HCFC-31, HFC-32, FCO-1114, FCO-1318my and FC-C318, more preferably selected from HFO-1234yf, HFC-245cb, HFC-125, HFC-134a, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

Example 7

[0264] Refrigerant performance of compositions of the present invention were calculated using conditions for a chiller. Compositions containing HFO-1234zeE, HFC-152a, and HFC-227ea were compared to results for R-515A (ASHRAE

designation for refrigerant mixtures containing 88 wt% HFO-1234zeE and 12 wt% HFC-227ea), R-515B (ASHRAE designation for refrigerant mixtures containing 91.1 wt% HFO-1234zeE and 8.9 wt% HFC-227ea), R-471A (ASHRAE designation for refrigerant mixtures containing 78.7 wt% HFO-1234zeE, 17 wt% HFO-1336mzzE, and 4.3 wt% HFC-227ea), R-476A (ASHRAE designation for refrigerant mixtures containing HFO-1234zeE, HFO-1336mzzE, and HFC-134a), and 134a. The conditions for the comparisons are as follows:

Condenser temperature	37.78 C
Evaporator temperature	4.4 C
Superheat	6.0 K
Compressor efficiency	85%

TABLE 7A: Comparison with R-515A

Composition	GWP	T_disch, C	Avg glide	Capacity, kJ/m3	Cap_cool vs incumbent	COP	COP_cool vs incumbent
R-515A	389	44.5	0.0008	1855	100.0	5.901	100.0
1234zeE/152a/227ea, wt%*							
88/3/9	294	45.27	0.088	1890	101.87	5.917	100.27
91/4.8/4.2	148	45.94	0.1316	1913	103.14	5.932	100.53

TABLE 7B: Comparison with R-515B

Composition	GWP	T_disch, C	Avg glide	Capacity, kJ/m3	Cap_cool vs incumbent	COP	COP_cool vs incumbent
R-515B	289	44.73	0.0004	1859	100.0	5.908	100.0
1234zeE/152a/227ea, wt%*							
88/3/9	294	45.27	0.088	1890	101.64	5.917	100.15
91/4.8/4.2	148	45.94	0.1316	1913	102.90	5.932	100.41

TABLE 7C: Comparison with R-471A

Composition	GWP	T_disch, C	Avg glide	Capacity, kJ/m3	Cap_cool vs incumbent	COP	COP_heat vs incumbent
R-471A	144	45.75	2.503	1661	100.0	5.921	100.0
1234zeE/152a/227ea, wt%*							
88/3/9	294	45.27	0.088	1890	113.74	5.917	99.93
91/4.8/4.2	148	45.94	0.1316	1913	115.16	5.932	100.19

TABLE 7D: Comparison with R-134a

Composition	GWP	T_disch, C	Avg glide	Capacity, kJ/m3	Cap_cool vs incumbent	COP	COP_heat vs incumbent
R-134a	1430	50.76	0	2502	100.0	5.923	100.0
1234zeE/152a/227ea, wt%*							
88/3/9	294	45.27	0.088	1890	75.52	5.917	99.90
91/4.8/4.2	148	45.94	0.1316	1913	76.46	5.932	100.15

[0265] The data demonstrates that the presently claimed compositions provide higher capacity and similar or improved COP, with low average glide and similar compressor discharge temperatures as compared to R-515A, R-515B, and R-471A. With respect to R-134a, the capacity is lower but COP essentially equivalent, discharge temperature lower, average glide is acceptable, and GWP is significantly reduced.

[0266] *It will be understood by those skilled in the art that weight percentage of each component is approximate such that the total amount of HFO-1234ze(E), HFC-152a and HFC-227ea may be less than 100 wt%, and the ternary composition of HFO-1234ze(E), HFC-152a, and HFC-227ea may further comprise one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFC-134, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropylene, HFO-1234ze(Z), HFC-245fa, HFO-1243zf, HFC-263fb, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160, CFC-114a, HFC-23, FC-1216, HCFC-22 and FC-218, more preferably selected from HFO-1234yf, HFC-245cb, HFC-125, HFC-134a, HFC-134, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

Example 8

[0267] Refrigerant performance of compositions of the present invention were calculated using conditions for low temperature refrigeration. Compositions containing HFO-1234zeE, HFC-152a, and HFC-32 were compared to results for R-404A (ASHRAE designation for refrigerant mixtures containing 44 wt% HFC-125, 52 wt% HFC-143a, and 4 wt% FC-134a), R-454C (ASHRAE designation for refrigerant mixtures containing 78.5 wt% HFO-1234yf and 21.5 wt% HFC-32), and R-449A (ASHRAE designation for refrigerant mixtures containing 25.3 wt% HFO-1234yf,

