TITLE OF THE INVENTION

COMPOSITIONS COMPRISING DIFLUOROPROPENE, TETRAFLUOROPROPENE, AND DIFLUOROMETHANE AND USES THEREOF

FIELD

[0001] The present disclosure relates to compositions useful as refrigerants, and in particular, for air-conditioning and heat pump systems. The compositions of the present disclosure are useful in methods for producing cooling and heating, and methods for replacing refrigerants in air-conditioning and heat pump 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 warming is another environmental concern in many of these applications. HFC refrigerants such as HFC-134a and HFC-125 respectively have global warming potentials (GWP) of 1,430 and 3,500 according to the UN's IPCC Fourth Assessment Report (AR4).

[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 also provide superior performance in a variety of applications, and which meet the standards of evolving regulations.

[0004] The present invention solves certain problems associated with conventional refrigerants and provides refrigerant blends containing 1,1-difluoropropene, which meet 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] Compositions disclosed herein relate to a fluoropropene composition comprising 1,1-difluoropropene (also called HFO-1252zc, or R-1252zc). This compound is shown herein to have advantageous properties for its use in refrigerant applications, such as air-conditioning and heat pumps. According to one embodiment, disclosed herein are compositions comprising HFO-1252zc, HFO-1234zeE, HFC-32, and at least one of HFC-134, HFC-134a, or CO_2., including:

HFO-1252zc, HFO-1234zeE, HFC-32, and HFC-134; or

HFO-1252zc, HFO-1234zeE, HFC-32, and CO2; or

HFO-1252zc, HFO-1234zeE, HFC-32, HFC-134, and CO2; or

HFO-1252zc, HFO-1234zeE, HFC-32, and HFC-134a; or

HFO-1252zc, HFO-1234zeE, HFC-32, HFC-134, and HFC-134a; or

HFO-1252zc, HFO-1234zeE, HFC-32, HFC-134a, and CO2.

[0007] The compositions of the above-described embodiment have a AGW of less than 300 or less than 150 or less than 149.

[0008] The compositions of the above-described embodiment have an average temperature glide of no more than 10.0 K.

[0009] The compositions of the above-described embodiment are classified as class 1, class 2L, class 2, or class 3, by ASHRAE for flammability.

[0010] According to one embodiment, the compositions of any of the above-described embodiments further comprise at least one additional compound selected from HCFC-22, HFC-23, HCC-30, HCFC-31, HCC-40, HFC-41, methane, HFC-125, HFC-134a, HFC-143, HFC-143a, HFC-152a, HFC-245cb, HCFC-253dc, HFC-254fb, HCC-260fb, HCFC-261fc, HCFC-262fc, HFC-263fb, HFC-272fb, propane, HFO-374, n-butane, allene, 2-butene, cyclobutene, 2-methyl propene, HCFO-1122, HFO-1132, HFO-1132a, HFO-1141, ethylene, HCFO-1233xf, HFO-1234yf, HCFO-1242zf, HFO-

1243zf, HCFO-1251, HCO-1260zf, HFO-1261zf, propylene, HFO-1345, HFO-1252ze, HFO-1252yf, HFO-1252zf, HFO-1252ye, and E/Z-t-BuO-CF=CH-CH_3.

[0011] According to one embodiment, the compositions of any of the above-described embodiments further comprise at least one additional compound selected from HCFC-22, HCC-40, HFO-1234yf, HFO-1243zf, HFC-263fb, HFO-1252ze, HFO-1252yf, HFO-1252zf, or HFO-1252ye.

[0012] According to an embodiment, the compositions of any of the above-described embodiments further comprise 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.

[0013] According to an embodiment, the compositions of any of the above-described embodiments further comprising a stabilizer, preferably one or more from the group consisting of nitromethane, ascorbic acid, terephthalic acid, azoles, phenolic compounds, cyclic monoterpenes, terpenes, phosphites, phosphates, phosphonates, thiols, and lactones, or preferably one or more from the group consisting of 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. When present, the stabilizer is present in an amount from about 0.001 to 1.0 weight percent based on the weight of the refrigerant.

[0014] According to an embodiment, the compositions of the any of the above-described embodiments further comprises a lubricant, preferably selected from one or more of the group consisting of polyalkylene glycol, polyol ester, poly-α-olefin, and polyvinyl ether, or preferably a polyol ester or a polyvinyl ether.

[0015] According to an embodiment, the compositions of any of the above-described embodiments includes a lubricant that has at least one property selected from the group consisting of volume resistivity of greater than 10^{10} Ω-m at 20 ºC; surface tension of from about 0.02 N/m to 0.04 N/m at 20 ºC; kinematic viscosity of from about 20 cSt to about 500 cSt at 40 ºC; a breakdown voltage of at least 25 kV; and a hydroxy value of at most 0.1 mg KOH/g.

[0016] According to an embodiment, the compositions of any of the above-described embodiments comprises at least one tracer, preferably present in an amount from about 1.0 ppm by weight to about 1000 ppm by weight and preferably selected from one or more of the group consisting of hydrofluorocarbons, hydrofluoroolefins, hydrochlorocarbons, hydrochloroolefins, hydrochlorofluorocarbons, hydrochlorofluoroolefins, hydrochlorocarbons, hydrochloroolefins, chlorofluorocarbons, chlorofluoroolefins, hydrocarbons, perfluorocarbons, perfluoroolefins, and combinations thereof.

[0017] According to an embodiment, any of the compositions of the above-described embodiments, further comprise at least one tracer 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.

[0018] According to an embodiment, the compositions of any of the above-described embodiments 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.

