

TITLE OF THE INVENTION

LOW GWP COMPOSITIONS COMPRISING HFO-1132 AND USES THEREOF

FIELD

[0001] The present disclosure relates to compositions useful as refrigerants, and in particular, for refrigeration systems. The compositions of the present disclosure are useful in methods for producing cooling, and methods for replacing refrigerants and refrigeration systems, including low and medium temperature refrigeration and transport refrigeration systems.

BACKGROUND

[0002] The fluorocarbon industry has been working for the past few decades to find replacement refrigerants for the 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, 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 warmings another environmental concern in many of these applications particularly in light of the Kigali Amendment. 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).

[0003] This regulatory landscape is continuously evolving, taking into consideration properties beyond just ODP and GWP. More particularly, there is a need for refrigerant compositions that not only meet low ODP standards and have low global warming potentials, but that also provide superior performance in a variety of applications and which meet the standards of evolving regulations.

[0004] The instant invention solves certain problems associated with conventional refrigerants and provides refrigerant blends containing 1,1-difluoropropene, which meets the evolving regulatory landscape.

SUMMARY

[0005] In order to meet the rapidly changing regulatory environment, the present inventors have identified a fluoroolefin compound that provides performance relative to existing refrigerants that will allow its use going forward even in view of the standards of the evolving regulatory landscape.

[0006] Certain embodiments disclosed herein relate to a fluoroethylene composition comprising 1,2-difluoroethylene (also called HFO-1132, or R-1132). This compound is shown herein to have advantageous properties for its use in refrigerant applications.

[0007] In one embodiment, disclosed herein are compositions comprising comprising HFO-1132 and at least one compound selected from the group consisting of HFC-32, HFC-134, and HFO-1234zeE.

[0008] According to any of the foregoing embodiments, also disclosed herein are compositions comprising, consisting of, or consisting essentially of HFO-1132, wherein said composition is selected from the group consisting of:

HFO-1132E;

HFO-1132E and HFC-32;

HFO-1132E and HFC-134;

HFO-1132 and HFO-1234zeE;

HFO-1132E, HFC-32, and HFO-1234zeE;

HFO-1132E, HFC-32, and HFC-134;

HFO-1132E, HFC-134 and HFO-1234zeE;

HFO-1132E, HFC-32, HFO-1234zeE, and HFC-134

HFO-1132Z, HFC-32, and HFO-1234zeE;

HFO-1132E, HFO-1132Z, HFC-32, and HFO-1234zeE; and

HFO-1132E, HFO-1132Z, HFO-1234zeE, and HFC-134.

HFO-1234zeE, HFC-32, and HFO-1132Z;

HFO-1234zeE, HFC-32, HFO-1132E, and HFO-1132Z; or

HFC-1234zeE, HFO-1132E, HFO-1132Z, and HFC-134.\

[0009] In one embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 56 to about 99 weight percent of HFO-1132E and about 1 to about 44 weight percent HFC-32. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 78 to about 99 weight percent of HFO-1132E and about 1 to about 22 weight percent of HFC-32. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 56 to about 60 weight percent of HFO-1132E and about 40 to about 44 weight percent of HFC-32. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 56 weight percent HFO-1132E and about 44 weight percent HFC-32.

[0010] In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 74 to about 99 weight percent of HFO-1132E and about 1 to about 26 weight percent HFC-134. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 87 to about 99 weight percent of HFO-1132E and about 1 to about 13 weight percent of HFC-134. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 74 weight percent HFO-1132E and about 26 weight percent HFC-134.

[0011] In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 1 to about 99 weight percent of HFO-1132E and about 1 to about 99 weight percent HFO-1234zeE. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 42 to about 61 weight percent of HFO-1132E and about 39 to about 58 weight percent of HFO-1234zeE

[0012] In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 20 to 71 weight percent HFO-1132E, from about 1 to 22 weight percent HFC-32, from about 1 to 13 weight percent HFC-134, and from about 18 to 59 weight percent HFO-1234zeE; or from about 20 to 48 weight percent HFO-1132E, from about 1 to 22 weight percent HFC-32, from about 1

to 13 weight percent HFC-134, and from about 33 to 59 weight percent HFO-1234zeE.

[0013] In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 0.5 to about 98.5 weight percent of HFO-1132E, about 0.5 to about 98.5 weight percent of HFO-1234zeE, and about 0.5 to about 44 weight percent HFC-32. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 0.5 to about 98.5 weight percent of HFO-1132E, about 0.5 to about 98.5 weight percent of HFO-1234zeE, and about 1 to about 22 weight percent HFC-32. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 8 to about 60 weight percent of HFO-1132E, about 40 to about 70 weight percent of HFO-1234zeE, and about 0.5 to about 22 of HFC-32. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 50 weight percent HFO-1132E, about 43 weight percent HFO-1234zeE and about 7 weight percent HFC-32. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 8 weight percent HFO-1132E, about 70 weight percent HFO-1234zeE, and about 22 weight percent HFC-32. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 8 to about 42 weight percent HFO-1132E, about 46 to about 70 weight percent HFO-1234zeE and about 4 to about 22 weight percent HFC-32. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 32 weight percent HFO-1132E, about 49 weight percent HFO-1234zeE and about 19 weight percent HFC-32. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 8 weight percent HFO-1132E, about 70 weight percent HFO-1234zeE and about 22 weight percent HFC-32.

[0014] In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 0.5 to about 98.5 wt-% of R-1132E, about 0.5 to about 98.5 wt-% R-1234zeE, and about 0.5 to about 26 wt-% R-134. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 0.5 to about 98.5 wt-% of R-1132E, about 0.5 to about 98.5 wt-% R-1234zeE, and about 0.5 to about 13 wt-% R-134. In another

embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 40 to about 98.5 wt-% of R-1132E, about 0.5 to about 58 wt-% of R-1234zeE, and about 0.5 to about 13 of R-134. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 40 to about 47 wt-% R-1132E, about 40 to about 52 wt-% R-1234zeE, and about 7 to about 3 wt-% R-134. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 47 wt-% R-1132E, about 40 wt-% R-1234zeE and about 13 wt-% R-134. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 40 wt-% R-1132E, about 47 wt-% R-1234zeE and about 13 wt-% R-134. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 47 wt-% R-1132E, about 40 wt-% R-1234zeE and about 13 wt-% R-134.

[0015] In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of 0.25 to about 98.5 weight percent of HFO-1132E, 0.25 to about 98.5 weight percent of HFO-1234zeE, 0.25 to about 26 weight percent HFC-134, and 0.25 to about 44 weight percent HFC-32. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of 0.25 to about 98.5 weight percent of HFO-1132E, 0.25 to about 98.5 weight percent of HFO-1234zeE, 0.25 to about 13 weight percent HFC-134, and 0.25 to about 21 weight percent HFC-32. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 9 to about 61 weight percent of HFO-1132E, about 28 to about 70 weight percent of HFO-1234zeE, 0.25 to about 13 weight percent of HFC-134, and 0.25 to about 21 weight percent of HFC-32. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 32 weight percent HFO-1132E, about 48 weight percent HFO-1234zeE, about 1 weight percent HFC-134, and about 19 weight percent HFC-32. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 9 weight percent HFO-1132E, about 69.6 weight percent HFO-1132E, about 0.5 weight percent HFC-134, and about 20.9 weight percent HFC-32. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 9 to about 48 weight percent HFO-

1132E, about 36 to about 70 weight percent HFO-1234zeE, about 0.5 to about 13 weight percent HFC-134, and about 0.5 to about 21 weight percent HFC-32. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 32 weight percent HFO-1132E, about 48 weight percent HFO-1234zeE, about 1 weight percent HFC-134, and about 19 weight percent HFC-32. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 9 weight percent HFO-1132E, about 69.6 weight percent HFO-1132E, about 0.5 weight percent HFC-134, and about 20.9 weight percent HFC-32

[0016] In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of from about 1 to 97 weight percent HFO-1132E, from about 1 to 97 weight percent HFO-1132Z, from about 1 to 44 weight percent HFC-32, and from about 1 to 97 weight percent HFO-1234zeE; or from about 1 to 97 weight percent HFO-1132E, from about 1 to 97 weight percent HFO-1132Z, from about 1 to 22 weight percent HFC-32, and from about 1 to 97 weight percent HFO-1234zeE; or from about 8 to 62 weight percent HFO-1132E, from about 1 to 67 weight percent HFO-1132Z, from about 1 to 22 weight percent HFC-32, and from about 1 to 70 weight percent HFO-1234zeE; or from about 8 to 41 weight percent HFO-1132E, from about 1 to 40 weight percent HFO-1132Z, from about 3 to 22 weight percent HFC-32, and from about 29 to 70 weight percent HFO-1234zeE; or from about 18 to 74 weight percent HFO-1132E, from about 1 to 54 weight percent HFO-1132Z, from about 1 to 22 weight percent HFC-32, and from about 1 to 59 weight percent HFO-1234zeE; or from about 18 to 45 weight percent HFO-1132E, from about 1 to 28 weight percent HFO-1132Z, from about 8 to 22 weight percent HFC-32, and from about 29 to 59 weight percent HFO-1234zeE.

[0017] In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of:

about 28 weight percent HFO-1132E, about 21.5 weight percent HFC-32, and about 50.5 weight percent HFO-1234zeE; or

about 32 weight percent HFO-1132Z, about 21 weight percent HFC-32, and about 47 weight percent HFO-1234zeE; or

about 15 weight percent HFO-1132E, about 13 weight percent HFO-1132Z,
about 21 weight percent HFC-32, and about 51 weight percent HFO-1234zeE;

or

about 36 weight percent HFO-1132E, about 4 weight percent HFO-1132Z,
about 16 weight percent HFC-32, and about 44 weight percent HFO-1234zeE;

or

about 9 weight percent HFO-1132E, about 40 weight percent HFO-1132Z,
about 22 weight percent HFC-32, and about 29 weight percent HFO-1234zeE;

or

about 49 weight percent HFO-1132E, about 2 weight percent HFO-1132Z,
about 7 weight percent HFC-32, and about 42 weight percent HFO-1234zeE; or

about 30 weight percent HFO-1132E, about 12 weight percent HFC-32, about 6
weight percent HFC-134, and about 52 weight percent HFO-1234zeE; or

about 30 weight percent HFO-1132E, about 40 weight percent HFO-1132Z,
about 22 weight percent HFC-32, and about 29 weight percent HFO-1234zeE;

or

about 21.5 weight percent HFO-1132E, about 65 weight percent HFO-1132Z,
about 13 weight percent HFC-32, and about 0.5 weight percent HFO-1234zeE.

[0018] According to any of the foregoing embodiments, also disclosed herein are compositions further comprising at least one additional compound selected from methane, ethane, HCFC-22, HFC-23, HCC-30, HCFC-31, HCC-40, HFC-41, HFCF-22, HFO-1141, HFO-1225yeE, HFO-1225yeZ, HFO-1234yf, HFO-1243zf, HFC-161, HFC-152, HFC-143, HFC-143a, HFC-134a, HCFO-1122, HCFO-1122aE, HCFO-1122aZ, HCC-150, HCFC-151, CFO-1112E, CFO-1112Z, HCFC-142a, HCFC-132, HCFC-133, HCFC-133b, HCFC-123, HFC-236fa, HFC-245fa, HFC-245eb, HFO-1123, HFO-1132a, HCFO-1131E, HCFO-1131Z, ethylene, and acetylene.

[0019] According to any of the foregoing embodiments, also disclosed herein are compositions wherein said composition further comprises from 0.1 to 200 ppm by weight of water; from about 10 ppm by volume to about 0.35 volume percent oxygen; and/or from about 100 ppm by volume to about 1.5 volume percent air or NAG.

[0020] According to any of the foregoing embodiments, also disclosed herein are compositions wherein said composition comprises a stabilizer.

[0021] According to any of the foregoing embodiments, also disclosed herein are compositions wherein the stabilizer is selected from the group consisting of nitromethane, ascorbic acid, terephthalic acid, azoles, phenolic compounds, cyclic monoterpenes, terpenes, phosphites, phosphates, phosphonates, thiols, and lactones.

[0022] According to any of the foregoing embodiments, also disclosed herein are compositions wherein the stabilizer is selected from tolutriazole, benzotriazole, tocopherol, hydroquinone, t-butyl hydroquinone, 2,6-di-terbutyl-4-methylphenol, fluorinated epoxides, n-butyl glycidyl ether, hexanediol diglycidyl ether, allyl glycidyl ether, butylphenylglycidyl ether, d-limonene, α -terpinene, β -terpinene, α -pinene, β -pinene, or butylated hydroxytoluene.

[0023] According to any of the foregoing embodiments, also disclosed herein are compositions wherein the stabilizer is present in an amount from about 0.001 to 1.0 weight percent based on the weight of the refrigerant.

[0024] According to any of the foregoing embodiments, also disclosed herein are compositions wherein the composition further comprises a lubricant.