24.3 wt% HFC-32, 24.7 wt% HFC-125, and 25.7 wt% HFC-134a). The conditions for the comparisons are as follows:

Condenser temperature	40 C
Evaporator temperature	-35 C
Return temperature	-10 C
Compressor efficiency	70%

TABLE 8: Comparison with R-404A

Composition	GWP	T_disch, C	Avg glide	Mass flow	Capacity, kJ/m ³	Cap_cool vs R-404A	COP	COP_cool vs R-404A
R-404A	3922	94.3	0.387		827.5	100	1.358	100
R-449A	1397	115	3.86		817.9	98.8	1.448	106.6
R-454A	239	118	4.45		889.3	108.7	1.447	106.6
R-454C	148	105	5.52		728.3	81.9	1.444	106.3
1234zeE/152a/32, wt%*								
60/10/30	216	126	8.27		657.9	90.3	1.515	111.6

[0268] The data demonstrates that the presently claimed composition provide improved COP as compared to R-404A and the other refrigerants shown. Additionally, the capacity is within 10% of that for R-404A with a significantly lower GWP.

[0269] *It will be understood by those skilled in the art that weight percentage of each component is approximate such that the total amount of HFO-1234ze(E), HFC-152a and HFC-32 may be less than 100 wt%, and the ternary composition of HFO-1234ze(E), HFC-152a, and HFC-32 may further comprise one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFC-134, HFC-227ea, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFO-1243zf, HFC-263fb, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160, CFC-114a, HFC-41, HCFC-22 and CFC-12, more preferably selected from HFO-1234yf, HFC-245cb, HFC-125, HFC-134a, HFC-134, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160.

Additional Embodiments

[0270] Embodiment 1: A composition comprising HFO-1234ze(E), HFC-152a, and at least one compound selected from the group consisting of HFC-227ea, HFO-

1336mzz(E), HFC-134, HFC-125, HFC-32, HFC-134a, HCFO-1224yd(Z), CO₂, and combinations thereof.

[0271] Embodiment 2: The composition of Embodiment 1, wherein said composition comprises one of:

- a. HFO-1234ze(E), HFC-152a, and HFC-227ea;
- b. HFO-1234ze(E), HFC-152a, and HFO-1336mzz(E);
- c. HFO-1234ze(E), HFC-152a, HFO-1336mzz(E), and HFC-227ea;
- d. HFO-1234ze(E), HFC-134, and HFC-152a;
- e. HFO-1234ze(E), HFC-125, and HFC-152a;
- f. HFO-1234ze(E), HFC-32, and HFC-152a;
- g. HFO-1234ze(E), HFC-152a and CO₂;
- h. HFO-1234ze(E), HFC-125, HFC-32, and HFC-152a; or
- f. HFO-1234ze(E), HFC-134a, HCFO-1224yd(Z), and HFC-152a.

[0272] Embodiment 3: The composition of Embodiment 1 or 2, comprising from about 88 to 91 weight percent HFO-1234ze(E), from about 4 to 9 weight percent HFC-227ea, and from about 3 to 5 weight percent HFC-152a.

[0273] Embodiment 4: The composition of Embodiment 1 or 2, comprising from about 70 to 80 weight percent HFO-1234ze(E), from about 5 to 20 weight percent HFO-1336mzz(E), from about 5 to 25 weight percent HFC-152a, and from about 1 to 3 weight percent HFC-227ea.

[0274] Embodiment 5: The composition of Embodiment 1 or 2, comprising from about 75 to 85 weight percent HFO-1234ze(E), from about 2 to 8 weight percent HFC-134, and from about 10 to 20 weight percent HFC-152a.

[0275] Embodiment 6: The composition of Embodiment 1 or 2, comprising from about 75 to 85 weight percent HFO-1234ze(E), from about 3 to 7 weight percent HFC-125, and from about 10 to 20 weight percent HFC-152a.

[0276] Embodiment 7: The composition of Embodiment 1 or 2, comprising from about 75 to 85 weight percent HFO-1234ze(E), from about 3 to 7 weight percent HFC-125, from about 3 to 7 weight percent HFC-32, and from about 5 to 15 weight

percent HFC-152a. The composition of Embodiment 1 or 2, comprising from about 75 to 85 weight percent HFO-1234ze(E), from about 3 to 7 weight percent HFC-134a, from about 3 to 7 weight percent HCFO-1224yd(Z), and from about 5 to 15 weight percent HFC-152a.

[0277] Embodiment 8: The composition of Embodiment 1 or 2, comprising about 60 weight percent HFO-1234ze(E), about 10 weight percent HFC-32, and about 30 weight percent HFC-152a.

[0278] Embodiment 9: The composition of any of Embodiments 1 to 8, further comprising at least one additional compound selected from the group consisting of HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-152a, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HCFO-1233xf, HCFO-1233zd, CFC-114, HCFC-124, HFO-2223, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, and HFC-263fb.