[0019] According to an embodiment, also disclosed herein are methods for cooling comprising evaporating the composition of any of the above-described embodiments in the vicinity of a body to be cooled and thereafter condensing said composition, wherein said cooling is provided by an air-conditioner or heat pump.

[0020] According to an embodiment, also disclosed herein are methods for heating comprising evaporating the composition any of the above-described embodiments and thereafter condensing said composition in the vicinity of a body to be heated, wherein said heating is provided by a heat pump.

[0021] According to an embodiment, also disclosed herein are systems for cooling or heating comprising the composition of any of the above-described embodiments. In another embodiment, the systems comprise an evaporator, compressor, condenser, and expansion device, each operably connected to perform a vapor compression cycle. In another embodiment, said air-conditioner or heat pump is a residential, light commercial, or industrial air-conditioner or heat pump. In another embodiment, the system may be a secondary system.

[0022] According to an embodiment, also disclosed herein is a method of replacing R-454C, propane, or R-410A in air-conditioning or heat pump systems comprising providing the composition of any of the above-described embodiments.

[0023] According to an embodiment, also disclosed herein is the use of the composition of any of the above-described embodiments in air-conditioning or heat pump systems.

DETAILED DESCRIPTION

[0024] This invention relates to compositions containing 1,1-difluoropropene (HFO-1252zc), difluoromethane (HFC-32), E-1,3,3,3-tetrafluoropropene (HFO-1234zeE), and at least one of 1,1,2,2-tetrafluoroethane (HFC-134), 1,1,1,2-tetrafluoroethane (HFC-134a), or carbon dioxide (CO_2). The compositions may potentially be candidates to replace refrigerants such as R-454C, R-410A, or propane with low Global Warming Potential (GWP), improved environmental fate characteristics, and improved energy efficiency (COP).

[0025] The compositions comprise, consist of, or consist essentially of HFO-1252zc, HFO-1234zeE, HFC-32, and at least one of HFC-134, HFC-134a, or CO_2. They provide refrigerant blends with low global warming potential and improved coefficient of performance as compared to existing refrigerants and other proposed replacements.

[0026] 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.

[0027] 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.

[0028] 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 air-conditioning and heat pump systems.

[0029] 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.

[0030] 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).

[0031] 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).

[0032] 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).

[0033] 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.

[0034] The net refrigeration effect is the quantity of heat that each kilogram of refrigerant absorbs in the evaporator to produce useful cooling.

[0035] 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.

[0036] 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.

[0037] 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-1252zc is estimated at 1.

[0038] 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-1252zc has zero ozone depletion potential.

[0039] 1,1-Difluoropropene (HFO-1252zc or R-1252zc) may be prepared by hydrogenation of 3,3,3-trifluoropropene (HFO-1243zf) over palladium on carbon catalyst to form 1,1,1-trifluoropropane (HFC-263fb), followed by dehydrofluorination of the HFC-263fb over chrome catalyst or by pyrolysis at high temperatures (see attorney docket number FL2084, filed herewith, and herein incorporated by reference).

[0040] E-1,3,3,3-Tetrafluoropropene (HFO-1234zeE or R-1234zeE) is available commercially from Honeywell (Charlotte, North Carolina, USA). And difluoromethane (HFC-32 or R-32), 1,1,2,2-tetrafluoroethane (HFC-134 or R-134), 1,1,1,2-tetrafluoroethane (HFC-134a, R-134a), and carbon dioxide (CO_2) are available commercially from various sources worldwide.

[0041] 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.

[0042] 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.

[0043] 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.

[0044] 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.

[0045] 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

[0046] In one embodiment, compositions comprise, consist of, or consist essentially of HFO-1252zc, HFO-1234zeE, HFC-32, and at least one of HFC-134, HFC-134a, or CO_2. These compositions provide low Global Warming Potential (GWP), improved environmental fate characteristics, and improved energy efficiency (COP). Additionally, many of the presently disclosed compositions provide capacity within 20% of that for R-454C.

[0047] In another embodiment, the compositions comprise, consist of, or consist essentially of:

HFO-1252zc, HFO-1234zeE, HFC-32, and HFC-134; or

HFO-1252zc, HFO-1234zeE, HFC-32, and CO_2; or

HFO-1252zc, HFO-1234zeE, HFC-32, HFC-134, and CO2; or

HFO-1252zc, HFO-1234zeE, HFC-32, and HFC-134a; or

HFO-1252zc, HFO-1234zeE, HFC-32, HFC-134, and HFC-134a; or

HFO-1252zc, HFO-1234zeE, HFC-32, HFC-134a, and CO_2.

[0048] With respect to the percentages of components in the compositions, all percentages are understood to be percent weight.

[0049] In an embodiment, the compositions comprise, consist of, or consist essentially of: about 1-30% HFO-1252zc, about 48-82% HFO-1234zeE, about 15-22% HFC-32, and about 1-4% HFC-134; or about 0.2-98.5% HFO-1252zc, about 0.2-98.5% of HFO-1234zeE, about 0.2-26.0% HFC-134, and about 0.2-43.8% HFC-32; or about 0.2-98.5% of HFO-1252zc, about 0.2%-98.5% of HFO-1234ze(E), about 0.2-12.9% of HFC-134, and about 0.2%-20.9% of HFC-32; or about 19.9-84.6% of HFO-1252zc, about 0.2-58.7% of HFO-1234ze(E), about 0.2-3.0% of HFC-134, and about 14.9%-20.9% of HFC-32; or about 19.9-22.9% of HFO-1252zc, about 55.7-58.7% of HFO-1234ze(E), about 0.5% of HFC-134, and about 20.9% of HFC-32; or about 22.9% HFO-1252zc, about 55.7% HFO-1234ze(E), about 0.5% HFC-134 and

about 20.9% HFC-32; or about 19.9% HFO-1252zc, about 58.7% HFO-1234ze(E), about 0.5% HFC-134, and about 20.9% HFC-32; or 1.0-21.0% HFO-1252zc, 64.0-92.0% HFO-1234ze(E), 1.0-11.0% HFC-134, and 1.0-9.0% HFC-32; or 15.0-21.0% HFO-1252zc, 63.0-76.0% HFO-1234zeE, 1.0-8.0% HFC-134, and 7.0-9.0% HFC-32; or 15.0-19.0% HFO-1252zc, 68.0-72.0% HFO-1234ze(E), 3.0-7.0% HFC-134, and 6.0-10.0% HFC-32; or about 17.0% HFO-1252zc, about 70.0% HFO-1234ze(E), about 5.0% HFC-134, and about 8.0% HFC-32.