[0025] According to any of the foregoing embodiments, also disclosed herein are compositions wherein said lubricant is at least one selected from the group consisting of polyalkylene glycol, polyol ester, poly- α -olefin, and polyvinyl ether.

[0026] According to any of the foregoing embodiments, also disclosed herein are compositions wherein said lubricant is a polyol ester or a polyvinyl ether.

[0027] According to any of the foregoing embodiments, also disclosed herein are compositions wherein said lubricant has at least one property selected from the group consisting of volume resistivity of greater than 10^{10} Ω -m at 20 °C; surface tension of from about 0.02 N/m to 0.04 N/m at 20 °C; kinematic viscosity of from about 20 cSt to about 500 cSt at 40 °C; a breakdown voltage of at least 25 kV; and a hydroxy value of at most 0.1 mg KOH/g.

[0028] According to any of the foregoing embodiments, also disclosed herein are compositions wherein the composition comprises at least one tracer.

[0029] According to any of the foregoing embodiments, also disclosed herein are compositions wherein said tracer is present in an amount from about 1.0 ppm by weight to about 1000 ppm by weight.

[0030] According to any of the foregoing embodiments, also disclosed herein are compositions wherein said at least one tracer is selected from the group consisting of hydrofluorocarbons, hydrofluoroolefins, hydrochlorocarbons, hydrochloroolefins, hydrochlorofluorocarbons, hydrochlorofluoroolefins, hydrochlorocarbons, hydrochloroolefins, chlorofluorocarbons, chlorofluoroolefins, hydrocarbons, perfluorocarbons, perfluoroolefins, and combinations thereof.

[0031] According to any of the foregoing embodiments, also disclosed herein are compositions wherein said at least one tracer is selected from the group consisting of HFC-23, HCFC-31, HFC-41, HFC-161, HFC-143a, HFC-134a, HFC-125, HFC-236fa, HFC-236ea, HFC-245cb, HFC-245fa, HFC-254eb, HFC-263fb, HFC-272ca, HFC-281ea, HFC-281fa, HFC-329p, HFC-329mmz, HFC338mf, HFC-338pcc, CFC-12, CFC-11, CFC-114, CFC-114a, HCFC-22, HCFC-123, HCFC-124, HCFC-124a, HCFC-141b, HCFC-142b, HCFC-151a, HCFC-244bb, HCC-40, HFO-1141, HCFO-1130, HCFO-1130a, HCFO-1131, HCFO-1122, HFO-1123, HFO-1234yf, HFO-1234ye, HFO-1243zf, HFO-1225ye, HFO-1225zc, PFC-116, PFC-C216, PFC-218, PFC-C318, PFC-1216, PFC-31-10mc, PFC-31-10my, and combinations thereof.

[0032] 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, and wherein degradation products of the composition are free of or substantially free of Group A Fluorinated Substances.

[0033] In another embodiment, also disclosed herein are methods for cooling comprising evaporating a composition of any of the foregoing embodiments in the vicinity of a body to be cooled and thereafter condensing said composition, wherein said cooling is provided by a refrigeration system.

[0034] In another embodiment, also disclosed herein are refrigeration systems comprising a composition of any of the foregoing embodiments.

[0035] In another embodiment, also disclosed herein are refrigeration systems comprising a composition of any of the foregoing embodiments, for use in high ambient applications, wherein outdoor temperatures are above about 35°C.

[0036] According to any of the foregoing embodiments, also disclosed herein are refrigeration systems comprising an evaporator, compressor, condenser, and expansion device, each operably connected to perform a vapor compression cycle.

[0037] According to any of the foregoing embodiments, also disclosed herein are refrigeration systems, wherein said refrigeration system is for residential, light commercial, or industrial refrigeration. In another embodiment, are refrigeration systems containing the compositions of any of the foregoing embodiments, wherein said system is for medium temperature refrigeration, low temperature refrigeration, or transport refrigeration.

[0038] According to any of the foregoing embodiments, also disclosed herein are methods of replacing R-454C in refrigeration systems comprising providing the composition of any of the foregoing embodiments to the system in place of R-454C.

[0039] According to any of the foregoing embodiments, also disclosed herein is the use of the compositions of any of the foregoing embodiments as refrigerant in low temperature refrigeration systems, medium temperature refrigeration systems, and/or transport refrigeration systems.

DETAILED DESCRIPTION

[0040] This invention relates to compositions comprising, consisting of, or consisting essentially of 1,2-difluoroethylene (HFO-1132), and at least one compound selected from the group difluoromethane (HFC-32), 1,1,2,2-tetrafluoroethane (R-134), and E-1,3,3,3-tetrafluoropropene (HFO-1234zeE). The compositions may potentially be candidates to replace refrigerants such as R-454C, R-404A, or R-449A with low Global Warming Potential (GWP), improved environmental fate characteristics, and improved energy efficiency (COP).

[0041] The compositions comprise, consist of, or consist essentially of HFO-1132 and at least one compound selected from the group consisting of HFC-32, HFC-134, and HFO-1234zeE. These blends provide refrigerant blends with low global

warming potential, improved glide as compared to other suggested refrigerant blends, and improved coefficient of performance as compared to existing refrigerants and other proposed replacements.

[0042] 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.

[0043] 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.

[0044] 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 (including heat pumps for cabin comfort cooling and heating in automobiles), mobile air conditioning units (for cooling of passenger compartments in automobiles), dehumidifiers, and combinations thereof. The focus of the present application is refrigeration systems, including low temperature refrigeration systems and medium temperature refrigeration systems.

[0045] 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.

[0046] 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).

[0047] 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).

[0048] 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).

[0049] 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 2 components.

[0050] The net refrigeration effect is the quantity of heat that each kilogram of refrigerant absorbs in the evaporator to produce useful cooling.

[0051] 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.

[0052] 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.

[0053] 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 United Nations Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4). The GWP of HFO-1132 (either E-, or Z- isomers or mixtures thereof) is estimated at 1.

[0054] 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. Hydrofluorocarbons (HFCs) and the hydrofluoro-olefins (HFO's) described herein have zero ODP because they do not contain chlorine, bromine or iodine, species known to contribute to ozone breakdown and depletion. HFO-1132 (either E-, or Z- isomers or mixtures thereof) has zero ozone depletion potential.

[0055] 1,2-difluoroethylene (HFO-1132) exists as two possible isomers, HFO-1132E and HFO-1132Z. As used herein HFO-1132 refers to either isomer individually, or a mixture of isomers. HFO-1132 may be prepared by dehydrochlorination of 1-chloro-1,2-difluoroethane (HCFC-142a) in either the gas phase or liquid phase as described in U.S. Patent Publication 2022-0017438A. The

reaction will produce both the E- and Z- isomers of the compound, but they are separable by distillation.

[0056] E-1,3,3,3-Tetrafluoropropene (HFO-1234zeE or HFO-1234zeE) is available commercially from Honeywell (Charlotte, North Carolina, USA). Difluoromethane (HFC-32 or R-32) and 1,1,2,2-tetrafluoroethane (HFC-134 or R-134) are available commercially from various sources worldwide.

[0057] 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.

[0058] 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.

[0059] 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.

[0060] 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.

[0061] 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.

REFRIGERANT COMPOSITIONS

[0062] In one embodiment, compositions comprise, consist of, or consist essentially of HFO-1132 and at least one selected from the group consisting of HFC-32, HFC-134, and HFO-1234zeE. These compositions provide low Global Warming Potential (GWP), improved environmental fate characteristics, and improved energy efficiency (COP) as compared to incumbent refrigerants.

[0063] In another embodiment, the compositions comprise, consist of, or consist essentially of about 56 to about 99 weight percent of HFO-1132E and about 1 to about 44 weight percent HFC-32. In another embodiment, the compositions comprise, consist of, or consist essentially of about 78 to about 99 weight percent of HFO-1132E and about 1 to about 22 weight percent of HFC-32. In another embodiment, the compositions comprise, consist of, or consist essentially of about 56 to about 60 weight percent of HFO-1132E and about 40 to about 44 weight percent of HFC-32. In another embodiment, the compositions comprise, consist of, or consist essentially of about 56 weight percent HFO-1132E and about 44 weight percent HFC-32.

[0064] In another embodiment, the compositions comprise, consist of, or consist essentially of about 74 to about 99 weight percent of HFO-1132E and about 1 to

about 26 weight percent HFC-134. In another embodiment, the compositions comprise, consist of, or consist essentially of about 87 to about 99 weight percent of HFO-1132E and about 1 to about 13 weight percent of HFC-134. In another embodiment, the compositions comprise, consist of, or consist essentially of about 74 weight percent HFO-1132E and about 26 weight percent HFC-134.

[0065] In another embodiment, the compositions comprise, consist of, or consist essentially of about 1 to about 99 weight percent of HFO-1132E and about 1 to about 99 weight percent HFO-1234zeE. In another embodiment, the compositions comprise, consist of, or consist essentially of about 42 to about 61 weight percent of HFO-1132E and about 39 to about 58 weight percent of HFO-1234zeE.

[0066] In another embodiment, the compositions comprise, consist of, or consist essentially of about 57 to about 98.5 weight percent of HFO-1132E, about 0.5 to about 26 weight percent HFC-134, and about 0.5 to about 43 weight percent HFC-32. In another embodiment, the compositions comprise, consist of, or consist essentially of about 79 to about 98.5 weight percent of HFO-1132E, about 0.5 to about 13 weight percent HFC-134, and about 0.5 to about 21 weight percent HFC-32. In another embodiment, the compositions comprise, consist of, or consist essentially of about 73 weight percent HFO-1132E, about 26 weight percent HFC-134 and about 1 weight percent HFC-32. In another embodiment, the compositions comprise, consist of, or consist essentially of about 86.6 weight percent HFO-1132E, about 12.9 weight percent HFC-134 and about 0.5 weight percent HFC-32, In another embodiment, the compositions comprise, consist of, or consist essentially of about 56.7 weight percent HFO-1132E, about 0.5 weight percent HFC-134 and about 42.8 weight percent HFC-32. In another embodiment, the compositions comprise, consist of, or consist essentially of about 78.6 weight percent HFO-1132E, about 0.5 weight percent HFC-134 and about 20.9 weight percent HFC-32.

[0067] In another embodiment, the compositions comprise, consist of, or consist essentially of about 18 to 70 weight percent HFO-1132E, about 1 to 22 weight percent HFC-32, and from about 30 to 60 weight percent HFO-1234zeE. In another embodiment, the compositions comprise, consist of, or consist essentially of from about 18 to 46 weight percent HFO-1132E, from about 8 to 22 weight percent HFC-32, and from about 37 to 60 weight percent HFO-1234zeE. In another embodiment,

the compositions comprise, consist of, or consist essentially of from about 28 to 30 weight percent HFO-1132E, from about 20 to 24 weight percent HFC-32, and from about 48 to 51 weight percent HFO-1234zeE.

[0068] In another embodiment, the compositions comprise, consist of, or consist essentially of 0.25 to about 98.5 weight percent of HFO-1132E, 0.25 to about 98.5 weight percent of HFO-1234zeE, 0.25 to about 26 weight percent HFC-134, and 0.25 to about 44 weight percent HFC-32. In another embodiment, the compositions comprise, consist of, or consist essentially of 0.25 to about 98.5 weight percent of HFO-1132E, 0.25 to about 98.5 weight percent of HFO-1234zeE, 0.25 to about 13 weight percent HFC-134, and 0.25 to about 21 weight percent HFC-32. In another embodiment, the compositions comprise, consist of, or consist essentially of about 9 to about 61 weight percent of HFO-1132E, about 28 to about 70 weight percent of HFO-1234zeE, 0.25 to about 13 weight percent of HFC-134, and 0.25 to about 21 weight percent of HFC-32. In another embodiment, the compositions comprise, consist of, or consist essentially of about 32 weight percent HFO-1132E, about 48 weight percent HFO-1234zeE, about 1 weight percent HFC-134, and about 19 weight percent HFC-32. In another embodiment, the compositions comprise, consist of, or consist essentially of about 9 weight percent HFO-1132E, about 69.6 weight percent HFO-1132E, about 0.5 weight percent HFC-134, and about 20.9 weight percent HFC-32. In another embodiment, the compositions comprise, consist of, or consist essentially of about 9 to about 48 weight percent HFO-1132E, about 36 to about 70 weight percent HFO-1234zeE, about 0.5 to about 13 weight percent HFC-134, and about 0.5 to about 21 weight percent HFC-32. In another embodiment, the compositions comprise, consist of, or consist essentially of about 32 weight percent HFO-1132E, about 48 weight percent HFO-1234zeE, about 1 weight percent HFC-134, and about 19 weight percent HFC-32. In another embodiment, the compositions comprise, consist of, or consist essentially of about 9 weight percent HFO-1132E, about 69.6 weight percent HFO-1132E, about 0.5 weight percent HFC-134, and about 20.9 weight percent HFC-32.