[0279] Embodiment 10: The composition of any of Embodiments 1 to 9, further comprising one or more additional compounds selected from the group consisting of HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropylene, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, preferably two or more compounds or preferably three or more compounds.

[0280] Embodiment 11: The composition of any of Embodiments 1 to 9, further comprising one or more additional compounds selected from the group consisting of HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160, preferably two or more compounds or preferably three or more compounds.

[0281] Embodiment 12: A composition comprising HFO-1234ze(E), HFC-152a, and one or more additional compounds selected from the group consisting of HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropylene, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160

and CFC-114a, preferably two or more compounds or preferably three or more compounds.

[0282] Embodiment 13: A composition comprising HFO-1234ze(E), HFC-152a, and one or more additional compounds selected from the group consisting of HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160, preferably two or more compounds or preferably three or more compounds.

[0283] Embodiment 14: The composition of Embodiment 12 or 13, the composition comprising one of:

- a. HFO-1234ze(E), HFC-152a, HFC-245cb and HFC-161;
- b. HFO-1234ze(E), HFC-152a, HFO-1243zf and HFC-161;
- c. HFO-1234ze(E), HFC-152a, HFO-1243zf and HCO-1140;
- d. HFO-1234ze(E), HFC-152a, HFC-134 and HFC-134a;
- e. HFO-1234ze(E), HFC-152a, HFO-1234yf and HFC-161;
- f. HFO-1234ze(E), HFC-152a, HFO-1234yf and HCC-160;
- g. HFO-1234ze(E), HFC-152a, HFO-1225zc and HFC-161;
- h. HFO-1234ze(E), HFC-152a, HFC-134 and HFC-161;
- i. HFO-1234ze(E), HFC-152a, HFC-134a and HFO-1140;
- j. HFO-1234ze(E), HFC-152a, HCC-40 and HFC-161;
- k. HFO-1234ze(E), HFC-152a, HFO-1225zc and HCO-1140;
- l. HFO-1234ze(E), HFC-152a, HFO-1225zc and HFC-161;
- m. HFO-1234ze(E), HFC-152a, HFO-1225zc and HCC-160
- n. HFO-1234ze(E), HFC-152a, HFO-1225zc and HFO-1243zf;
- o. HFO-1234ze(E), HFC-152a, HFC-245cb and HFO-1234yf;
- p. HFO-1234ze(E), HFC-152a, HFO-1234yf and HFC-134a;
- q. HFO-1234ze(E), HFC-152a, HFO-1234yf and HFC-134;
- r. HFO-1234ze(E), HFC-152a, HFO-1234yf and HFO-1243zf;
- s. HFO-1234ze(E), HFC-152a, HFC-245cb and HFC-134a;

- t. HFO-1234ze(E), HFC-152a, HFC-245cb and HFC-134; or
- u. HFO-1234ze(E), HFC-152a, HFC-245cb and HFO-1243zf.

[0284] Embodiment 15: The composition of Embodiment 12 or 13, the composition comprising one of:

- a. HFO-1234ze(E), HFC-152a, HFC-245cb, HFO-1234yf and HFC-161;
- b. HFO-1234ze(E), HFC-152a, HFC-245cb, HFO-1234yf and HCO-1140;
- c. HFO-1234ze(E), HFC-152a, HFC-245cb, HFO-1234yf and HCC-160;
- d. HFO-1234ze(E), HFC-152a, HFC-245cb, HFO-1234yf and HCC-40;
- e. HFO-1234ze(E), HFC-152a, HFC-134, HFC-134a and HFO-1140;
- f. HFO-1234ze(E), HFC-152a, HFO-134, HFC-134a and HFC-161;
- g. HFO-1234ze(E), HFC-152a, HFC-134, HFC-134a and HCO-40;
- h. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1243zf and HFC-161;
- i. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1243zf and HCO-1140;
- j. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1243zf and HCC-40;
- k. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1243zf and HFO-1234yf;
- l. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1234yf and HFC-134a;
- m. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1234yf and HFC-134;
- n. HFO-1234ze(E), HFC-152a, HFO-1243zf, HFC-245cb and HFO-1234yf;
- o. HFO-1234ze(E), HFC-152a, HFO-1243zf, HFC-134 and HFC-134a;
- p. HFO-1234ze(E), HFC-152a, HFO-1234yf, HFC-134 and HFC-134a;
- q. HFO-1234ze(E), HFC-152a, HFO-1243zf, HFC-245cb and HFC-134a;
- r. HFO-1234ze(E), HFC-152a, HFO-1243zf, HFC-245cb and HFC-134;
- s. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1243zf, HFO-1234yf and HFC-245cb;
- t. HFO-1234ze(E), HFC-152a, HFO-1234yf, HFC-245cb, HFC-134a and HFC-134; or
- u. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1234yf, HFC-134a and HFC-134.