[0050] In another embodiment, the compositions comprise, consist of, or consist essentially of: about 13 to 30% HFO-1252zc, about 54 to 72% HFO-1234zeE, about 8 to 14% HFC-32, and about 1 to 4% CO2; or about 13 to about 30% HFO-1252zc, about 54 to about 72% HFO-1234zeE, about 8 to about 14% HFC-32, and about 1 to about 4% CO2; or about 0.2-98.5% of HFO-1252zc, about 0.2-98.5% of HFO-1234ze(E), about 0.2-44.0% of HFC-32, and about 0.2%-8.0% of CO2 ; or about 0.2-98.5% of HFO-1252zc, about 0.2-98.5% of HFO-1234ze(E), about 0.2-22.0% of HFC-32, and about 0.2-3.0% of CO2; or about 27.9-84.6% of HFO-1252zc, about 0.2-51.7% of HFO-1234ze(E), about 11.0-22.0% of HFC-32, and about 0.2-2.0% of CO2; or about 27.9-64.7% of HFO-1252zc, about 12.9-51.7% of HFO-1234ze(E), about 15.0-22.0% of HFC-32, and about 0.5-1.0% of CO2; or about 64.0% HFO-1252zc, about 13.0% HFO-1234ze(E), about 22.0% HFC-32, and about 1.0% CO2; or about 27.9% HFO-1252zc, about 51.7% HFO-1234ze(E), about 19.9% HFC-32, and about 0.5% CO2.

[0051] In another embodiment, the compositions comprise, consist of, or consist essentially of: about 5 to 30% HFO-1252zc, about 46 to 77% HFO-1234zeE, about 5 to 22% HFC-32, about 1 to 10% HFC-134, and about 1 to 4% CO_2; or about 1 to 21% HFO-1252zc, about 42 to 82% HFO-1234zeE, about 11 to 22% HFC-32, about 1 to 6% HFC-134, and about 1 to 3% CO_2; or about 0.2-98.5% of HFO-1252zc, about 0.2-98.5% of HFO-1234ze(E), about 0.2-26.0% of HFC-134, about 0.2-43.8% of HFC-32, and about 0.2-3.0% of CO2; or about 0.2-98.5% of HFO-1252zc, about 0.2-98.5% of HFO-1234ze(E), about 0.2-12.9% of HFC-134, about 0.2-20.9% of HFC-32, and about 0.2-3.0% of CO2; or about 24.9-84.6% of HFO-1252zc, about 0.2-53.7% of HFO-1234ze(E), about 0.2-6.0% of HFC-134, about 11.0-20.9% of HFC-32, and about 0.2-2.0% of CO2; or about 24.9-63.7% of HFO-1252zc, about 13.9-53.7% of HFO-1234ze(E), about 0.2-5.0% of HFC-134, about 13.0-20.9% of

HFC-32, and about 0.2-2.0% of CO2; or about 6.0-20.0% of HFO-1252zc, about 55.0-73.0% of HFO-1234zeE, about 11.0-22.0% of HFC-32, and about 1.0-2.0% of CO2; or about 5-30% HFO-1252zc, about 46-77% HFO-1234zeE, about 5-22% HFC-32, about 1-10% HFC-134, and about 1-4% CO2; or about 1-21% HFO-1252zc, about 42-82% HFO-1234zeE, about 11-22% HFC-32, about 1-6% HFC-134, and about 1-3% CO2; or about 63.7% HFO-1252zc, about 13.9% HFO-1234ze(E), about 0.5% HFC-134, about 20.9% HFC-32, and about 1.0% CO2; or about about 24.9% HFO-1252zc, about 53.7% HFO-1234ze(E), about 0.2% HFC-134, about 20.9% HFC-32, and about 0.2% CO2.

[0052] In another embodiment, the compositions comprise, consist of, or consist essentially of: about 1 to 21% HFO-1252zc, about 57 to 82% HFO-1234zeE, about 16 to 22% HFC-32, and about 1 to 3% HFC-134a; or about 0.1-21.0% HFO-1252zc, about 58.0-80.0% HFO-1234zeE, about 16.0-20.0% HFC-32, and about 1.0-3.0% HFC-134a.