[0069] In another embodiment, the compositions comprise, consist of, or consist essentially of from about 1 to 97 weight percent HFO-1132E, from about 1 to 97 weight percent HFO-1132Z, from about 1 to 44 weight percent HFC-32, and from about 1 to 97 weight percent HFO-1234zeE, In another embodiment, the

compositions comprise, consist of, or consist essentially of from about 1 to 97 weight percent HFO-1132E, from about 1 to 97 weight percent HFO-1132Z, from about 1 to 22 weight percent HFC-32, and from about 1 to 97 weight percent HFO-1234zeE; or from about 8 to 62 weight percent HFO-1132E, from about 1 to 67 weight percent HFO-1132Z, from about 1 to 22 weight percent HFC-32, and from about 1 to 70 weight percent HFO-1234zeE. In another embodiment, the compositions comprise, consist of, or consist essentially of from about 8 to 41 weight percent HFO-1132E, from about 1 to 40 weight percent HFO-1132Z, from about 3 to 22 weight percent HFC-32, and from about 29 to 70 weight percent HFO-1234zeE. In another embodiment, the compositions comprise, consist of, or consist essentially of from about 18 to 74 weight percent HFO-1132E, from about 1 to 54 weight percent HFO-1132Z, from about 1 to 22 weight percent HFC-32, and from about 1 to 59 weight percent HFO-1234zeE. In another embodiment, the compositions comprise, consist of, or consist essentially of from about 18 to 45 weight percent HFO-1132E, from about 1 to 28 weight percent HFO-1132Z, from about 8 to 22 weight percent HFC-32, and from about 29 to 59 weight percent HFO-1234zeE.

[0070] In another embodiment, the compositions comprise at least one of:

about 28 weight percent HFO-1132E, about 21.5 weight percent HFC-32, and about 50.5 weight percent HFO-1234zeE; or

about 32 weight percent HFO-1132Z, about 21 weight percent HFC-32, and about 47 weight percent HFO-1234zeE; or

about 15 weight percent HFO-1132E, about 13 weight percent HFO-1132Z, about 21 weight percent HFC-32, and about 51 weight percent HFO-1234zeE; or

about 36 weight percent HFO-1132E, about 4 weight percent HFO-1132Z, about 16 weight percent HFC-32, and about 44 weight percent HFO-1234zeE; or

about 9 weight percent HFO-1132E, about 40 weight percent HFO-1132Z, about 22 weight percent HFC-32, and about 29 weight percent HFO-1234zeE; or

about 49 weight percent HFO-1132E, about 2 weight percent HFO-1132Z,
about 7 weight percent HFC-32, and about 42 weight percent HFO-1234zeE; or
about 30 weight percent HFO-1132E, about 12 weight percent HFC-32, about 6
weight percent HFC-134, and about 52 weight percent HFO-1234zeE; or
about 30 weight percent HFO-1132E, about 40 weight percent HFO-1132Z,
about 22 weight percent HFC-32, and about 29 weight percent HFO-1234zeE;
or
about 21.5 weight percent HFO-1132E, about 65 weight percent HFO-1132Z,
about 13 weight percent HFC-32, and about 0.5 weight percent HFO-1234zeE.

[0071] 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 or working fluids, 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.

[0072] 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.

[0073] 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).

[0074] 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).

[0075] 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.

[0076] In an embodiment, the above-disclosed compositions may further comprise at least one additional compound selected from the group consisting of methane, ethane, HCFC-22 (dichlorodifluoromethane), HFC-23 (trifluoromethane), HCC-30 (dichloromethane), HCFC-31 (chlorofluoromethane), HCC-40 (chloromethane), HFC-41 (fluoromethane), HFO-1141 (fluoroethylene), HFO-1225yeE (E-1,2,3,3,3-pentafluoropropene), HFO-1225yeZ (Z-1,2,3,3,3-pentafluoropropene), HFO-1234yf (2,3,3,3-tetrafluoropropene), HFO-1243zf (3,3,3-trifluoropropene), HFC-161 (fluoroethane), HFC-152 (1,2-difluoroethane), HFC-143 (1,1,2-trifluoroethane), HFC-143a (1,1,1-trifluoroethane), HCFO-1122 (2-chloro-1,1-difluoroethene), HCFO-1122aE (E-1-chloro-1,2-difluoroethylene), HCFO-1122aZ (Z-1-chloro-1,2-difluoroethylene), HCC-150 (1,2-dichloroethane), HCFC-151 (1-chloro-2-fluoroethane), CFO-1112E (E-1,2-dichloro-1,2-difluoroethylene), CFO-1112Z (Z-1,2-dichloro-1,2-difluoroethylene), HCFC-142a (1-chloro-1,2-difluoroethane), HCFC-132 (1,2-dichloro-1,2-difluoroethane), HCFC-133 (1-chloro-1,1,2-trifluoroethane), HCFC-133b (2-chloro-1,1,1-trifluoroethane), HCFC-123 (1,1-dichloro-2,2,2-trifluoroethane), HFC-236fa (1,1,1,3,3,3-hexafluoropropane), HFC-245fa (1,1,1,3,3-pentafluoropropane), HFC-245eb (1,1,1,2,3-pentafluoropropane), HFO-1123 (trifluoroethylene), HFO-1132a (1,1-difluoroethylene), HCFO-1131E (E-1-chloro-2-fluoroethylene), HCFO-1131Z (Z-1-chloro-2-fluoroethylene), ethylene, and acetylene..

[0077] In another embodiment, the above-disclosed compositions may further comprise at least one additional compound selected from HCFC-22, HCC-40, HFO-1234yf, HFO-1243zf, HFO-1132a, and HFO-1252ye. In another embodiment, the above-disclosed compositions may further comprise at least one additional compound selected from HCFC-22, HCC-40, HFO-1234yf, HFO-1243zf, HFO-1132a, and HFO-1252ye. In another embodiment, the above-disclosed

compositions may further comprise at least one additional compound comprising HFO-1234yf. In another embodiment, the above-disclosed compositions may further comprise at least one additional compound comprising HFO-1234yf. In another embodiment, the above-disclosed compositions may further comprise at least one additional compound comprising HFO-1243zf. In another embodiment, the above-disclosed compositions may further comprise at least one additional compound comprising HCFC-142a. In another embodiment, the compositions comprising, consisting of, or consisting essentially of HFO-1132 and at least one compound selected from the group consisting of HFC-32, HFC-134, and HFO-1234zeE may further comprise at least one additional compound comprising HCFC-22 or HCC-40.

[0078] The amount of additional compounds present in any of the foregoing refrigerant compositions can be greater than 0 ppm and less than 5,000 ppm and, in particular, can range from greater than zero to about 1,000 ppm, about 5 to about 500 ppm and about 1 to about 100 ppm.

[0079] In one embodiment, the amount of additional compounds present in any of the foregoing refrigerant compositions can be greater than 0 and less than 1 wt% of the refrigerant composition, preferably less than 0.5 weight percent, or more preferably less than 0.1 weight percent.

[0080] The above-disclosed compositions will perform more consistently and be more stable with only minor amounts of water present. Thus, the 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.

[0081] Additionally, the above-disclosed compositions will perform more consistently and be more stable with only minor amounts of oxygen or air present. Therefore, the above-disclosed 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.

[0082] In another embodiment, the above-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 tolutriazole 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.

[0083] If the composition does include a stabilizer, it may include any amount from 0.001 wt% up to 1 wt%, preferably from about 0.001 to about 0.5 weight percent, more preferably, from about 0.001 to about 0.3 weight percent of any of the stabilizers listed above.

[0084] In another embodiment, the above-disclosed compositions may contain a tracer compound or tracers. The tracer may comprise two or more tracer compounds. In some embodiments, the tracer is present in the compositions at a total concentration of about 50 parts per million by weight (ppm) to about 1000 ppm, based on the weight of the total composition. In other embodiments, the tracer is present at a total concentration of about 50 ppm to about 500 ppm. Alternatively, the tracer is present at a total concentration of about 100 ppm to about 300 ppm.

[0085] The tracer may be present in predetermined quantities to allow detection of any dilution, contamination or other alteration of the composition. The presence of certain compounds in the composition may indicate by what method or process one of the components has been produced. The tracer may also be added to the composition in a specified amount in order to identify the source of the composition. In this manner, detection of infringement on patent rights may be accomplished. The

tracers may be refrigerant compounds but are present in the composition at levels that are unlikely to impact performance of the refrigerant component of the composition.

[0086] Tracer compounds may be hydrofluorocarbons, hydrofluoroolefins, hydrochlorocarbons, hydrochloroolefins, hydrochlorofluorocarbons, hydrochlorofluoroolefins, hydrochlorocarbons, hydrochloroolefins, chlorofluorocarbons, chlorofluoroolefins, hydrocarbons, perfluorocarbons, perfluoroolefins, and combinations thereof. Examples of tracer compounds include, but are not limited to HFC-23 (trifluoromethane), HCFC-31 (chlorofluoromethane), HFC-41 (fluoromethane), HFC-161 (fluoroethane), HFC-143a (1,1,1-trifluoroethane), HFC-134a (1,1,1,2-tetrafluoroethane), HFC-125 (pentafluoroethane), HFC-236fa (1,1,1,3,3,3-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-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 (1,1,1-trifluoro-2-methylpropane), 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 (1,1,-dichloro-1,2,2,2-tetrafluoroethane), HCFC-22 (chlorodifluoromethane), HCFC-123 (1,1-dichloro-2,2,2-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 (fluoroethene), HCFO-1130 (1,2-dichloroethene), HCFO-1130a (1,1-dichloroethene), HCFO-1131 (1-chloro-2-fluoroethene), HCFO-1122 (2-chloro-1,1-difluoroethene), HFO-1123 (1,1,2-trifluoroethene), HFO-1234ye (1,2,3,3-tetrafluoropropene), HFO-1243zf (3,3,3-trifluoropropene), HFO-1225ye (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 (hexafluoroethane), PFC-31-10mc

(1,1,1,2,2,3,3,4,4,4-decafluorobutane), PFC-31-10my (1,1,1,2,3,3,3-heptafluoro-2-trifluoromethylpropane), and combinations thereof.

[0087] In another embodiment, the above-disclosed compositions further comprise at least one lubricant. Lubricants may be selected from polyol ester (POE), polyvinyl ether (PVE), poly- α -olefin (PAO), and polyalkylene glycol (PAG). In another embodiment, the above-disclosed compositions further comprise at least one lubricant selected from polyol ester (POE) or polyvinyl ether (PVE).

[0088] 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.

[0089] 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.

[0090] In another embodiment, the above-disclosed compositions are combined with a PAG lubricant or a PVE lubricant or a POE lubricant for usage in a low temperature or medium temperature refrigeration system.

[0091] When the above-disclosed compositions include 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.

[0092] In another embodiment, the above-disclosed compositions are used to introduce lubricant into the air-conditioning or heat pump 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.

[0093] 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.

[0094] 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.

[0095] 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.

[0096] 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.

[0097] 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).

[0098] 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.

[0099] 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.

[0100] 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, CF₃I, and/or Krytox[®] lubricants, also incorporated by reference and described in patent application "Refrigerant compositions comprising fluoroolefins and uses thereof WO2009018117A1."

[0101] In one embodiment, as used herein, "Group A Fluorinated Substances" includes any substance that (i) contains at least one fully fluorinated methyl (–CF₃) or methylene (–CF₂–) 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).

[0102] 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 (–CF₃) or methylene (–CF₂–) 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.

[0103] Thus, according to some embodiments, the above-disclosed compositions 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 wt.% and ≤ 5 wt.%, or > 0 wt.% and ≤ 4 wt.%, or > 0 wt.% and ≤ 3 wt.%, or > 0 wt.% and ≤ 2 wt.%, or > 0 wt.% and ≤ 1 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.

[0104] Further, in some embodiments, degradation products of above-disclosed compositions 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.

[0105] The above-disclosed compositions 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 another

embodiment, any of the foregoing refrigerant compositions can be prepared by blending HFO-1132 and at least one compound selected from the group consisting of HFC-32, HFC-134, and HFO-1234zeE, and, in some cases, at least one of the additional compounds.

[0106] In a further embodiment, the above-disclosed 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 AND SYSTEMS

[0107] The above-disclosed compositions are useful in numerous methods and systems that provide refrigeration and freezing.

[0108] In one embodiment, provided is a method of cooling comprising evaporating one of the above-disclosed compositions in the vicinity of a body to be cooled and thereafter condensing said composition. In another embodiment, the cooling is provided by a refrigeration system.

[0109] 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. The refrigeration system may be for providing low temperature refrigeration, medium temperature refrigeration, and/or transport refrigeration. Low and medium temperature refrigeration systems include 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. Additionally, the refrigeration system may be a cascade refrigeration system that allows the temperature to be stepped down to lower values in a cascade fashion.

[0110] In another embodiment, is provided a refrigeration system comprising one of the above-disclosed compositions. In another embodiment, the above-disclosed compositions comprised within the refrigeration system further includes a lubricant. The refrigeration system comprises an evaporator, compressor, condenser, and expansion device, each operably connected to perform a vapor compression cycle.

[0111] In another embodiment, the refrigeration system is a secondary loop system.