[0285] Embodiment 16: The composition of any of Embodiments 1 to 15, further comprising less than 100 ppm wt water, preferably less than 20 ppm wt water, and more preferably less than 10 ppm wt water.

[0286] Embodiment 17: The composition of any of Embodiments 1 to 16, further comprising less than 5 volume percent non-adsorbable gases (NAG), preferably less than 3 volume percent NAG, and more preferably less than 1.5 volume percent NAG.

[0287] Embodiment 18: The composition of any of Embodiments 1 to 17, further comprising less than 0.35 volume percent oxygen.

[0288] Embodiment 19: The composition of any of Embodiments 1 to 18, further comprising at least one stabilizer.

[0289] Embodiment 20: The composition of any of Embodiments 1 to 19, further comprising at least one lubricant selected from the group consisting of polyol ester, polyvinyl ether, and polyalkylene glycol.

[0290] Embodiment 21: The composition of any of Embodiments 1 to 20, wherein said composition has GWP(AR4) less than 750, preferably GWP less than 300, and more preferably less than 150.

[0291] Embodiment 22: The composition of any of Embodiments 1 to 21, wherein said composition is characterized as flammability class 1 (non-flammable), flammability class 2L (mildly flammable), or flammability class 2.

[0292] Embodiment 23: The composition of any of Embodiments 1 to 22, further comprising a hydrocarbon selected from the group consisting of propane, propylene, cyclopropane, isobutane, n-butane, isobutene, and combinations thereof.

[0293] Embodiment 24: The composition of any of Embodiments 1 to 23, wherein the composition is free of or substantially free of Group A Fluorinated Substances, and wherein degradation products of the composition are free of or substantially free of Group A Fluorinated Substances.

[0294] Embodiment 25: A process for producing cooling comprising condensing the composition of any of Embodiments 1 to 24 and thereafter evaporating said composition in the vicinity of a body to be cooled.

- [0295] Embodiment 26: A process for producing heating comprising evaporating the composition of any of Embodiments 1 to 24 and thereafter condensing said composition in the vicinity of a body to be heated.
- [0296] Embodiment 27: A refrigeration, air conditioning, heat pump, or chiller apparatus containing the composition of any of Embodiments 1 to 24.
- [0297] Embodiment 28: The apparatus of Embodiment 27 comprising an evaporator, a compressor, a condenser, and an expansion device.
- [0298] Embodiment 29: The apparatus of Embodiment 27 or 28 comprising a chiller.
- [0299] Embodiment 30: The apparatus of Embodiment 27 or 28 comprising a heat pump.
- [0300] Embodiment 31: The apparatus of Embodiment 27 or 28 comprising an air conditioner or air conditioning system.
- [0301] Embodiment 32: The apparatus of Embodiment 27 or 28 comprising a refrigerator or refrigeration system.
- [0302] Embodiment 33: The apparatus of Embodiment 27, 28 or 32 comprising a low temperature refrigeration system.
- [0303] Embodiment 34: The apparatus of Embodiment 27, 28 or 32 comprising a medium temperature refrigeration system.
- [0304] Embodiment 35: The apparatus of Embodiment 27, 28 or 32 comprising a transport refrigeration system.
- [0305] Embodiment 36: The apparatus of Embodiment 27, 28 or 30 comprising a high temperature heat pump system.
- [0306] Embodiment 37: The apparatus of Embodiment 27, 28 or 30 comprising an automobile heat pump system.
- [0307] Embodiment 38: The apparatus of Embodiment 37 comprising a secondary loop system.
- [0308] Embodiment 39: A method for replacing a first refrigerant in a refrigeration, air conditioning, heat pump, or chiller apparatus, the first refrigerant being selected

from the group consisting of R-22, HFC-134a, propane, HFO-1234yf, R-407C, R-404A, R-410A, R-513A, R-454A, R-454B, R-454C, R-448A, R-449A, R-449B, R-449C, R-1234zeE, R-515B, R-471A, R-476A, R-482A, R-452A, and R-452C, the method comprising providing the composition of any of Embodiments 1 to 24 to the refrigeration, air conditioning, heat pump, or chiller apparatus.