[0053] In another embodiment, the compositions comprise, consist of, or essentially consist of: about 1.0-96.0% of HFO-1252zc, about 1.0-96.0% of HFO-1234ze(E), about 1.0-40.0% of HFC-32, about 1.0-24.0% of HFC-134, and about 1.0-21.0% of HFC-134a; or about 1.0-96.0% of HFO-1252zc, about 1.0-96.0% of HFO-1234ze(E), about 1.0-18.0% of HFC-32, about 1.0-11.0% of HFC-134, and about 1.0-10.0% of HFC-134a; or about 36.0-82.0% of HFO-1252zc, about 1.0-44.0% of HFO-1234ze(E), about 15.0-18.0% of HFC-32, about 1.0-3.0% of HFC-134, about 1.0-2.0% of HFC-134a; or about 36.0-63.0% of HFO-1252zc, about 17.0-44.0% of HFO-1234ze(E), about 16.0-18.0% of HFC-32, about 1.0-2.0% of HFC-134, and about 1.0-2.0% of HFC-134a; or about 63.0% HFO-1252zc, about 17.0% HFO-1234ze(E), about 1.0% HFC-134, about 1.0% HFC-134a, and about 18.0% HFC-32; or about 53.0% HFO-1252zc, about 28.0% HFO-1234ze(E), about 16.0% HFC-32, about 2.0% HFC-134, and about 1.0% HFC-134a; or about 1.0% to 96.0% of HFO-1252zc, about 1.0% to 96.0% of HFO-1234ze(E), about 1.0% to 40.0% of HFC-32, about 1.0% to 25.0% of HFC-134, and about 1.0% to 21.0% of HFC-134a; or about 1.0% to 96.0% of HFO-1252zc, about 1.0% to 96.0% of HFO-1234ze(E), about 1.0% to 18.0% of HFC-32, about 1.0% to 11.0% of HFC-134, and about 1.0% to 10.0% of HFC-134a; or about 45.0% to 81.0% of HFO-1252zc, about 1.0% to 35.0% of HFO-1234zeE, about 16.0% to 18.0% of HFC-32, about 1.0% to 2.0% of

HFC-134, and about 1.0% to 2.0% of HFC-134a; or about 45.0% to 63.0% of HFO-1252zc, about 17.0% to 35.0% of HFO-1234zeE, about 17.0% to 18.0% of HFC-32, about 1.0% to 1.0% of HFC-134, and about 1.0% to 1.0% of HFC-134a; or about 63.0% HFO-1252zc, about 17.0% HFO-1234zeE, about 18.0% HFC-32, about 1.0% HFC-134, about 1.0% HFC-134a; or about 54.0% HFO-1252zc, about 27.0% HFO-1234zeE, about 17.0% HFC-32, about 1.0% HFC-134, and about 1.0% HFC-134a.

[0054] In another embodiment, the compositions comprise, consist of, or essentially consist of: about 2.0% to 92.0% of HFO-1252zc, 2.0% to 92.0% of HFO-1234ze(E), 2.0% to 40.0% of HFC-32. 2.0% to 22.0% of HFC-134a, and 2.0% to 78.0% of CO2; or about 2.0% to 92.0% of HFO-1252zc, 2.0% to 92.0% of HFO-1234ze(E), 2.0% to 18.0% of HFC-32, 2.0% to 10.0% of HFC-134a, and 2.0% to 78.0% of CO2; or about 34.0% to 84.0% of HFO-1252zc, 2.0% to 46.0% of HFO-1234ze(E), 10.0% to 18.0% of HFC-32, 2.0% to 6.0% of HFC-134a, and 2.0% to 2.0% of CO2; or about 34.0% to 62.0% of HFO-1252zc, 16.0% to 46.0% of HFO-1234ze(E), 12.0% to 18.0% of HFC-32, 2.0% to 4.0% of HFC-134a, and 2.0% to 2.0% of CO2; or about 62.0% HFO-1252zc, 16.0% HFO-1234ze(E), 18.0% HFC-32, 2.0% HFC-134a, and 2.0% CO2; or about 46.0% HFO-1252zc, 38.0% HFO-1234ze(E), 12.0% HFC-32, 2.0% HFC-134a, and 2.0% CO2; or about 2.0% to 92.0% of HFO-1252zc, 2.0% to 92.0% of HFO-1234ze(E), 2.0% to 40.0% of HFC-32, and 2.0% to 22.0% of HFC-134a, and 2.0% to 92.0% of CO2; or about 28.0% to 82.0% of HFO-1252zc, 2.0% to 40.0% of HFO-1234ze(E), 4.0% to 28.0% of HFC-32, 2.0% to 20.0% of HFC-134a, and 2.0% to 4.0% of CO2; or about 28.0% to 66.0% of HFO-1252zc, 2.0% to 40.0% of HFO-1234ze(E), 4.0% to 28.0% of HFC-32, 2.0% to 20.0% of HFC-134a, and 2.0% to 4.0% of CO2; or about 52.0% HFO-1252zc, 14.0% HFO-1234ze(E), 26.0% HFC-32, 6.0% HFC-134a, and 2.0% CO2; or about 58.0% HFO-1252zc, 26.0% HFO-1234ze(E), 12.0% HFC-32, 2.0% HFC-134a, and 2.0% CO2.

[0055] The compositions disclosed herein provide GWP less than or equal to 300 or less than equal to 150 or less than or equal to 149, a COP comparable to or improved over R-454C, and cooling capacity comparable to or within 20% of that for R-454C. Additionally, the compositions provide acceptable average temperature glide and reasonable compressor discharge temperatures. Further, the

compositions as defined above are estimated to be classified as class 1 or 2 or 2L for flammability by ASHRAE.

[0056] 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.

[0057] 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/ft^3 (0.10 kg/m^3); 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.

[0058] 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/ft^3 (0.10 kg/m^3); and 3) have a heat of combustion <8169 Btu/lb (19,000 kJ/kg).

[0059] 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.

[0060] HFO-1252zc can be combined with HFC-32 and HFO-1234zeE and at least one of HFC-134, HFC-134a, and/or CO_2 and provide estimated class 1 or class 2 or class 2L flammability as defined by ANSI/ASHRAE standard 34 and ISO 817. Class 2 and class 2L flammability may be manageable in refrigeration systems. Specific applications may have different requirements, with regards to flammability.