[0112] It has been found that the above-disclosed compositions will have some temperature glide in the heat exchangers. Thus, the systems will operate more efficiently if the heat exchangers are operated in counter-current mode or cross-current mode with counter-current tendency. Counter-current tendency means that the closer the heat exchanger can get to counter-current mode the more efficient the heat transfer. Thus, refrigeration heat exchangers, in particular, evaporators, are designed to provide some aspect of counter-current tendency. Therefore, provided herein is a low or medium temperature refrigeration system wherein said system includes one or more heat exchangers (either evaporators, condensers, or both) that operate in counter-current mode or cross-current mode with counter-current tendency. Additionally, the above-disclosed compositions can be used in systems with heat exchangers operating in cross-current mode.

[0113] In another embodiment, provided herein is a refrigeration system containing one of the above-disclosed compositions, wherein said system includes one or more heat exchangers (either evaporators, condensers, or both) that operate in counter-current mode, cross-current mode, or cross-current mode with counter-current tendency.

[0114] In one embodiment, a method is provided for replacing R-454C in refrigeration systems comprising providing one of the above-disclosed compositions to the system in place of R-454C.

[0115] In one embodiment, the above-disclosed compositions are useful as refrigerant in low temperature refrigeration systems, medium temperature refrigeration systems, cascade refrigeration systems, and/or transport refrigeration systems. In another embodiment, the above-disclosed compositions are useful as refrigerant in any of the refrigeration systems described herein above.

EXAMPLES

Examples for commercial refrigeration

[0116] In the examples to follow, the conditions for medium temperature refrigeration are -7 °C and 40 °C as the average evaporator and condenser temperatures, 18 °C as the return temperature and 0 K of subcooling.

Example 1: HFO-1132Z, HFO-1132E, HFO-1234zeE and HFC-32

[0117] Broadly, a composition range of 1 to 97 wt-% of HFO-1132Z, 1 to 97 wt-% of HFO-1132E, 1 to 97 wt-% HFO-1234zeE, and 1 to 44 wt-% HFC-32 will have a GWP less than 300, a maximum average glide of about 10 K, a cooling capacity range that is 51% less to 65% greater than the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range is 4% less and 6% greater than the cooling capacity of R-454C evaluated with the same conditions set.

Similarly, a composition range of 1 to 97 wt-% of HFO-1132Z, 1 to 97 wt-% of HFO-1132E, 1 to 97 wt-% HFO-1234zeE, and 1 to 22 wt-% HFC-32 will have a GWP less than 150, a maximum average glide of about 10 K, a cooling capacity range that is 49% less and 59% greater than the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range is 4% less and 6% greater than the cooling capacity of R-454C evaluated with the same conditions set. Table X3 lists example compositions within the GWP<300 range that have ASHRAE flammability classifications of 2L or 2.

[0118] Preferred blend composition ranges for medium temperature refrigeration within a composition range of 1 to 67 wt-% of HFO-1132Z, 8 to 62 wt-% of HFO-1132E, 1 to 70 wt-% of HFO-1234zeE, and 1 to 22 of HFC-32 will have a GWP < 150, a maximum heat exchanger glide of 11 K (in the condenser), an ASHRAE flammability classification of 2L or 2, and a cooling capacity range of 10 less than to 10% greater than that of R-454C evaluated at the same conditions set. The optimal composition for cooling capacity in this range is at 2 wt-% HFO-1132Z, 49 wt-% HFO-1132E, 42 wt-% HFO-1234zeE, and 7 wt-% HFC-32, where the COP is about the same as that for R-454C under the same conditions, the GWP is 3 and the average glide is 8 K, and the ASHRAE flammability classification is 2. The optimal composition for cooling COP in this range is at 65 wt-% HFO-1132Z, 21.5 wt-%

HFO-1132E, 0.5 wt-% HFO-1234zeE, and 13 wt-% HFC-32, where the cooling capacity is 10% less than that for R-454C under the same conditions, the GWP is 89 and the average glide is 7 K, and the ASHRAE flammability classification is 2.

[0119] Even more preferred composition ranges for cooling mode that result in ASHRAE flammability classifications of 2L are 1 to 40 wt-% HFO-1132Z, 8 to 41 wt-% HFO-1132E, 29 to 70 wt-% HFO-1234zeE, and 3 to 22 wt-% HFC-32, where the minimum and maximum cooling capacities are 10% less and 10% greater than those of R-454C respectively at the same cycle conditions. The composition for this maximum cooling capacity for a 2L blend is 4 wt-% HFO-1132Z, 36 wt-% HFO-1132E, 44 wt-% HFO-1234zeE and 16 wt-% HFC-32, where the COP for cooling is about the same as that for R-454C under the same cycle conditions. The composition for this maximum cooling efficiency, which is 5% greater than that for R-454C at the same cycle conditions, for a 2L blend is 40 wt-% HFO-1132Z, 9 wt-% HFO-1132E, 29 wt-% HFO-1234zeE and 22 wt-% HFC-32, where the cooling capacity is 10% less than that for R-454C under the same cycle conditions.

Table X1: Medium Temperature Refrigeration conditions, cycle metric performance and fluid property ranges for HFO-1132Z/HFO-1132E/HFO-1234zeE/HFC-32 in Example 1.

wt-frac R1132(Z)	wt-frac R1132(E)	wt-frac R1234ze (E)	wt-frac HFC-32	GWP AR5	ASHRAE flammab ility class	Glide (K)	CAP_c (relative to R- 454C)	COP_c (relative to R- 454C)
0.02	0.77	0.05	0.16	108.4	2	1.97	0.97	1.53
0.04	0.59	0.23	0.14	95.1	2	6.03	0.99	1.30
0.06	0.28	0.50	0.16	108.9	2L	9.23	1.02	1.02
0.08	0.42	0.26	0.24	162.9	2L	6.98	1.00	1.26
0.10	0.36	0.12	0.42	284.6	2L	4.69	0.98	1.42
0.13	0.41	0.41	0.05	34.5	2	8.13	1.02	0.99
0.15	0.29	0.20	0.36	244.1	2L	6.71	1.00	1.27
0.18	0.29	0.50	0.03	21.1	2	7.43	1.04	0.84
0.21	0.42	0.18	0.19	129.1	2	7.43	1.01	1.18
0.24	0.11	0.65	0.01	4.4	2L	3.80	1.06	0.65
0.27	0.03	0.70	0.01	4.5	2L	1.57	1.07	0.58
0.30	0.56	0.13	0.01	7.4	2	6.69	1.03	1.06

wt-frac R1132(Z)	wt-frac R1132(E)	wt-frac R1234ze (E)	wt-frac HFC-32	GWP AR5	ASHRAE flammab ility class	Glide (K)	CAP_c (relative to R- 454C)	COP_c (relative to R- 454C)
0.33	0.01	0.63	0.03	21.4	2L	2.20	1.07	0.61
0.37	0.28	0.23	0.12	82.0	2	7.60	1.04	0.95
0.41	0.34	0.21	0.04	27.9	2	6.80	1.04	0.90
0.45	0.07	0.14	0.34	231.0	2L	7.48	1.04	1.01
0.51	0.30	0.03	0.16	109.1	2	7.35	1.04	1.00
0.57	0.07	0.23	0.13	89.1	2	5.52	1.06	0.79
0.66	0.15	0.17	0.02	14.7	2	3.90	1.07	0.74

Example 2: HFO-1132E, HFO-1234zeE, HFC-134 and HFC-32

[0120] Broadly, a composition range of 0.25 to 98.5 wt-% of HFO-1132E, 0.25 to 98.5 wt-% of HFO-1234zeE, 0.25 to 26 wt-% HFC-134, and 0.25 to 44 wt-% HFC-32 will have a GWP less than 300, a maximum average glide of about 10 K, a cooling capacity range that is 50% less to 69% greater than the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range is 4% less and 6% greater than the cooling capacity of R-454C evaluated with the same conditions set. Similarly, a composition range of 0.25 to 98.5 wt-% of HFO-1132E, 0.25 to 98.5 wt-% of HFO-1234zeE, 0.25 to 13 wt-% HFC-134, and 0.25 to 21 wt-% HFC-32 will have a GWP less than 150, a maximum average glide of about 9.9 K, a cooling capacity range that is 50% less and 64% greater than the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range is 4% less and 6% greater than the cooling capacity of R-454C evaluated with the same conditions set. Table X2 lists example compositions within the GWP<300 range that have ASHRAE flammability classifications of 2L or 2.

[0121] Preferred blend composition ranges for medium temperature refrigeration within a composition range of 9 to 61 wt-% of HFO-1132E, 28 to 70 wt-% of HFO-1234zeE, 0.25 to 13 wt-% of HFC-134, and 0.25 to 21 of HFC-32 will have a GWP < 150, a maximum average heat exchanger glide of 9.9 K, an ASHRAE flammability classification of 2L or 2, and a cooling capacity range of 10 less than to 10% greater than that of R-454C evaluated at the same conditions set. The optimal composition for cooling capacity in this range is at 32 wt-% HFO-1132E, 48 wt-% HFO-1234zeE, 1 wt-% HFC-134, and 19 wt-% HFC-32, where the COP is about 1% greater than

that for R-454C under the same conditions, the GWP is 140 and the average glide is 8.8 K, and the ASHRAE flammability classification is 2L. The optimal composition for cooling COP in this range, which is 3% greater than the COP for cooling of R-454C at these same conditions, is at 9 wt-% HFO-1132E, 69.6 wt-% HFO-1132E, 0.5 wt-% HFC-134, and 20.9 wt-% HFC-32, where the cooling capacity is 10% less than that for R-454C under the same conditions, the GWP is 148 and the average glide is 9.9 K, and the ASHRAE flammability classification is 2L.

[0122] Even more preferred composition ranges for cooling mode that result in ASHRAE flammability classifications of 2L are 9 to 48 wt-% HFO-1132E, 36 to 70 wt-% HFO-1234zeE, 0.5 to 13 wt-% HFC-134, and 0.5 to 21 wt-% HFC-32, where the minimum and maximum cooling capacities are 10% less and 10% greater than those of R-454C respectively at the same cycle conditions. The composition for this maximum cooling capacity for a 2L blend is 32 wt-% HFO-1132E, 48 wt-% HFO-1234zeE, 1 wt-% HFC-134, and 19 wt-% HFC-32, where the COP is about 1% greater than that for R-454C under the same conditions, the GWP is 140 and the average glide is 8.8 K, and the ASHRAE flammability classification is 2L. The optimal composition for cooling COP in this range is at 9 wt-% HFO-1132E, 69.6 wt-% HFO-1132E, 0.5 wt-% HFC-134, and 20.9 wt-% HFC-32, where the cooling capacity is 10% less than that for R-454C under the same conditions, the GWP is 148 and the average glide is 9.9 K, and the ASHRAE flammability classification is 2L.

Table X2: Medium Temperature Refrigeration conditions, cycle metric performance and fluid property ranges for HFO-1132E/HFO-1234zeE/HFC-134/HFC-32 in Example 2.

wt-frac R1132(E)	wt-frac R1234ze(E))	wt-frac R134	wt-frac HFC-32	GWP AR5	ASHRAE flammability class	Glide (K)	CAP_c(% dev from R-454C)	COP_c(% dev from R-454C)
0.55	0.02	0.02	0.41	300	2L	1.1	-4	64
0.985	0.002	0.002	0.01	10	2	0.2	-3	55
0.002	0.657	0.002	0.338	232	2L	9.6	2	-1
0.01	0.985	0.002	0.002	5	2L	0.7	6	-49
0.756	0.002	0.002	0.239	164	2	0.2	-4	65
0.41	0.32	0.26	0.01	298	2L	7.4	2	-6
0.002	0.975	0.002	0.02	17	2L	1.9	5	-47

wt-frac R1132(E)	wt-frac R1234ze(E)	wt-frac R134	wt-frac HFC-32	GWP AR5	ASHRAE flammabili ty class	Glide (K)	CAP_c(% dev from R-454C)	COP_c(% dev from R-454C)
0.002	0.557	0.002	0.438	300	2L	8.4	1	11
0.002	0.816	0.179	0.002	203	2L	0.4	6	-48
0.557	0.002	0.002	0.438	299	2L	0.1	-4	69
0.002	0.985	0.01	0.002	14	2L	0.4	6	-50
0.002	0.736	0.259	0.002	292	2L	0.4	6	-47
0.002	0.746	0.249	0.002	281	2L	0.4	6	-47
0.567	0.002	0.002	0.428	292	2L	0.1	-4	69
0.577	0.002	0.002	0.418	286	2L	0.1	-4	69
0.587	0.002	0.002	0.408	279	2L	0.1	-4	68
0.597	0.002	0.002	0.398	272	2L	0.1	-4	68
0.607	0.002	0.002	0.388	266	2	0.1	-4	68
0.617	0.002	0.002	0.378	259	2	0.2	-4	68
0.627	0.002	0.002	0.368	252	2	0.2	-4	68
0.637	0.002	0.002	0.358	245	2	0.2	-4	68
0.647	0.002	0.002	0.348	239	2	0.2	-4	67
0.657	0.002	0.002	0.338	232	2	0.2	-4	67
0.667	0.002	0.002	0.328	225	2	0.2	-4	67
0.677	0.002	0.002	0.318	218	2	0.2	-4	67
0.687	0.002	0.002	0.308	212	2	0.2	-4	67
0.04	0.706	0.005	0.249	175	2L	10	3	-9
0.826	0.005	0.08	0.09	150	2	2.1	-3	50
0.985	0.002	0.01	0.002	13	2	0.3	-3	53
0.002	0.935	0.06	0.002	69	2L	0.4	6	-49
0.866	0.002	0.002	0.129	90	2	0.3	-3	61
0.507	0.358	0.129	0.005	149	2	7.4	1	2
0.02	0.975	0.002	0.002	5	2L	1.2	6	-48
0.358	0.428	0.005	0.209	147	2L	8.3	0	16
0.517	0.478	0.002	0.002	5	2	7.6	1	1
0.786	0.002	0.002	0.209	144	2	0.3	-4	64
0.002	0.866	0.129	0.002	147	2L	0.4	6	-49