[0309] Embodiment 40: A composition comprising HFO-1234ze(E) and:

- a. at least one compound selected from the group consisting of HFC-23, HFC-32, HFC-125, HFC-143a, HFC-134, HFC-152a, HFO-1132a, HFO-1132(E), HFO-1132(Z), HFO-1234ze(Z), HCFO-1233zd(E), HCFO-1233zd(Z), HFC-245fa, HFO-1336mzz(E), HFO-1336mzz(Z), HCC-1130(E), HCC-1130(Z), CFO-1112(E), CFO-1112(Z), HFC-356mcf, HFC-356mff and combinations thereof; or
- b. at least one compound selected from the group consisting of HFO-1234yf, HFC-227ea, HFO-1225ye(E), HCFO-1224yd(Z), HFC-134a; and combinations thereof; and
- c. optionally at least one compound selected from the group consisting of propane, propylene, cyclopropane, isobutane, n-butane, and isobutene.

[0310] Embodiment 41. Use of the composition according to any of Embodiments 1 to 24, preferably any of Embodiments 12 to 24, as a blowing agent for formation of a foam.

[0311] Embodiment 42. A process of forming a foam comprising: adding a foamable composition to a blowing agent; and

[0312] reacting said foamable composition under conditions effective to form a foam, wherein said blowing agent comprises the composition according to any of Embodiments 1 to 24, preferably any of Embodiments 12 to 24.

[0313] Embodiment 43. A foam formed by the process according to Embodiment 42.

[0314] Although certain aspects, embodiments and principals have been described above, it is understood that this description is made only way of example and not as limitation of the scope of the invention or appended claims. The foregoing various aspects, embodiments and principals can be used alone and in combinations with each other.

CLAIMS

What is claimed is:

1. A composition comprising HFO-1234ze(E), HFC-152a, and at least one compound selected from the group consisting of HFC-227ea, HFO-1336mzz(E), HFC-134, HFC-125, HFC-32, HFC-134a, HCFO-1224yd(Z), CO₂, and combinations thereof.
2. The composition of claim 1, wherein said composition comprises one of:
 - a. HFO-1234ze(E), HFC-152a, and HFC-227ea;
 - b. HFO-1234ze(E), HFC-152a, and HFO-1336mzz(E);
 - c. HFO-1234ze(E), HFC-152a, HFO-1336mzz(E), and HFC-227ea;
 - d. HFO-1234ze(E), HFC-134, and HFC-152a;
 - e. HFO-1234ze(E), HFC-125, and HFC-152a;
 - f. HFO-1234ze(E), HFC-32, and HFC-152a;
 - g. HFO-1234ze(E), HFC-152a and CO₂;
 - h. HFO-1234ze(E), HFC-125, HFC-32, and HFC-152a; or
 - i. HFO-1234ze(E), HFC-134a, HCFO-1224yd(Z), and HFC-152a.
3. The composition of claim 1 or 2, comprising from about 88 to 91 weight percent HFO-1234ze(E), from about 4 to 9 weight percent HFC-227ea, and from about 3 to 5 weight percent HFC-152a.
4. The composition of claim 1 or 2, comprising from about 70 to 80 weight percent HFO-1234ze(E), from about 5 to 20 weight percent HFO-1336mzz(E), from about 5 to 25 weight percent HFC-152a, and from about 1 to 3 weight percent HFC-227ea.
5. The composition of claim 1 or 2, comprising from about 75 to 85 weight percent HFO-1234ze(E), from about 2 to 8 weight percent HFC-134, and from about 10 to 20 weight percent HFC-152a.
6. The composition of claim 1 or 2, comprising from about 75 to 85 weight percent HFO-1234ze(E), from about 3 to 7 weight percent HFC-125, and from about 10 to 20 weight percent HFC-152a.

7. The composition of claim 1 or 2, comprising from about 75 to 85 weight percent HFO-1234ze(E), from about 3 to 7 weight percent HFC-125, from about 3 to 7 weight percent HFC-32, and from about 5 to 15 weight percent HFC-152a. The composition of claim 1 or 2, comprising from about 75 to 85 weight percent HFO-1234ze(E), from about 3 to 7 weight percent HFC-134a, from about 3 to 7 weight percent HCFO-1224yd(Z), and from about 5 to 15 weight percent HFC-152a.
8. The composition of claim 1 or 2, comprising about 60 weight percent HFO-1234ze(E), about 10 weight percent HFC-32, and about 30 weight percent HFC-152a.
9. The composition of any of claims 1 to 8, further comprising at least one additional compound selected from the group consisting of HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-152a, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HCFO-1233xf, HCFO-1233zd, CFC-114, HCFC-124, HFO-2223, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, and HFC-263fb.
10. The composition of any of claims 1 to 9, further comprising one or more additional compounds selected from the group consisting of HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, preferably two or more compounds or preferably three or more compounds.
11. The composition of any of claims 1 to 9, further comprising one or more additional compounds selected from the group consisting of HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160, preferably two or more compounds or preferably three or more compounds.
12. A composition comprising HFO-1234ze(E), HFC-152a, and one or more additional compounds selected from the group consisting of HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa,

HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropyne, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, preferably two or more compounds or preferably three or more compounds.