[0061] The compositions disclosed herein comprising, consisting of, or consisting essentially of HFO-1252zc, HFO-1234zeE, HFC-32, and at least one of HFC-134, HFC-134a, or CO_2, are estimated to be classified as class 2L flammability.

[0062] Any of the above-mentioned embodiments directed to compositions comprising, consisting of, or consisting essentially of HFO-1252zc, HFO-1234zeE, HFC-32, and at least one of HFC-134, HFC-134a, or CO_2 may further comprise at least one additional compound from the list in Table A

TABLE A

Code	Name-ASHRAE Designation	Formula
R-22	chlorodifluoromethane	CHF_2Cl
R-23	trifluoromethane (HFC-23)	CHF_3
R-30	dichloromethane (HCC-30)	CH_2Cl_2
R-31	chlorofluoromethane (HCFC-31)	CH_2FCl
R-40	methyl chloride (HCC-40)	CH_3Cl
R-41	Fluoromethane (HFC-41)	CH_3F
R-50	methane	CH_4
R-125	1,1,2,2,2-pentafluoroenthane (HFC-125)	CF_2CF_3
R-134a	1,1,1,2-tetrafluoroethane (HFC-134a)	CH_2FCF_3
R-143	1,1,2-trifluoroethane (HFC-143)	CF_2CH_2F
R-143a	1,1,1-trifluoroethane(HFC-143a)	CF_3CH_3
R-152a	1,1,difluoroethane (HFC-152a)	CHF_2CH_3
R-245cb	1,1,1,2,2-pentafluoropropane (HFC-245cb)	$CF_3CF_2CH_3$
R-253dc	2-chloro-1,1,1-trifluoropropane (HCFC-253dc)	$CF_3CHClCH_3$
R-254fb	1,1,1,3-tetrafluoropropane (HFC-254fb)	$CF_3CH_2CH_2F$
R-260fb	1,1,1-trichloropropane (HCC-260fb)	$CCl_3CH_2CH_3$
R-261fc	1,1-dichloro-1-fluoropropane (HCFC-261fc)	$CCl_2FCH_2CH_3$
R-262fc	1-chloro-1,1-difluoropropane (HCFC-262fc)	$CClF_2CH_2CH_3$
R-263fb	1,1,1-trifluoropropane (HFC-263fb)	$CF_3CH_2CH_3$
R-272fb	1,1-difluoropropane (HFC-272fb)	$CHF_2CH_2CH_3$
R-290	propane (HC-290)	$CH_3CH_2CH_3$
R-374	tetrafluorobutene (HFO-374)	$C_4H_6F_4$
R-600	butane (HC-600)	$CH_3CH_2CH_2CH_3$
	allene	$H_2C=C=CH_2$
	2-butene	$CC_3CH=CHCH_3$
	cyclobutene	C_4H_6
	2-methylpropene	$CH_3(CH_3)C=CF_3$
R-1122	1-chloro-2,2-difluoroethylene (HCFO-1122)	$CHCl=CF_2$
R-1132	1,2-difluoroethene (HFO-1132)	CHF=CHF
R-1132a	1,1-difluorothene ((HFO-1132a)	$CH=CF_2$

Code	Name-ASHRAE Designation	Formula
R-1141	fluoroethene (HFO-1141)	CH_2=CHF
R-1150	ethylene (HO-1150)	CH_2=CH_2
R-1233xf	2-chloro-3,3,3-trifluoropropene (HCFO-1233xf)	CF_3CCl=CH_2
R-1234yf	2,3,3,3-tetrafluoropropene(HFO-1234yf)	CF3CH=CHF
R-1242zf	3-chloro-3,3-difluoropropene (HCFO-1242zf)	$CClF_2CH$=CH_2
R-1243zf	3,3,3-trifluoropropene (HFO-1243zf)	CF_3CH=CH_2
R-1251	HCFO-1251 isomer	C_3H_4FCl
R-1251	HCFO-1251 isomer	C_3H_4FCl
R-1252ze	1,3-difluoropropene (HFO-1252ze)	CH_2FCH=CHF
R-1252yf	2,3-difluoropropene (HFO-1252yf)	CH_2FCF=CH_2
R-1252zf	3,3-difluoropropene (HFO-1252zf)	CHF_2CH=CH_2
R-1252ye	1,2-difluoropropene (HFO1252ye)	CH_3CF=CHF
R-1260zf	3-chloropropene (HCO-1260zf)	CH_2ClCH=CH_2
R-1261	3-fluoro-1-propene (HFO-1261)	CH_2FCH=CH_2
R-1270	propylene (HO-1270)	CH_3CH=CH_2
R-1345	pentafluorobutene (HFO-1345)	$C_4H_3F_5$
	E/Z-*t*-BuO-CF=CH-CH_3	E/Z-t-BuO-CF=CH-CH_3

[0063] In an embodiment, any of the compositions of the above-mentioned embodiments further comprise at least one additional compound selected from HCFC-22, HCC-40, HFC-134a, HFO-1234yf, HFO-1243zf, HFO-263fb, HFO-1252ze, HFO-1252yf, HFO-1252zf, and HFO-1252ye. In another embodiment, any of the compositions of the above-mentioned embodiments further comprise at least one additional compound comprising HFO-1234yf. In another embodiment, any of the compositions of the above-mentioned embodiments further comprise at least one additional compound comprising HFO-1243zf. In another embodiment, any of the compositions of the above-mentioned embodiments further comprise at least one additional compound comprising HFO-263fb.