wt-frac R1132(E)	wt-frac R1234ze(E))	wt-frac R134	wt-frac HFC-32	GWP AR5	ASHRAE flammability class	Glide (K)	CAP_c(% dev from R-454C)	COP_c(% dev from R-454C)
0.09	0.696	0.005	0.209	148	2L	9.9	3	-10
0.15	0.65	0.03	0.17	149	2L	9.5	3	-10
0.607	0.388	0.002	0.002	5	2	7.1	0	10
0.587	0.279	0.129	0.005	149	2	6.9	1	10
0.527	0.338	0.129	0.005	149	2	7.3	1	4
0.498	0.498	0.002	0.002	5	2	7.7	1	-1
0.269	0.517	0.005	0.209	148	2L	9.1	1	8
0.428	0.567	0.002	0.002	5	2	7.8	2	-8
0.32	0.48	0.01	0.19	140	2L	8.8	1	10
0.19	0.65	0.02	0.14	118	2L	9.4	2	-10
0.53	0.41	0.01	0.05	45	2	7.7	0	10
0.577	0.398	0.005	0.02	19	2	7.4	0	10
0.48	0.36	0.09	0.07	149	2L	7.8	1	9
0.408	0.458	0.129	0.005	149	2L	7.5	2	-8
0.229	0.617	0.005	0.149	107	2L	9.5	2	-5
0.139	0.647	0.005	0.209	148	2L	9.8	2	-5
0.428	0.438	0.129	0.005	149	2L	7.5	2	-6
0.408	0.458	0.005	0.129	94	2L	8.5	1	10
0.03	0.84	0.08	0.05	124.3	2L	4.7	-39	5
0.07	0.75	0.14	0.04	184.6	2L	5	-36	4
0.11	0.67	0.2	0.02	238.2	2L	4.8	-35	5
0.15	0.6	0.16	0.09	240.7	2L	7.8	-21	4
0.19	0.53	0.18	0.1	269.8	2L	8.1	-15	3
0.23	0.46	0.09	0.22	250.2	2L	8.9	5	2
0.27	0.37	0.12	0.24	297.3	2L	8.3	12	1
0.34	0.58	0.03	0.05	68	2L	8.5	-9	2
0.38	0.47	0.03	0.12	115.3	2L	8.7	6	1
0.42	0.38	0.11	0.09	184.5	2L	8.2	6	1
0.46	0.3	0.2	0.04	251.4	2L	7.7	3	1
0.5	0.23	0.18	0.09	262.8	2L	7.5	15	0

wt-frac R1132(E)	wt-frac R1234ze(E)	wt-frac R134	wt-frac HFC-32	GWP AR5	ASHRAE flammability class	Glide (K)	CAP_c(% dev from R-454C)	COP_c(% dev from R-454C)
0.54	0.16	0.09	0.21	243.1	2L	5.6	35	-1
0.58	0.07	0.14	0.21	299	2L	4.9	40	-2
0.62	0.03	0.02	0.33	245.8	2	1.4	61	-4
0.66	0.07	0.02	0.25	191.7	2	2.4	54	-3
0.77	0.05	0.08	0.1	157.4	2	3.3	44	-2
0.97	0.01	0.01	0.01	18	2	0.6	53	-3

Example 3: HFO-1132E, HFO-1234zeE and HFC-32

[0123] Broadly, a composition range of 0.5 to 98.5 wt-% of HFO-1132E, 0.5 to 98.5 wt-% of HFO-1234zeE, and 0.5 to 44 wt-% HFC-32 will have a GWP less than 300, a maximum average glide of about 10 K, a cooling capacity range that is 49% less to 69% greater than the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range is 4% less and 6% greater than the cooling capacity of R-454C evaluated with the same conditions set. Similarly, a composition range of 0.5 to 98.5 wt-% of HFO-1132E, 0.5 to 98.5 wt-% of HFO-1234zeE, and 1 to 22 wt-% HFC-32 will have a GWP less than 150, a maximum average glide of about 10 K, a cooling capacity range that is 49% less and 64% greater than the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range is 4% less and 6% greater than the cooling capacity of R-454C evaluated with the same conditions set. Table X3 lists example compositions within the GWP < 300 range that have ASHRAE flammability classifications of 2L or 2.

[0124] Preferred blend composition ranges for medium temperature refrigeration within a composition range of 8 to 60 wt-% of HFO-1132E, 40 to 70 wt-% of HFO-1234zeE, and 0.5 to 22 of HFC-32 will have a GWP < 150, a maximum average heat exchanger glide of 10 K, an ASHRAE flammability classification of 2L or 2, and a cooling capacity range of 10 less than to 10% greater than that of R-454C evaluated at the same conditions set. The optimal composition for cooling capacity in this range is at 50 wt-% HFO-1132E, 43 wt-% HFO-1234zeE and 7 wt-% HFC-32, where the COP is about the same as that for R-454C under the same conditions, the GWP is 48 and the average glide is 8 K, and the ASHRAE flammability classification is 2.

The optimal composition for cooling COP in this range is at 8 wt-% HFO-1132E, 70 wt-% HFO-1132E 22 wt-% HFC-32, where the cooling capacity is 9% less than that for R-454C under the same conditions, the GWP is less than 150 and the average glide is 10 K, and the ASHRAE flammability classification is 2L.

[0125] Even more preferred composition ranges for cooling mode that result in ASHRAE flammability classifications of 2L are 8 to 42 wt-% HFO-1132E, 46 to 70 wt-% HFO-1234zeE and 4 to 22 wt-% HFC-32, where the minimum and maximum cooling capacities are 10% less and 10% greater than those of R-454C respectively at the same cycle conditions. The composition for this maximum cooling capacity for a 2L blend is 32 wt-% HFO-1132E, 49 wt-% HFO-1234zeE and 19 wt-% HFC-32, where the COP is about 1% greater than that for R-454C under the same conditions, the GWP is 129 and the average glide is 8.9 K, and the ASHRAE flammability classification is 2L. The optimal composition for cooling COP in this range is at 8 wt-% HFO-1132E, 70 wt-% HFO-1132E and 22 wt-% HFC-32, where the cooling capacity is 9% less than that for R-454C under the same conditions, the GWP is 149 and the average glide is 10 K, and the ASHRAE flammability classification is 2L.

Table X3: Medium Temperature Refrigeration conditions, cycle metric performance and fluid property ranges for HFO-1132E/HFO-1234zeE/ HFC-32 in Example 3.

wt-frac R1132(E)	wt-frac R1234ze(E))	wt-frac R32	GWP AR5	ASHRAE flammability class	Glide (K)	CAP_c(% dev from R-454C)	COP_c(% dev from R-454C)
0.01	0.55	0.44	298	2L	8.3	1	12
0.985	0.01	0.005	3	2	0.3	-3	53
0.005	0.617	0.378	257	2L	9.2	2	4
0.01	0.985	0.005	4	2L	1	6	-49
0.826	0.005	0.169	115	2	0.3	-4	62
0.11	0.45	0.44	298	2L	7.4	0	22
0.338	0.657	0.005	4	2L	7.7	3	-17
0.557	0.005	0.438	296	2L	0.1	-4	69
0.687	0.005	0.308	209	2	0.2	-4	67
0.677	0.005	0.318	216	2	0.2	-4	67
0.667	0.005	0.328	222	2	0.2	-4	67
0.657	0.005	0.338	229	2	0.2	-4	67

wt-frac R1132(E)	wt-frac R1234ze(E))	wt-frac R32	GWP AR5	ASHRAE flammability class	Glide (K)	CAP_c(% dev from R-454C)	COP_c(% dev from R-454C)
0.65	0.01	0.34	230	2	0.3	-4	67
0.647	0.005	0.348	236	2	0.2	-4	67
0.64	0.01	0.35	237	2	0.3	-4	67
0.637	0.005	0.358	243	2	0.1	-4	68
0.63	0.01	0.36	244	2	0.3	-4	67
0.627	0.005	0.368	249	2	0.1	-4	68
0.62	0.01	0.37	251	2	0.3	-4	67
0.617	0.005	0.378	256	2	0.1	-4	68
0.61	0.01	0.38	257	2	0.3	-4	67
0.607	0.005	0.388	263	2	0.1	-4	68
0.6	0.01	0.39	264	2L	0.3	-4	68
0.597	0.005	0.398	269	2L	0.1	-4	68
0.59	0.01	0.4	271	2L	0.2	-4	68
0.587	0.005	0.408	276	2L	0.1	-4	69
0.577	0.005	0.418	283	2L	0.1	-4	69
0.567	0.005	0.428	290	2L	0.1	-4	69
0.04	0.71	0.25	170	2L	10	3	-9
0.01	0.77	0.22	150	2L	9.8	3	-16
0.985	0.005	0.01	7	2	0.2	-3	54
0.005	0.896	0.1	68	2L	6.9	4	-35
0.005	0.985	0.01	8	2L	1.2	6	-49
0.965	0.005	0.03	20	2	0.2	-3	56
0.18	0.6	0.22	150	2L	9.7	2	0
0.229	0.766	0.005	4	2L	6.7	4	-27
0.776	0.005	0.219	148	2	0.3	-4	64
0.786	0.005	0.209	141	2	0.3	-4	64
0.78	0.01	0.21	142	2	0.4	-4	63
0.77	0.01	0.22	149	2	0.4	-4	63
0.08	0.7	0.22	150	2L	10	3	-9
0.597	0.398	0.005	4	2	7.2	0	9

wt-frac R1132(E)	wt-frac R1234ze(E))	wt-frac R32	GWP AR5	ASHRAE flammability class	Glide (K)	CAP_c(% dev from R-454C)	COP_c(% dev from R-454C)
0.09	0.7	0.21	143	2L	10	3	-10
0.15	0.63	0.22	150	2L	9.8	2	-2
0.527	0.468	0.005	4	2	7.6	1	2
0.5	0.43	0.07	48	2	8	0	10
0.3	0.63	0.07	48	2L	8.9	2	-10
0.56	0.41	0.03	21	2	7.5	0	10
0.53	0.42	0.05	34	2	7.8	0	10
0.42	0.46	0.12	82	2L	8.5	1	10
0.26	0.52	0.22	149	2L	9.1	1	8
0.36	0.6	0.04	28	2L	8.4	2	-9
0.32	0.49	0.19	129	2L	8.9	1	10
0.03	0.93	0.04	28	2L	4.5	-42	4
0.07	0.86	0.07	48	2L	7	-33	4
0.11	0.79	0.1	68	2L	8.6	-24	3
0.15	0.72	0.13	89	2L	9.4	-15	3
0.19	0.65	0.16	109	2L	9.7	-7	2
0.23	0.58	0.19	129	2L	9.5	1	2
0.27	0.51	0.22	149	2L	9	9	1
0.31	0.44	0.25	170	2L	8.3	17	0
0.35	0.37	0.28	190	2L	7.3	25	-1
0.39	0.3	0.31	210	2L	6.2	33	-2
0.43	0.23	0.34	230	2L	4.9	42	-2
0.47	0.16	0.37	251	2L	3.5	50	-3
0.51	0.09	0.4	271	2L	2	58	-3
0.55	0.02	0.43	291	2L	0.5	67	-4
0.59	0.01	0.4	271	2L	0.2	68	-4
0.63	0.16	0.21	142	2	4.1	45	-3
0.68	0.13	0.19	129	2	3.5	47	-3
0.74	0.07	0.19	129	2	2.1	55	-3
0.81	0.16	0.03	20	2	4.1	36	-2

wt-frac R1132(E)	wt-frac R1234ze(E))	wt-frac R32	GWP AR5	ASHRAE flammability class	Glide (K)	CAP_c(% dev from R-454C)	COP_c(% dev from R-454C)
0.95	0.04	0.01	7	2	1.2	50	-3

Example 4: HFO-1132E, HFC-134 and HFC-32

[0126] Broadly, a composition range of 57 to 98.5 wt-% of HFO-1132E, 0.5 to 26 wt-% HFC-134, and 0.5 to 43 wt-% HFC-32 will have a GWP less than 300, a maximum average glide of about 5.1 K, a cooling capacity range that is 27% to 69% greater than the cooling capacity of R-454C evaluated with the same conditions set, and the COP range is 4% to 1% less than the COP of R-454C evaluated with the same conditions set. Similarly, and also broadly, a composition range of 79 to 98.5 wt-% of HFO-1132E, 0.5 to 13 wt-% HFC-134, and 0.5 to 21 wt-% HFC-32 will have a GWP less than 150, a maximum average glide of about 2.7 K, a cooling capacity range that is 41% to 64% greater than the cooling capacity of R-454C evaluated with the same conditions set, and the COP range is 4% to 2% less than the cooling COP of R-454C evaluated with the same conditions set. Table X4 lists example compositions within the GWP<300 range that have ASHRAE flammability classifications of 2L or 2.