13. A composition comprising HFO-1234ze(E), HFC-152a, and one or more additional compounds selected from the group consisting of HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160, preferably two or more compounds or preferably three or more compounds.

14. The composition of claim 12 or 13, the composition comprising one of:

- a. HFO-1234ze(E), HFC-152a, HFC-245cb and HFC-161;
- b. HFO-1234ze(E), HFC-152a, HFO-1243zf and HFC-161;
- c. HFO-1234ze(E), HFC-152a, HFO-1243zf and HCO-1140;
- d. HFO-1234ze(E), HFC-152a, HFC-134 and HFC-134a;
- e. HFO-1234ze(E), HFC-152a, HFO-1234yf and HFC-161;
- f. HFO-1234ze(E), HFC-152a, HFO-1234yf and HCC-160;
- g. HFO-1234ze(E), HFC-152a, HFO-1225zc and HFC-161;
- h. HFO-1234ze(E), HFC-152a, HFC-134 and HFC-161;
- i. HFO-1234ze(E), HFC-152a, HFC-134a and HFO-1140;
- j. HFO-1234ze(E), HFC-152a, HCC-40 and HFC-161;
- k. HFO-1234ze(E), HFC-152a, HFO-1225zc and HCO-1140;
- l. HFO-1234ze(E), HFC-152a, HFO-1225zc and HFC-161;
- m. HFO-1234ze(E), HFC-152a, HFO-1225zc and HCC-160
- n. HFO-1234ze(E), HFC-152a, HFO-1225zc and HFO-1243zf;
- o. HFO-1234ze(E), HFC-152a, HFC-245cb and HFO-1234yf;
- p. HFO-1234ze(E), HFC-152a, HFO-1234yf and HFC-134a;
- q. HFO-1234ze(E), HFC-152a, HFO-1234yf and HFC-134;
- r. HFO-1234ze(E), HFC-152a, HFO-1234yf and HFO-1243zf;

- s. HFO-1234ze(E), HFC-152a, HFC-245cb and HFC-134a;
 - t. HFO-1234ze(E), HFC-152a, HFC-245cb and HFC-134; or
 - u. HFO-1234ze(E), HFC-152a, HFC-245cb and HFO-1243zf.
15. The composition of claim 12 or 13, the composition comprising one of:
- a. HFO-1234ze(E), HFC-152a, HFC-245cb, HFO-1234yf and HFC-161;
 - b. HFO-1234ze(E), HFC-152a, HFC-245cb, HFO-1234yf and HCO-1140;
 - c. HFO-1234ze(E), HFC-152a, HFC-245cb, HFO-1234yf and HCC-160;
 - d. HFO-1234ze(E), HFC-152a, HFC-245cb, HFO-1234yf and HCC-40;
 - e. HFO-1234ze(E), HFC-152a, HFC-134, HFC-134a and HFO-1140;
 - f. HFO-1234ze(E), HFC-152a, HFO-134, HFC-134a and HFC-161;
 - g. HFO-1234ze(E), HFC-152a, HFC-134, HFC-134a and HCO-40;
 - h. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1243zf and HFC-161;
 - i. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1243zf and HCO-1140;
 - j. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1243zf and HCC-40;
 - k. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1243zf and HFO-1234yf;
 - l. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1234yf and HFC-134a;
 - m. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1234yf and HFC-134;
 - n. HFO-1234ze(E), HFC-152a, HFO-1243zf, HFC-245cb and HFO-1234yf;
 - o. HFO-1234ze(E), HFC-152a, HFO-1243zf, HFC-134 and HFC-134a;
 - p. HFO-1234ze(E), HFC-152a, HFO-1234yf, HFC-134 and HFC-134a;
 - q. HFO-1234ze(E), HFC-152a, HFO-1243zf, HFC-245cb and HFC-134a;
 - r. HFO-1234ze(E), HFC-152a, HFO-1243zf, HFC-245cb and HFC-134;
 - s. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1243zf, HFO-1234yf and HFC-245cb;
 - t. HFO-1234ze(E), HFC-152a, HFO-1234yf, HFC-245cb, HFC-134a and HFC-134; or
 - u. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1234yf, HFC-134a and HFC-134.