[0064] Some of the compounds present in the compositions of the present invention identified in Table 1 may exist as different configurational isomers or stereoisomers. The present invention is intended to include all single configurational isomers, single stereoisomers or any combination or mixture thereof. For instance, 1,2-difluoroethene (HFO-1132) is meant to represent the cis-isomer (Z), trans-isomer (E), or any combination or mixture of both isomers in any ratio. Single isomers or multiple isomers of the same compound may be used in any proportion.

[0065] The amounts 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.

[0066] 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.

[0067] The compositions comprising, consisting of, or consisting essentially of HFO-1252zc, HFO-1234zeE, HFC-32, and at least one of HFC-134, HFC-134a, or CO_2 will perform more consistently and be more stable with only minor amounts of water present. Thus, in an embodiment, the compositions of any of the above-mentioned embodiments 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.

[0068] Additionally, the compositions comprising, consisting of, or consisting essentially of HFO-1252zc, HFO-1234zeE, HFC-32, and at least one of HFC-134, HFC-134a, or CO_2 will perform more consistently and be more stable with only minor amounts of oxygen or air present. Therefore, in another embodiment, the compositions of any of the above-mentioned embodiments 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.

[0069] In another embodiment, the compositions of any of the above-mentioned embodiments also contains 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.

[0070] 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.

[0071] In embodiments, the compositions of the above-mentioned embodiments 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.

[0072] 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.

[0073] 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.

[0074] In another embodiment, the compositions of any of the above-described embodiments further comprise at least one lubricant. Lubricants may be selected from polyol ester, polyvinyl ether, and polyalkylene glycol. Lubricants may also comprise those commonly known as “mineral oils” in the field of compression

refrigeration lubrication. Mineral oils comprise paraffins (i.e. straight-chain and branched-carbon-chain, saturated hydrocarbons), naphthenes (i.e. cyclic or ring structure saturated hydrocarbons, which may be paraffins) and aromatics (i.e. unsaturated, cyclic hydrocarbons containing one or more rings characterized by alternating double bonds). Lubricants of the present invention further comprise those commonly known as “synthetic oils” in the field of compression refrigeration lubrication. Synthetic oils comprise alkylaryls (i.e. linear and branched alkyl alkylbenzenes), synthetic paraffins and naphthenes, silicones, and polyalphaolefins. Representative conventional lubricants of the present invention are the commercially available BVM 100 N (paraffinic mineral oil sold by BVA Oils), napthenic 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.

[0075] 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.

[0076] In one particular embodiment, the compositions of any of the above-described embodiments are combined with a PAG lubricant or a PVE lubricant or a POE lubricant for usage in an air-conditioning system or heat pump system. 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. If lubricant compatibility is an issue, a system may optionally include an oil separator in order to function more reliably.

[0077] In another embodiment, the compositions of any of the above-described embodiments is 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. 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. 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.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. 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.

[0078] 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).

[0079] 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.

[0080] Mouli et al. (WO 2008/027595 and WO 2009/042847) teaches 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.

[0081] 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, CF_3I, and/or Krytox® lubricants, also incorporated by reference and described in patent application "Refrigerant compositions comprising fluoroolefins and uses thereof WO2009018117A1."

[0082] In one embodiment, as used herein, " Group A Fluorinated Substances" includes any substance that (i) contains at least one fully fluorinated methyl ($–CF_3$) or methylene ($–CF_2–$) carbon atom (without any H/Cl/Br/I attached to it); and (ii) meets the criterion for persistence in soil/sediment and water established in Annex XIII (Section 1.1.1) of the European Union's REACH Regulation (https://reachonline.eu/reach/en/annex-xiii-1-1.1-1.1.1.html as accessed on May 2, 2023) and referenced in the Annex XV Restriction Report dated March 22, 2023, the disclosure of which is hereby incorporated by reference (https://echa.europa.eu/documents/10162/f605d4b5-7c17-7414-8823-b49b9fd43aea

as accessed on May 2, 2023). In one embodiment, Group A Fluorinated Substances include, but are not limited to, trifluoroacetic acid (TFA).

[0083] As used herein, "Group A Fluorinated Substances" includes any substance that has a Henry's Law constant ≤ 250 Pa*m^3/mol and contains at least one fully fluorinated methyl (–CF_3) or methylene (–CF_2–) carbon atom (without any H/Cl/Br/I attached to it). In one embodiment, Group A Fluorinated Substances include, but are not limited to, TFA.

[0084] Thus, according to some embodiments, compositions of any of the above-described embodiments 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.

[0085] Further, in some embodiments, degradation products of compositions of any of the above-described embodiments 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.

METHODS AND SYSTEMS

[0086] The compositions comprising, consisting of, or consisting essentially of HFO-1252zc, HFO-1234zeE, HFC-32, and at least one of HFC-134, HFC-134a, or CO_2 are useful in numerous methods and systems that provide air-conditioning and heating.

[0087] In one embodiment, provided is a method of cooling comprising evaporating a composition comprising, consisting of, or consisting essentially of HFO-1252zc, HFO-1234zeE, HFC-32, and at least one of HFC-134, HFC-134a, or CO_2 in the vicinity of a body to be cooled and thereafter condensing said composition, wherein said cooling is provided by an air-conditioner or heat pump.

[0088] In one embodiment, the air conditioner may be a residential, commercial, or industrial air-conditioning system. These may include, but are not limited to, window, ducted, ductless, packaged terminal, and those exterior to, but connected to the building, such as rooftop systems. The present method may be particularly useful in high ambient temperature regions, due to the high critical temperature of blends

containing HFO-1252zc, HFO-1234zeE, HFC-32, and at least one of HFC-134, HFC-134a, or CO_2.

[0089] In another embodiment, provided is a method of heating comprising evaporating a composition comprising HFO-1252zc, HFO-1234zeE, HFC-32, and at least one of HFC-134, HFC-134a, or CO_2 and thereafter condensing said composition in the vicinity of a body to be heated, wherein said heating is provided by a heat pump.