[0127] The optimal 2L composition for efficiency that has a GWP less than 300, which is 1% less than the COP of incumbent fluid R-454C evaluated at the same conditions, is 73 wt-% HFO-1132E, 26 wt-% HFC-134 and 1 wt-% HFC-32, where the CAP for cooling 27% greater than that for the CAP of R-454C evaluated at the same conditions and the average glide is 5.1 K. Similarly, the optimal composition for efficiency that has a GWP less than 150, which is 2% less than the COP of incumbent fluid R-454C evaluated at the same conditions, is 86.6 wt-% HFO-1132E, 12.9 wt-% HFC-134 and 0.5 wt-% HFC-32, where the CAP for cooling is 41% greater respectively than that for the CAP of R-454C evaluated at the same conditions and the average glide is 2.7 K.

[0128] The optimal composition for cooling capacity, which is 69% greater respectively than the capacity of incumbent fluid R-454C evaluated at the same conditions, that has a GWP less than 300, an ASHRAE flammability classification of 2L, a maximum average glide of 0.2 K, and COP efficiency of 4% less than the COP

of incumbent fluid R-454C evaluated at the same conditions, is 56.7 wt-% HFO-1132E, 0.5 wt-% HFC-134 and 42.8 wt-% HFC-32. Similarly, the optimal composition for cooling capacity, which is 64% greater than the capacities of incumbent fluid R-454C evaluated at the same conditions, that has a GWP less than 150, a maximum average glide of 0.2 K and COP that is 4% less than the COP of incumbent fluid R-454C evaluated at the same conditions, is 78.6 wt-% HFO-1132E, 0.5 wt-% HFC-134 and 20.9 wt-% HFC-32.

Table X4: Residential Heat Pump conditions in cooling mode, cycle metric performance and fluid property ranges for HFO-1132E/HFC-134/HFC-32 in Example 4.

wt-frac R1132(E)	wt-frac R134	wt-frac R32	GWP AR5	ASHRAE flammability class	Glide (K)	COP _c (% dev from R-454C)	CAP _c (% dev from R-454C)
0.57	0.02	0.41	300	2L	0.6	-4	66
0.985	0.005	0.01	12	2	0.1	-3	55
0.567	0.005	0.428	295	2L	0.2	-4	69
0.73	0.26	0.01	298	2	5.1	-1	27
0.796	0.005	0.199	140	2	0.3	-4	63
0.975	0.02	0.005	26	2	0.4	-3	53
0.736	0.259	0.005	293	2	5	-1	27
0.597	0.005	0.398	275	2L	0.2	-4	68
0.6	0.01	0.39	275	2L	0.3	-4	67
0.587	0.005	0.408	282	2L	0.2	-4	68
0.59	0.01	0.4	282	2L	0.3	-4	68
0.577	0.005	0.418	289	2L	0.2	-4	69
0.58	0.01	0.41	289	2L	0.3	-4	68
0.57	0.01	0.42	296	2L	0.3	-4	68
0.677	0.005	0.318	221	2	0.2	-4	67
0.667	0.005	0.328	228	2	0.2	-4	67
0.657	0.005	0.338	235	2	0.2	-4	67
0.647	0.005	0.348	241	2	0.2	-4	67
0.637	0.005	0.358	248	2	0.2	-4	68
0.627	0.005	0.368	255	2	0.2	-4	68

wt-frac R1132(E)	wt-frac R134	wt-frac R32	GWP AR5	ASHRAE flammability class	Glide (K)	COP_c (% dev from R-454C)	CAP_c (% dev from R-454C)
0.63	0.01	0.36	255	2	0.3	-4	67
0.617	0.005	0.378	262	2	0.2	-4	68
0.62	0.01	0.37	262	2	0.3	-4	67
0.607	0.005	0.388	268	2	0.2	-4	68
0.61	0.01	0.38	268	2	0.3	-4	67
0.8	0.03	0.17	149	2	0.9	-3	59
0.786	0.005	0.209	147	2	0.2	-4	64
0.866	0.129	0.005	148	2	2.7	-2	41
0.955	0.005	0.04	33	2	0.2	-3	56
0.915	0.08	0.005	93	2	1.7	-2	46
0.6	0.01	0.39	275	2L	0.3	-4	67
0.58	0.01	0.41	289	2L	0.3	-4	68
0.61	0.08	0.31	299	2L	2.2	-3	57
0.9	0.06	0.04	94	2	1.4	-3	50
0.85	0.03	0.12	115	2	0.9	-3	57
0.80595	0.005	0.18905	134	2	0.3	-4	63
0.85	0.11	0.04	150	2	2.5	-2	45
0.79	0.05	0.16	164	2	1.4	-3	56
0.77	0.05	0.18	178	2	1.4	-3	57
0.79	0.11	0.1	191	2	2.7	-3	47
0.76	0.09	0.15	202	2	2.3	-3	51
0.73	0.07	0.2	214	2	1.9	-3	55
0.76	0.14	0.1	225	2	3.3	-2	44
0.68	0.04	0.28	234	2	1.2	-4	61
0.77	0.2	0.03	244	2	4.2	-2	34
0.73	0.16	0.11	254	2	3.8	-2	42
0.73	0.18	0.09	263	2	4.2	-2	39
0.73	0.2	0.07	271	2	4.5	-2	36
0.65	0.1	0.25	281	2	2.7	-3	53
0.66	0.14	0.2	292	2	3.6	-3	47

Example 5: HFO-1132E and HFO-1234zeE

[0129] Broadly, a composition range of 1 to 99 wt-% of HFO-1132E and 1 to 99 wt-% HFO-1234zeE will have a GWP less than 6, a maximum average glide of about 7.8 K, a cooling capacity range that is 50% less to 53% greater than the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range is 3% less to 1% more than the cooling COP of R-454C evaluated with the same conditions set. Table X5 lists example compositions within the GWP<6 range that have ASHRAE flammability classifications of 2L or 2.

[0130] Preferred blend composition ranges within 42 to 61 wt-% of HFO-1132E and 39 to 58 wt-% of HFO-1234zeE will have GWP < 6, a maximum heat exchanger glide of 8.4 K (in the condenser), an ASHRAE flammability classification 2, and minimum and maximum cooling capacities of 10% less and 10% more than that of R-454C evaluated at the same conditions set.

Table X5: Medium Temperature Refrigeration conditions, cycle metric performance and fluid property ranges for HFO-1132E/HFO-1234zeE in Example 5.

wt-frac R1132(E)	wt-frac R1234ze (E)	GWP AR5	ASHRAE flammab ility class	Glide (K)	COP_c (% dev from R- 454C)	CAP_c (% dev from R- 454C)
0.01	0.99	1.0	~1	0.5	6	-50
0.98	0.02	0.2	~1	0.6	-3	52
0.94	0.06	0.5	~1	1.8	-3	46
0.89	0.11	0.7	~1	3.0	-2	40
0.84	0.16	1.0	~1	4.0	-2	35
0.79	0.21	1.3	~1	4.9	-1	29
0.74	0.26	1.6	~1	5.7	-1	23
0.69	0.31	1.9	~1	6.3	0	18
0.64	0.36	2.2	~1	6.8	0	13
0.61	0.39	0.4	~1	7.1	0	10
0.59	0.41	2.5	~1	7.2	1	8
0.54	0.46	2.8	~1	7.5	1	3
0.49	0.51	3.1	~1	7.7	2	-2
0.44	0.56	3.4	~1	7.8	2	-7

0.42	0.58	0.6	~1	7.8	2	-9
0.39	0.61	3.7	~1	7.7	2	-12
0.34	0.66	4.0	~1	7.5	3	-17
0.29	0.71	4.3	~1	7.2	3	-22
0.24	0.76	4.6	~1	6.7	4	-27
0.19	0.81	4.9	~1	5.9	4	-32
0.14	0.86	5.2	~1	4.9	4	-37
0.09	0.91	5.5	~1	3.6	5	-42
0.04	0.96	5.8	~1	1.8	5	-47
0.99	0.01	0.0	~1	0.3	-3	53

Example 6: HFO-1132E and HFO-134

[0131] Broadly, a composition range of 74 to 99 wt-% of HFO-1132E and 1 to 26 wt-% HFO-1234zeE will have a GWP less than 300, a maximum average glide of about 5 K, a cooling capacity range that is 27% to 54% greater than the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range is 3% to 1% less than the cooling COP of R-454C evaluated with the same conditions set. Table X6 lists example compositions within the GWP<300 range that have ASHRAE flammability classifications of 2.

[0132] Preferred blend composition ranges for cooling within a composition range of 87 to 99 wt-% of HFO-1132E and 1 to 13 wt-% of HFO-1234zeE will have GWP < 150, a maximum heat exchanger glide of 2.9 K (in the evaporator), an ASHRAE flammability classification 2, minimum and maximum cooling capacities of 40% and 54% more than that of R-454C evaluated at the same conditions set, and minimum and maximum cooling COPs of 3% and 2% less than that of R-454C evaluated at the same conditions set.

[0133] The optimal composition for efficiency, which is 1% less than that for R-454C at the same conditions, is 74 wt-% HFO-1132E and 26 wt-% HFC-32, which has a GWP less than 300, an average glide of 4.8 K, 26% greater CAP than that for R-454C at the same conditions and has an ASHRAE flammability classification of 2.

Table X6: Residential Heat Pump conditions in cooling mode, cycle metric performance and fluid property ranges for HFO-1132E/HFC-134 in Example 6.

wt-frac R1132(E)	wt-frac R134	GWP AR5	ASHRAE flammab ility class	Glide (K)	COP _c (% dev from R- 454C)	CAP _c (% dev from R- 454C)
0.99	0.01	11	2	0.2	-2.77	53.51
0.97	0.03	34	2	0.6	-2.67	51.29
0.96	0.04	45	2	0.8	-2.60	50.18
0.95	0.05	56	2	1.0	-2.57	49.08
0.94	0.06	67	2	1.3	-2.50	47.98
0.92	0.08	90	2	1.7	-2.37	45.79
0.91	0.09	101	2	1.9	-2.30	44.70
0.89	0.11	123	2	2.3	-2.17	42.53
0.88	0.12	134	2	2.5	-2.10	41.46
0.87	0.13	146	2	2.7	-2.04	40.39
0.86	0.14	157	2	2.9	-1.97	39.31
0.85	0.15	168	2	3.1	-1.87	38.25
0.83	0.17	190	2	3.4	-1.70	36.13
0.82	0.18	202	2	3.6	-1.64	35.08
0.81	0.19	213	2	3.8	-1.54	34.03
0.8	0.2	224	2	4.0	-1.47	32.98
0.79	0.21	235	2	4.2	-1.37	31.94
0.77	0.23	258	2	4.5	-1.17	29.87
0.76	0.24	269	2	4.7	-1.07	28.83
0.75	0.25	280	2	4.9	-0.97	27.81
0.74	0.26	291	2	5.0	-0.87	26.78

Example 7: HFO-1132E and HFO-32

[0134] Broadly, a composition range of 56 to 99 wt-% of HFO-1132E and 1 to 44 wt-% HFC-32 will have a GWP less than 300, a maximum average glide of about 0.1 K in, a cooling capacity range that is 55% to 70% greater than the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range is 4% to 3% less than the cooling COP of R-454C evaluated with the same conditions set.

Table X7 lists example compositions within the GWP<300 range that have ASHRAE flammability classifications of 2L and 2.

[0135] Preferred blend composition ranges for cooling within a composition range of 78 to 99 wt-% of HFO-1132E and 1 to 22 wt-% of HFO-1234zeE will have GWP < 150, a maximum heat exchanger glide of 0.2 K (in the condenser), an ASHRAE flammability classification 2, and minimum and maximum cooling capacities of 55% to 65% more than that of R-454C evaluated at the same conditions set.

[0136] Other preferred blend compositions within a composition range of 56 to 60 wt-% of HFO-1132E and 40 to 44 wt-% of HFO-1234zeE will have GWP < 300, a maximum heat exchanger glide less than 0.1 K (in the condenser), an ASHRAE flammability classification 2L, and minimum and maximum cooling capacities of 69% to 70% more than that of R-454C evaluated at the same conditions set.