16. The composition of any of claims 1 to 15, further comprising less than 100 ppm wt water, preferably less than 20 ppm wt water, and more preferably less than 10 ppm wt water.
17. The composition of any of claims 1 to 16, further comprising less than 5 volume percent non-adsorbable gases (NAG), preferably less than 3 volume percent NAG, and more preferably less than 1.5 volume percent NAG.
18. The composition of any of claims 1 to 17, further comprising less than 0.35 volume percent oxygen.
19. The composition of any of claims 1 to 18, further comprising at least one stabilizer.
20. The composition of any of claims 1 to 19, further comprising at least one lubricant selected from the group consisting of polyol ester, polyvinyl ether, and polyalkylene glycol.
21. The composition of any of claims 1 to 20, wherein said composition has GWP(AR4) less than 750, preferably GWP less than 300, and more preferably less than 150.
22. The composition of any of claims 1 to 21, wherein said composition is characterized as flammability class 1 (non-flammable), flammability class 2L (mildly flammable), or flammability class 2.
23. The composition of any of claims 1 to 22, further comprising a hydrocarbon selected from the group consisting of propane, propylene, cyclopropane, isobutane, n-butane, isobutene, and combinations thereof.
24. The composition of any of claims 1 to 23, wherein the composition is free of or substantially free of Group A Fluorinated Substances, and wherein degradation products of the composition are free of or substantially free of Group A Fluorinated Substances.
25. A process for producing cooling comprising condensing the composition of any of claims 1 to 24 and thereafter evaporating said composition in the vicinity of a body to be cooled.

26. A process for producing heating comprising evaporating the composition of any of claims 1 to 24 and thereafter condensing said composition in the vicinity of a body to be heated.
27. A refrigeration, air conditioning, heat pump, or chiller apparatus containing the composition of any of claims 1 to 24.
28. The apparatus of claim 27 comprising an evaporator, a compressor, a condenser, and an expansion device.
29. The apparatus of claim 27 or 28 comprising a chiller.
30. The apparatus of claim 27 or 28 comprising a heat pump.
31. The apparatus of claim 27 or 28 comprising an air conditioner or air conditioning system.
32. The apparatus of claim 27 or 28 comprising a refrigerator or refrigeration system.
33. The apparatus of claim 27, 28 or 32 comprising a low temperature refrigeration system.
34. The apparatus of claim 27, 28 or 32 comprising a medium temperature refrigeration system.
35. The apparatus of claim 27, 28 or 32 comprising a transport refrigeration system.
36. The apparatus of claim 27, 28 or 30 comprising a high temperature heat pump system.
37. The apparatus of claim 27, 28 or 30 comprising an automobile heat pump system.
38. The apparatus of claim 37 comprising a secondary loop system.
39. A method for replacing a first refrigerant in a refrigeration, air conditioning, heat pump, or chiller apparatus, the first refrigerant being selected from the group consisting of R-22, HFC-134a, propane, HFO-1234yf, R-407C, R-404A, R-410A, R-513A, R-454A, R-454B, R-454C, R-448A, R-449A, R-449B, R-449C, R-1234zeE, R-515B, R471A, R-476A, R-482A, R-452A, and R-452C, the

method comprising providing the composition of any of claims 1 to 24 to the refrigeration, air conditioning, heat pump, or chiller apparatus.

40. A composition comprising HFO-1234ze(E) and:
- a. at least one compound selected from the group consisting of HFC-23, HFC-32, HFC-125, HFC-143a, HFC-134, HFC-152a, HFO-1132a, HFO-1132(E), HFO-1132(Z), HFO-1234ze(Z), HCFO-1233zd(E), HCFO-1233zd(Z), HFC-245fa, HFO-1336mzz(E), HFO-1336mzz(Z), HCC-1130(E), HCC-1130(Z), CFO-1112(E), CFO-1112(Z), HFC-356mcf, HFC-356mff and combinations thereof; or
 - b. at least one compound selected from the group consisting of HFO-1234yf, HFC-227ea, HFO-1225ye(E), HCFO-1224yd(Z), HFC-134a; and combinations thereof; and
 - c. optionally at least one compound selected from the group consisting of propane, propylene, cyclopropane, isobutane, n-butane, and isobutene.
41. Use of the composition according to any of claims 1 to 24, preferably any of claims 12 to 24, as a blowing agent for formation of a foam.
42. A process of forming a foam comprising: adding a foamable composition to a blowing agent; and
- reacting said foamable composition under conditions effective to form a foam, wherein said blowing agent comprises the composition according to any of claims 1 to 24, preferably any of claims 12 to 24.
43. A foam formed by the process according to claim 42.
44. A blowing agent composition comprising HFO-1234ze(E), HFC-152a, and one or more additional compounds selected from the group consisting of HFO-1234yf, HFC-245cb, HFO-1225ye(E), HFO-1225ye(Z), HFO-1225zc, HFC-236fa, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, trifluoropropylene, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a, preferably two or more compounds or preferably three or more compound.