[0090] In one embodiment, the heat pump is a residential, light commercial or industrial heat pump system. These may include, but are not limited to, residential heat pumps that provide comfort air-conditioning and heating, hot water heat pumps for heating air (by secondary loop) or for heating water for residential or commercial use, heat pumps for heating manufacturing process equipment, and high temperature heat pumps. Due to the high critical temperature of blends containing HFO-1252zc, HFO-1234zeE, HFC-32, and at least one of HFC-134, HFC-134a, or CO_2 it is possible to heat water to higher temperatures than propane or R-454C or R-410A.

[0091] In another embodiment, the method for producing cooling is particularly useful in regions where the ambient temperature can exceed at least 35ºC.

[0092] In geographic areas with high ambient temperatures, where air conditioning becomes essential, refrigerant compositions with high critical temperatures and high thermal stability are desirable. Currently available hydrofluorocarbon (HFC) refrigerants such as R-410A, R-407C or R-32 have relatively low critical temperatures. As a consequence, these refrigerants do not perform well in extreme hot environments. The energy efficiency of a refrigerant generally decreases as the condensing temperature approaches the refrigerant critical temperature during operation at high ambient temperatures. In hot climates, R-22 has remained the refrigerant of choice for much air conditioning and refrigeration applications as it is not flammable and has a higher critical temperature so that it delivers higher cooling capacity and higher energy efficiency in hot climates as compared to R-410A or R-32. However, R-22 is an ozone depleting substance in the Montreal Protocol to reduce ozone depletion. As such, R-22 has been mandated and legislated for phase out for manufacture for and use in air conditioning and refrigeration. There is interest

in finding a refrigerant with the lowest possible direct GWP and also that performs well in hot climate (or high ambient) temperature regions.

[0093] In the method for producing cooling the body to be cooled may be defined as any space, location, object, or body for which it is desirable to provide cooling. Examples include spaces, open or enclosed, that require cooling such as a residence, such as an apartment or apartment building, university dormitory, townhouse or other attached house, or a single-family home; or the body to be cooled may be any other building, such as an office building, supermarket, college or university classroom or administration buildings.

[0094] In another embodiment, a method for producing air conditioning in high ambient temperatures is provided. The method comprises evaporating a composition comprising, consisting of, or consisting essentially of HFO-1252zc, HFO-1234zeE, HFC-32, and at least one of HFC-134, HFC-134a, or CO_2 and thereafter condensing said composition. The method is particularly useful in regions where ambient temperatures can exceed 35ºC or more.

[0095] In another embodiment, a method is provided for replacing HCFC-22 in high ambient air conditioning apparatus comprising providing a composition comprising, consisting essentially of, or consisting of HFO-1252zc, HFO-1234zeE, HFC-32, and at least one of HFC-134, HFC-134a, or CO_2 to said apparatus. The method of replacing HCFC-22 is particularly useful in regions where ambient temperatures can exceed 35ºC or more.

[0096] Similarly, in some industrial air conditioning applications heat must be released in high ambient temperature environments. HCFC-124 has been used as the working fluid in such applications. HCFC-124 is also controlled under the Montreal protocol as an ozone depleting substance and more environmentally sustainable replacements are desirable. Thus, a method is provided for replacing HCFC-124 in industrial air conditioning apparatus, comprising providing a composition comprising, consisting essentially of, or consisting of HFO-1252zc, HFO-1234zeE, HFC-32, and at least one of HFC-134, HFC-134a, or CO_2 to said apparatus. The method of replacing HCFC-124 is particularly useful in regions where ambient temperatures can exceed 35ºC or more.

[0097] In another embodiment, the method for producing cooling and method for replacing HCFC-22 or HCFC-124 are useful for systems operating in ambient temperatures of 40ºC or higher. In another embodiment, the method for producing cooling is useful for systems operating in ambient temperatures of 45ºC or higher. In another embodiment, the method for producing cooling is useful for systems operating in ambient temperatures of 50ºC or higher. In another embodiment, the method for producing cooling is useful for systems operating in ambient temperatures of 55ºC or higher. In another embodiment, the method for producing cooling is useful for systems operating in ambient temperatures of 60ºC or higher. In another embodiment, the method for producing cooling is useful for systems operating in ambient temperatures from 35-50ºC. In another embodiment, the method for producing cooling is useful for systems operating in ambient temperatures from 35-60ºC. In another embodiment, the method for producing cooling is useful for systems operating in ambient temperatures from 40- 60ºC. In another embodiment, the method for producing cooling is useful for systems operating in ambient temperatures from 45-60ºC. In another embodiment, the method for producing cooling is useful for systems operating in ambient temperatures from 50-60ºC.

[0098] In another embodiment, is provided a system for cooling or heating comprising a composition comprising HFO-1252zc, HFO-1234zeE, HFC-32, and at least one of HFC-134, HFC-134a, or CO_2 and optionally a lubricant. The system comprises an evaporator, compressor, condenser, and expansion device, each operably connected to perform a vapor compression cycle.

[0099] The air-conditioner or heat pump system may be a residential, light commercial, or industrial air-conditioner or heat pump. Various such systems are described previously herein.

[0100] In another embodiment, the air-conditioner or heat pump system is a secondary loop system.

[0101] It has been found that the compositions comprising, consisting of, or consisting essentially of HFO-1252zc, HFO-1234zeE, HFC-32, and at least one of HFC-134, HFC-134a, or CO_2 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, air-conditioner or heat pump system heat exchangers, in particular, evaporators, are designed to provide some aspect of counter-current tendency. Therefore, provided herein is an air conditioning or heat pump 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.