[0137] The optimal composition for capacity, which is 70% greater than that for R-454C at the same conditions, is 56 wt-% HFO-1132E and 44 wt-% HFC-32, which has a GWP less than 300, an average glide of <0.1 K, 4% less COP than that for R-454C at the same conditions and has an ASHRAE flammability classification of 2L.

Table X7: Residential Heat Pump conditions in cooling mode, cycle metric performance and fluid property ranges for HFO-1132E/HFC-32 in Example 7.

wt-frac R1132(E)	wt-frac R32	GWP AR5	ASHRAE flammab ility class	Glide (K)	COP_c (% dev from R- 454C)	CAP_c (% dev from R- 454C)
0.56	0.44	298	1	0.00	0.96	1.70
0.57	0.43	291	1	0.00	0.96	1.69
0.58	0.42	284	1	0.00	0.96	1.69
0.59	0.41	278	1	0.00	0.96	1.69
0.6	0.4	271	1	0.01	0.96	1.69
0.61	0.39	264	2	0.01	0.96	1.69
0.62	0.38	257	2	0.01	0.96	1.69
0.63	0.37	250	2	0.01	0.96	1.69
0.64	0.36	244	2	0.02	0.96	1.68
0.65	0.35	237	2	0.02	0.96	1.68
0.66	0.34	230	2	0.03	0.96	1.68

0.67	0.33	223	2	0.03	0.96	1.68
0.68	0.32	217	2	0.04	0.96	1.68
0.69	0.31	210	2	0.04	0.96	1.67
0.7	0.3	203	2	0.05	0.96	1.67
0.71	0.29	196	2	0.05	0.96	1.67
0.72	0.28	190	2	0.06	0.96	1.67
0.73	0.27	183	2	0.07	0.96	1.66
0.74	0.26	176	2	0.07	0.96	1.66
0.77	0.23	156	2	0.10	0.96	1.65
0.78	0.22	149	2	0.10	0.96	1.65
0.79	0.21	142	2	0.11	0.96	1.64
0.8	0.2	135	2	0.12	0.96	1.64
0.81	0.19	129	2	0.12	0.96	1.64
0.82	0.18	122	2	0.13	0.96	1.63
0.83	0.17	115	2	0.13	0.96	1.63
0.84	0.16	108	2	0.14	0.96	1.63
0.85	0.15	102	2	0.14	0.96	1.62
0.86	0.14	95	2	0.15	0.97	1.62
0.89	0.11	74	2	0.15	0.97	1.60
0.9	0.1	68	2	0.15	0.97	1.60
0.91	0.09	61	2	0.14	0.97	1.59
0.92	0.08	54	2	0.14	0.97	1.59
0.93	0.07	47	2	0.13	0.97	1.58
0.94	0.06	41	2	0.12	0.97	1.58
0.95	0.05	34	2	0.11	0.97	1.57
0.96	0.04	27	2	0.09	0.97	1.57
0.97	0.03	20	2	0.07	0.97	1.56
0.98	0.02	14	2	0.05	0.97	1.56
0.99	0.01	7	2	0.03	0.97	1.55

Example 8: HFO-1132E, HFO-1234zeE and HFC-134

[0138] Broadly, a composition range of 0.5 to 98.5 wt-% of R-1132E, 0.5 to 98.5 wt-% R-1234zeE, and 0.5 to 26 wt-% R-134 will have a GWP less than 300, a maximum average glide of about 7.8 K, a cooling capacity range that is 50% less and 53% greater than the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range is 3% less and 6% greater than the cooling COP of R-454C evaluated with the same conditions set. Similarly, a composition range of 0.5 to 98.5 wt-% of R-1132E, 0.5 to 98.5 wt-% R-1234zeE, and 0.5 to 13 wt-% R-134 will have a GWP less than 150, a maximum average glide of about 7.8 K, a cooling capacity range that is 50% less and 53% greater than the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range is 3% less and 6% greater than the cooling COP of R-454C evaluated with the same conditions set. Table X4 lists example compositions within the GWP<300 range that have ASHRAE flammability classifications of 1, 2L or 2.

[0139] Preferred blend composition ranges for cooling within a composition range of 40 to 98.5 wt-% of R-1132E, 0.5 to 58 wt-% of R-1234zeE, and 0.5 to 13 of R-134 will have a GWP < 150, a maximum average heat exchanger glide of 7.8 K, an ASHRAE flammability classification of 2L or 2, and a minimum cooling capacity of 10% less than that of R-454C evaluated at the same conditions set.

[0140] Even more preferred composition ranges that result in ASHRAE flammability classifications of 2L are 40 to 47 wt-% R-1132E, 40 to 52 wt-% R-1234zeE, and 7 to 13 wt-% R-134, where the minimum and maximum cooling capacities are 10% less and 3% less than those of R-454C respectively. The composition for this maximum cooling capacity (3% less than that of R-454C) for a 2L blend is 47 wt-% R-1132E, 40 wt-% R-1234zeE and 13 wt-% R-134, where the COP for cooling is about 2% greater than that for R-454C under the same cycle conditions.

[0141] The optimal composition for cooling efficiency, which is 2% greater than the COP of incumbent fluid R-454C evaluated at the same conditions, is 40 wt-% R-1132E, 47 wt-% R-1234zeE and 13 wt-% R-134, where the CAP for cooling is 10% less than that for the CAP of R-454C, the average glide is 7.4 K, the GWP is 146, and the flammability class is 2L. The optimal composition for cooling capacity, which

is 2% less than for R-454C under the same conditions, is 47 wt-% R-1132E, 40 wt-% R-1234zeE and 13 wt-% R-134, where the COP for cooling is 2% greater than the COP of R-454C for cooling, the average glide is 7.4 K, the GWP is 146, and the flammability class is 2L.

Table X8: Medium temperature refrigeration conditions in cooling mode, cycle metric performance and fluid property ranges for R-1132E/R-1234zeE/R-134 in Example 4.

wt-frac R1132(E)	wt-frac R1234ze (E)	wt-frac R-134	GWP AR5	ASHRAE flammability class	Glide (K)	COP _h (% dev from R- 454C)	CAP _h (% dev from R- 454C)
0.005	0.736	0.259	290	2L	0.3	6	-47
0.005	0.746	0.249	279	2L	0.3	6	-48
0.005	0.866	0.129	146	2L	0.3	6	-49
0.005	0.876	0.119	135	2L	0.3	6	-49
0.005	0.886	0.109	123	2L	0.3	6	-49
0.005	0.905	0.09	101	2L	0.3	6	-49
0.005	0.985	0.01	12	2L	0.3	6	-50
0.01	0.73	0.26	292	2L	0.5	6	-47
0.01	0.86	0.13	146	2L	0.5	6	-48
0.01	0.985	0.005	7	2L	0.5	6	-50
0.03	0.71	0.26	292	1	1.3	6	-45
0.04	0.7	0.26	292	1	1.7	6	-44
0.05	0.69	0.26	292	1	2.0	6	-43
0.19	0.55	0.26	292	2L	5.4	4	-29
0.4	0.47	0.13	146	2L	7.4	2	-10
0.4	0.47	0.13	146	2L	7.4	2	-10
0.4	0.48	0.12	135	2L	7.4	2	-10
0.4	0.48	0.12	135	2L	7.4	2	-10
0.408	0.587	0.005	6	2	7.7	2	-11
0.41	0.46	0.13	146	2L	7.4	2	-9
0.41	0.47	0.12	135	2L	7.4	2	-9
0.41	0.48	0.11	124	2L	7.5	2	-9
0.41	0.49	0.1	112	2L	7.5	2	-9

wt-frac R1132(E)	wt-frac R1234ze (E)	wt-frac R-134	GWP AR5	ASHRAE flammab ility class	Glide (K)	COP_h (% dev from R- 454C)	CAP_h (% dev from R- 454C)
0.41	0.5	0.09	101	2L	7.5	2	-9
0.41	0.51	0.08	90	2L	7.5	2	-9
0.41	0.52	0.07	79	2L	7.6	2	-10
0.41	0.52	0.07	79	2L	7.6	2	-10
0.418	0.577	0.005	6	2	7.8	2	-10
0.42	0.45	0.13	146	2L	7.4	2	-8
0.42	0.46	0.12	135	2L	7.4	2	-8
0.42	0.47	0.11	124	2L	7.5	2	-8
0.42	0.48	0.1	112	2L	7.5	2	-8
0.42	0.49	0.09	101	2L	7.5	2	-8
0.42	0.5	0.08	90	2L	7.5	2	-8
0.43	0.44	0.13	146	2L	7.4	2	-7
0.43	0.45	0.12	135	2L	7.5	2	-7
0.43	0.46	0.11	124	2L	7.5	2	-7
0.43	0.47	0.1	112	2L	7.5	2	-7
0.43	0.48	0.09	101	2L	7.5	2	-7
0.438	0.557	0.005	6	2	7.8	2	-8
0.44	0.43	0.13	146	2L	7.4	2	-6
0.44	0.44	0.12	135	2L	7.5	2	-6
0.44	0.45	0.11	124	2L	7.5	2	-6
0.44	0.46	0.1	112	2L	7.5	2	-6
0.45	0.42	0.13	146	2L	7.4	2	-5
0.45	0.43	0.12	135	2L	7.5	2	-5
0.45	0.44	0.11	124	2L	7.5	2	-5
0.46	0.41	0.13	146	2L	7.4	2	-4
0.46	0.42	0.12	135	2L	7.4	2	-4
0.47	0.4	0.13	146	2L	7.4	2	-3
0.55	0.32	0.13	146	2	7.1	1	5
0.64	0.23	0.13	146	2	6.5	0	15
0.746	0.249	0.005	6	2	5.6	-1	24

wt-frac R1132(E)	wt-frac R1234ze (E)	wt-frac R-134	GWP AR5	ASHRAE flammab ility class	Glide (K)	COP _h (% dev from R- 454C)	CAP _h (% dev from R- 454C)
0.766	0.229	0.005	6	2	5.3	-1	26
0.955	0.005	0.04	45	2	1	-3	50
0.975	0.02	0.005	6	2	0.7	-3	51
0.98	0.01	0.01	11	2	0.5	-3	52
0.985	0.005	0.01	11	2	0.4	-3	53
0.985	0.01	0.005	6	2	0.4	-3	53

[0142] While the invention has been described with reference to a preferred embodiment, it will be understood by those skilled in the art that various changes may be made, and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

CLAIMS

What is claimed is:

1. A composition comprising HFO-1132 and at least one compound selected from the group consisting of HFC-32, HFC-134, and HFO-1234zeE.
2. The composition of claim 1, comprising at least one of:
 - HFO-1132E;
 - HFO-1132E and HFC-32;
 - HFO-1132E and HFC-134;
 - HFO-1132 and HFO-1234zeE;
 - HFO-1132E, HFC-32, and HFO-1234zeE;
 - HFO-1132E, HFC-32, and HFC-134;
 - HFO-1132E, HFC-134 and HFO-1234zeE;
 - HFO-1132E, HFC-32, HFO-1234zeE, and HFC-134
 - HFO-1132Z, HFC-32, and HFO-1234zeE;
 - HFO-1132E, HFO-1132Z, HFC-32, and HFO-1234zeE; and
 - HFO-1132E, HFO-1132Z, HFO-1234zeE, and HFC-134.
3. The composition of any of claims 1-2, comprising:
 - about 56 to about 99 weight percent of HFO-1132E and about 1 to about 44 weight percent HFC-32; or
 - about 78 to about 99 weight percent of HFO-1132E and about 1 to about 22 weight percent of HFC-32; or
 - about 56 to about 60 weight percent of HFO-1132E and about 40 to about 44 weight percent of HFC-32; or
 - about 56 weight percent HFO-1132E and about 44 weight percent HFC-32.
4. The composition of any of claims 1-2, comprising:
 - about 74 to about 99 weight percent of HFO-1132E and about 1 to about 26 weight percent HFC-134; or

about 87 to about 99 weight percent of HFO-1132E and about 1 to about 13 weight percent of HFC-134; or

about 74 weight percent HFO-1132E and about 26 weight percent HFC-134.

5. The composition of any of claims 1-2, comprising:

about 1 to about 99 weight percent of HFO-1132E and about 1 to about 99 weight percent HFO-1234zeE; or

about 42 to about 61 weight percent of HFO-1132E and about 39 to about 58 weight percent of HFO-1234zeE.