45. A blowing agent composition comprising HFO-1234ze(E), HFC-152a, and one or more additional compounds selected from the group consisting of HFO-1234yf, HFC-245cb, HFC-134, HFC-134a, HFC-125, HFO-1225zc, HFO-1243zf, HFC-161, HCC-40, HCO-1140 and HCC-160, preferably two or more compounds or preferably three or more compounds.
46. The blowing agent composition of claim 44 or 45, the composition comprising one of:
- a. HFO-1234ze(E), HFC-152a, HFC-245cb and HFC-161;
 - b. HFO-1234ze(E), HFC-152a, HFO-1243zf and HFC-161;
 - c. HFO-1234ze(E), HFC-152a, HFO-1243zf and HCO-1140;
 - d. HFO-1234ze(E), HFC-152a, HFC-134 and HFC-134a;
 - e. HFO-1234ze(E), HFC-152a, HFO-1234yf and HFC-161;
 - f. HFO-1234ze(E), HFC-152a, HFO-1234yf and HCC-160;
 - g. HFO-1234ze(E), HFC-152a, HFO-1225zc and HFC-161;
 - h. HFO-1234ze(E), HFC-152a, HFC-134 and HFC-161;
 - i. HFO-1234ze(E), HFC-152a, HFC-134a and HFO-1140;
 - j. HFO-1234ze(E), HFC-152a, HCC-40 and HFC-161;
 - k. HFO-1234ze(E), HFC-152a, HFO-1225zc and HCO-1140;
 - l. HFO-1234ze(E), HFC-152a, HFO-1225zc and HFC-161;
 - m. HFO-1234ze(E), HFC-152a, HFO-1225zc and HCC-160
 - n. HFO-1234ze(E), HFC-152a, HFO-1225zc and HFO-1243zf;
 - o. HFO-1234ze(E), HFC-152a, HFC-245cb and HFO-1234yf;
 - p. HFO-1234ze(E), HFC-152a, HFO-1234yf and HFC-134a;
 - q. HFO-1234ze(E), HFC-152a, HFO-1234yf and HFC-134;
 - r. HFO-1234ze(E), HFC-152a, HFO-1234yf and HFO-1243zf;
 - s. HFO-1234ze(E), HFC-152a, HFC-245cb and HFC-134a;
 - t. HFO-1234ze(E), HFC-152a, HFC-245cb and HFC-134; or
 - u. HFO-1234ze(E), HFC-152a, HFC-245cb and HFO-1243zf.

47. The blowing agent composition of claim 44 or 45, the composition comprising one of:

- a. HFO-1234ze(E), HFC-152a, HFC-245cb, HFO-1234yf and HFC-161;
- b. HFO-1234ze(E), HFC-152a, HFC-245cb, HFO-1234yf and HCO-1140;
- c. HFO-1234ze(E), HFC-152a, HFC-245cb, HFO-1234yf and HCC-160;
- d. HFO-1234ze(E), HFC-152a, HFC-245cb, HFO-1234yf and HCC-40;
- e. HFO-1234ze(E), HFC-152a, HFC-134, HFC-134a and HFO-1140;
- f. HFO-1234ze(E), HFC-152a, HFO-134, HFC-134a and HFC-161;
- g. HFO-1234ze(E), HFC-152a, HFC-134, HFC-134a and HCO-40;
- h. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1243zf and HFC-161;
- i. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1243zf and HCO-1140;
- j. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1243zf and HCC-40;
- k. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1243zf and HFO-1234yf;
- l. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1234yf and HFC-134a;
- m. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1234yf and HFC-134;
- n. HFO-1234ze(E), HFC-152a, HFO-1243zf, HFC-245cb and HFO-1234yf;
- o. HFO-1234ze(E), HFC-152a, HFO-1243zf, HFC-134 and HFC-134a;
- p. HFO-1234ze(E), HFC-152a, HFO-1234yf, HFC-134 and HFC-134a;
- q. HFO-1234ze(E), HFC-152a, HFO-1243zf, HFC-245cb and HFC-134a;
- r. HFO-1234ze(E), HFC-152a, HFO-1243zf, HFC-245cb and HFC-134;
- s. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1243zf, HFO-1234yf and HFC-245cb;
- t. HFO-1234ze(E), HFC-152a, HFO-1234yf, HFC-245cb, HFC-134a and HFC-134; or
- u. HFO-1234ze(E), HFC-152a, HFO-1225zc, HFO-1234yf, HFC-134a and HFC-134.

48. The blowing agent composition of any of claims 44 to 47, further comprising less than 100 ppm wt water, preferably less than 20 ppm wt water, and more preferably less than 10 ppm wt water.
49. The blowing agent composition of any of claims 44 to 48, wherein a ratio of HFO-1234ze(E):HFC-152a is from about 40:60 to about 60:40, preferably about 50:50 ratio, more preferably about 45:55.
50. Use of the blowing agent composition of any of claims 44 to 49 for making polystyrene foam.