6. The composition of any of claims 1 or 2, comprising:

about 0.5 to about 98.5 weight percent of HFO-1132E, about 0.5 to about 98.5 weight percent of HFO-1234zeE, and about 0.5 to about 44 weight percent HFC-32; or

about 0.5 to about 98.5 weight percent of HFO-1132E, about 0.5 to about 98.5 weight percent of HFO-1234zeE, and about 1 to about 22 weight percent HFC-32; or

about 8 to about 60 weight percent of HFO-1132E, about 40 to about 70 weight percent of HFO-1234zeE, and about 0.5 to about 22 of HFC-32; or

about 50 weight percent HFO-1132E, about 43 weight percent HFO-1234zeE and about 7 weight percent HFC-32; or

about 8 weight percent HFO-1132E, about 70 weight percent HFO-1234zeE, and about 22 weight percent HFC-32; or

about 8 to about 42 weight percent HFO-1132E, about 46 to about 70 weight percent HFO-1234zeE and about 4 to about 22 weight percent HFC-32; or

about 32 weight percent HFO-1132E, about 49 weight percent HFO-1234zeE and about 19 weight percent HFC-32; or

about 8 weight percent HFO-1132E, about 70 weight percent HFO-1234zeE and about 22 weight percent HFC-32.

7. The composition of any of claims 1 or 2, comprising:

about 57 to about 98.5 weight percent of HFO-1132E, about 0.5 to about 26 weight percent HFC-134, and about 0.5 to about 43 weight percent HFC-32; or

about 79 to about 98.5 weight percent of HFO-1132E, about 0.5 to about 13 weight percent HFC-134, and about 0.5 to about 21 weight percent HFC-32; or

about 73 weight percent HFO-1132E, about 26 weight percent HFC-134 and about 1 weight percent HFC-32; or

about 86.6 weight percent HFO-1132E, about 12.9 weight percent HFC-134 and about 0.5 weight percent HFC-32; or

about 56.7 weight percent HFO-1132E, about 0.5 weight percent HFC-134 and about 42.8 weight percent HFC-32; or

about 78.6 weight percent HFO-1132E, about 0.5 weight percent HFC-134 and about 20.9 weight percent HFC-32.

8. The composition of any of claims 1 or 2, comprising:

about 0.5 to about 98.5 wt-% of HFO-1132E, about 0.5 to about 98.5 wt-% HFO-1234zeE, and about 0.5 to about 26 wt-% HFC-134; or

about 0.5 to about 98.5 wt-% of HFO-1132E, about 0.5 to about 98.5 wt-% HFO-1234zeE, and about 0.5 to about 13 wt-% HFC -134; or

about 40 to about 98.5 wt-% of HFO-1132E, about 0.5 to about 58 wt-% of HFO-1234zeE, and about 0.5 to about 13 of HFC -134; or

about 40 to about 47 wt-% HFO-1132E, about 40 to about 52 wt-% HFO-1234zeE, and about 7 to about 3 wt-% HFC -134; or

about 47 wt-% HFO-1132E, about 40 wt-% HFO-1234zeE and about 13 wt-% HFC -134; or

about 40 wt-% HFO-1132E, about 47 wt-% HFO-1234zeE and about 13 wt-% HFC -134; or

about 47 wt-% HFO-1132E, about 40 wt-% HFO-1234zeE and about 13 wt-% HFC -134.

9. The composition of any of claims 1 or 2, comprising:

0.25 to about 98.5 weight percent of HFO-1132E, 0.25 to about 98.5 weight percent of HFO-1234zeE, 0.25 to about 26 weight percent HFC-134, and 0.25 to about 44 weight percent HFC-32; or

0.25 to about 98.5 weight percent of HFO-1132E, 0.25 to about 98.5 weight percent of HFO-1234zeE, 0.25 to about 13 weight percent HFC-134, and 0.25 to about 21 weight percent HFC-32; or

about 9 to about 61 weight percent of HFO-1132E, about 28 to about 70 weight percent of HFO-1234zeE, 0.25 to about 13 weight percent of HFC-134, and 0.25 to about 21 weight percent of HFC-32; or

about 32 weight percent HFO-1132E, about 48 weight percent HFO-1234zeE, about 1 weight percent HFC-134, and about 19 weight percent HFC-32; or

about 9 weight percent HFO-1132E, about 69.6 weight percent HFO-1132E, about 0.5 weight percent HFC-134, and about 20.9 weight percent HFC-32; or

about 9 to about 48 weight percent HFO-1132E, about 36 to about 70 weight percent HFO-1234zeE, about 0.5 to about 13 weight percent HFC-134, and about 0.5 to about 21 weight percent HFC-32; or

about 32 weight percent HFO-1132E, about 48 weight percent HFO-1234zeE, about 1 weight percent HFC-134, and about 19 weight percent HFC-32; or

about 9 weight percent HFO-1132E, about 69.6 weight percent HFO-1132E, about 0.5 weight percent HFC-134, and about 20.9 weight percent HFC-32.

10. The composition of any of claims 1 or 2, comprising:

about 1 to 97 weight percent HFO-1132E, from about 1 to 97 weight percent HFO-1132Z, from about 1 to 44 weight percent HFC-32, and from about 1 to 97 weight percent HFO-1234zeE; or

about 1 to 97 weight percent HFO-1132E, from about 1 to 97 weight percent HFO-1132Z, from about 1 to 22 weight percent HFC-32, and from about 1 to 97 weight percent HFO-1234zeE; or

about 8 to 62 weight percent HFO-1132E, from about 1 to 67 weight percent HFO-1132Z, from about 1 to 22 weight percent HFC-32, and from about 1 to 70 weight percent HFO-1234zeE; or

about 8 to 41 weight percent HFO-1132E, from about 1 to 40 weight percent HFO-1132Z, from about 3 to 22 weight percent HFC-32, and from about 29 to 70 weight percent HFO-1234zeE; or

about 18 to 74 weight percent HFO-1132E, from about 1 to 54 weight percent HFO-1132Z, from about 1 to 22 weight percent HFC-32, and from about 1 to 59 weight percent HFO-1234zeE; or

about 18 to 45 weight percent HFO-1132E, from about 1 to 28 weight percent HFO-1132Z, from about 8 to 22 weight percent HFC-32, and from about 29 to 59 weight percent HFO-1234zeE.

11. The composition of any of claims 1 or 2, comprising:

about 1 to 69 weight percent HFO-1132Z, from about 28 to 44 weight percent HFC-32, and from about 1 to 72 weight percent HFO-1234zeE; or

about 1 to 69 weight percent HFO-1132Z, from about 28 to 44 weight percent HFC-32, and from about 1 to 72 weight percent HFO-1234zeE.

12. The composition of any of claims 1 or 2, comprising:

about 15 weight percent HFO-1132E, about 13 weight percent HFO-1132Z, about 21 weight percent HFC-32, and about 51 weight percent HFO-1234zeE; or

about 36 weight percent HFO-1132E, about 4 weight percent HFO-1132Z, about 16 weight percent HFC-32, and about 44 weight percent HFO-1234zeE; or

about 9 weight percent HFO-1132E, about 40 weight percent HFO-1132Z, about 22 weight percent HFC-32, and about 29 weight percent HFO-1234zeE; or

about 49 weight percent HFO-1132E, about 2 weight percent HFO-1132Z, about 7 weight percent HFC-32, and about 42 weight percent HFO-1234zeE; or

about 30 weight percent HFO-1132E, about 40 weight percent HFO-1132Z, about 22 weight percent HFC-32, and about 29 weight percent HFO-1234zeE;

about 21.5 weight percent HFO-1132E, about 65 weight percent HFO-1132Z, about 13 weight percent HFC-32, and about 0.5 weight percent HFO-1234zeE.

13. The composition of any of claims 1 to 12, further comprising at least one additional compound selected from methane, ethane, HCFC-22, HFC-23, HCC-30, HCFC-31, HCC-40, HFC-41, HFCF-22, HFO-1141, HFO-1225yeE, HFO-1225yeZ, HFO-1234yf, HFO-1243zf, HFC-161, HFC-152, HFC-143, HFC-143a, HFC-134a, HCFO-1122, HCFO-1122aE, HCFO-1122aZ, HCC-150, HCFC-151, CFO-1112E, CFO-1112Z, HCFC-142a, HCFC-132, HCFC-133, HCFC-133b, HCFC-123, HFC-236fa, HFC-245fa, HFC-245eb, HFO-1123, HFO-1132a, HCFO-1131E, HCFO-1131Z, ethylene, and acetylene.
14. The composition of any of claims 1 to 13, further comprising at least one additional compound selected from HCFC-22, HCC-40, HFO-1234yf, HFO-1243zf, HFC-245fa, and HFC-134a.
15. The composition of any of claims 1 to 14, wherein said composition further comprises from 0.1 to 200 ppm by weight of water; from about 10 ppm by volume to about 0.35 volume percent oxygen; and/or from about 100 ppm by volume to about 1.5 volume percent air or NAG.
16. The composition of any of claims 1 to 15, wherein said composition comprises a stabilizer.
17. The composition of claim 16, wherein the stabilizer is selected from the group consisting of nitromethane, ascorbic acid, terephthalic acid, azoles, phenolic compounds, cyclic monoterpenes, terpenes, phosphites, phosphates, phosphonates, thiols, and lactones.

18. The composition of any of claims 16 or 17, wherein the stabilizer is selected from toluotriazole, benzotriazole, tocopherol, hydroquinone, t-butyl hydroquinone, 2,6-di-terbutyl-4-methylphenol, fluorinated epoxides, n-butyl glycidyl ether, hexanediol diglycidyl ether, allyl glycidyl ether, butylphenylglycidyl ether, d-limonene, α -terpinene, β -terpinene, α -pinene, β -pinene, or butylated hydroxytoluene.
19. The composition of any of claims 16 to 18, wherein the stabilizer is present in an amount from about 0.001 to 1.0 weight percent based on the weight of the refrigerant.
20. The composition of any of claims 1 to 14, wherein the composition further comprises a lubricant.
21. The composition of claim 20, wherein said lubricant is at least one selected from the group consisting of polyalkylene glycol, polyol ester, poly- α -olefin, and polyvinyl ether.
22. The composition of claims 21, wherein said lubricant is a polyol ester or a polyvinyl ether.
23. The composition of any of claims 20 to 22, wherein said lubricant has at least one property selected from the group consisting of volume resistivity of greater than $10^{10} \Omega\cdot\text{m}$ at 20 °C; surface tension of from about 0.02 N/m to 0.04 N/m at 20 °C; kinematic viscosity of from about 20 cSt to about 500 cSt at 40 °C; a breakdown voltage of at least 25 kV; and a hydroxy value of at most 0.1 mg KOH/g.
24. The composition of any of claims 1 to 23, wherein the composition comprises at least one tracer.
25. The composition of claim 24, wherein said tracer is present in an amount from about 1.0 ppm by weight to about 1000 ppm by weight.
26. The composition of any of claims 24 or 25, wherein said at least one tracer is selected from the group consisting of hydrofluorocarbons, hydrofluoroolefins, hydrochlorocarbons, hydrochloroolefins, hydrochlorofluorocarbons, hydrochlorofluoroolefins, hydrochlorocarbons, hydrochloroolefins,

chlorofluorocarbons, chlorofluoroolefins, hydrocarbons, perfluorocarbons, perfluoroolefins, and combinations thereof.

27. The method of any of claims 24 to 26, wherein said at least one tracer is selected from the group consisting of HFC-23, HCFC-31, HFC-41, HFC-161, HFC-143a, HFC-134a, HFC-125, HFC-236fa, HFC-236ea, HFC-245cb, HFC-245fa, HFC-254eb, HFC-263fb, HFC-272ca, HFC-281ea, HFC-281fa, HFC-329p, HFC-329mmz, HFC338mf, HFC-338pcc, CFC-12, CFC-11, CFC-114, CFC-114a, HCFC-22, HCFC-123, HCFC-124, HCFC-124a, HCFC-141b, HCFC-142b, HCFC-151a, HCFC-244bb, HCC-40, HFO-1141, HCFO-1130, HCFO-1130a, HCFO-1131, HCFO-1122, HFO-1123, HFO-1234yf, HFO-1234ye, HFO-1243zf, HFO-1225ye, HFO-1225zc, PFC-116, PFC-C216, PFC-218, PFC-C318, PFC-1216, PFC-31-10mc, PFC-31-10my, and combinations thereof.
28. The composition of any of claims 1 to 27, 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.
29. A method for cooling comprising evaporating a composition of any of claims 1 to 28 in the vicinity of a body to be cooled and thereafter condensing said composition, wherein said cooling is provided by a refrigeration system.
30. A refrigeration system comprising a composition of any of claims 1 to 28.
31. A refrigeration system comprising a composition of any of claims 1 to 28, for use in high ambient applications, wherein outdoor temperatures are above about 35°C.
31. The system of claim 29 or 30, comprising an evaporator, compressor, condenser, and expansion device, each operably connected to perform a vapor compression cycle.
32. The system of claim 29, 30, or 31, wherein said refrigeration system is for residential, light commercial, or industrial refrigeration.

33. The system of any of claims 29 to to 32, wherein said system is for medium temperature refrigeration, low temperature refrigeration, or transport refrigeration.
34. A method of replacing R-454C in refrigeration systems comprising providing the composition of any of claims 1 to 28 to the system in place of R-454C.
35. Use of the composition of any of claims 1 to 28 as refrigerant in low temperature refrigeration systems, medium temperature refrigeration systems, and/or transport refrigeration systems.