[0102] Additionally, the compositions of the present invention can be used in systems with heat exchangers operating in cross-current mode.

[0103] In another embodiment, provided herein is an air-conditioner or heat pump system containing compositions comprising, consisting of, or consisting essentially of HFO-1252zc, HFO-1234zeE, HFC-32, and at least one of HFC-134, HFC-134a, or CO_2, 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.

[0104] In another embodiment, also disclosed herein is a method of replacing R-454C, propane, or R-410A in air-conditioning or heat pump systems comprising providing any of the foregoing compositions.

[0105] In another embodiment, also disclosed herein is the use of any of the foregoing compositions in air-conditioning or heat pump systems.

[0106] The following Example are provided to illustrate certain aspects of the invention and shall not limit the scope of the appended claims.

EXAMPLES

Example 1

[0107] The presently claimed compositions containing HFO-1252zc, HFO-1234zeE, HFC-134, and HFC-32 are compared to R-454C (ASHRAE designation for a refrigerant containing 78.5 wt% HFO-1234yf and 21.5 wt% HFC-32) and R-410A (ASHRAE designation for a refrigerant containing 50 wt% HFC-125 and 50 wt%

HFC-32) under the conditions for a residential air-conditioner shown below. Tables 1A and 1B provide the calculated results.

Conditions:
T_condenser = 46.1ºC
T_evaporator = 10.0ºC
subcool = 8.3 K
evaporator superheat = 11.1 K
compressor efficiency = 0.7

[0108] The data demonstrates that compositions comprising HFO-1252zc, HFO-1234zeE, HFC-134, and HFC-32 provide higher COP (a measure of energy efficiency) than R-454C, and CAP (cooling capacity) within 20% of that for R-454C.

[0109] Broadly, for cooling mode, a composition range of 0.2% to 98.5% of R-1252ZC, 0.2% to 98.5% of HFO-1234ZE(E), 0.2% to 26.0% of HFC-134, and 0.2% to 43.8% of HFC-32 will have a GWP less than 300, a maximum average glide of about 9.9 K, a cooling capacity range that has a deviation range of -48.1% to 22.3% from the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range has a deviation range from -2.4% to 5.4% than that of the cooling COP of R-454C evaluated with the same conditions set.

[0110] Similarly, but a little less broadly for cooling mode, a composition range of 0.2% to 98.5% of R-1252ZC, 0.2% to 98.5% of HFO-1234ZE(E), 0.2% to 12.9% of HFC-134, and 0.2% to 20.9% of HFC-32 will have a GWP less than 150, a maximum average glide of about 9.6 K, an ASHRAE flammability classification of 3, 2L and 2, a cooling capacity range has a deviation of -48.1% to -2.2% from the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range has a deviation of 1.5% to 5.0% than that of the cooling COP of R-454C evaluated with the same conditions set.

[0111] Preferred blend composition ranges for cooling mode within a composition range of 19.9% to 84.6% of R-1252ZC, 0.2% to 58.7% of HFO-1234ZE(E), 0.2% to 3.0% of HFC-134, and 14.9% to 20.9% of HFC-32 will have a GWP < 150, a maximum average heat exchanger glide of 9.4 K, an ASHRAE flammability classification of 2, 3 and 2L, the minimum and maximum cooling capacities are -

10.0% and -2.2% than that of R-454C evaluated at the same conditions set, and the minimum and maximum cooling COP efficiencies are 1.5% and 2.5% than that of R-454C evaluated at the same conditions set.

[0112] Even more preferred blend composition ranges for cooling mode within a composition range of 19.9% to 22.9% of R-1252ZC, 55.7% to 58.7% of HFO-1234ZE(E), 0.5% to 0.5% of HFC-134, and 20.9% to 20.9% of HFC-32 will have a GWP < 150, a maximum average heat exchanger glide of 9.4 K, an ASHRAE flammability classification of 2L, the minimum and maximum cooling capacities are -9.9% and -9.2% than that of R-454C evaluated at the same conditions set, and the minimum and maximum cooling COP efficiencies are 2.4% and 2.5% than that of R-454C evaluated at the same conditions set.

[0113] The composition for the even more preferred maximum cooling capacity, which is -9.2% than that of R-454C, is 22.9 wt-% R-1252ZC, 55.7 wt-% HFO-1234ZE(E), 0.5 wt-% HFC-134 and 20.9 wt-% HFC-32, where the COP for cooling is 2.4% than that for R-454C under the same cycle conditions, the maximum average heat exchanger glide is 9.3 K and its ASHRAE flammability classification is 2L.

The composition for the even more preferred maximum cooling COP efficiency, which is 2.5% than that of R-454C, is 19.9 wt-% R-1252ZC, 58.7 wt-% HFO-1234ZE(E), 0.5 wt-% HFC-134, and 20.9 wt-% HFC-32, where the CAP for cooling is -9.9% than that for R-454C under the same cycle conditions, the maximum average heat exchanger glide is 9.4 K and its ASHRAE flammability classification is 2L.

TABLE 1A

Composition (wt fraction)				GWP (AR5)	T_bp (degC)	T_c (degC)	T_disch (degC)	avg glide (K)	COP cool (rel)	CAP cool (rel)
1252zc	1234zeE	R134	R32							
0.30	0.51	0.04	0.15	147.2	-38.6	101.9	75.8	6.51	1.03	0.81
0.28	0.54	0.03	0.15	136.0	-38.7	102.0	75.7	6.74	1.03	0.80
0.28	0.55	0.02	0.15	124.8	-38.8	101.9	75.7	6.84	1.03	0.80
0.30	0.50	0.03	0.17	149.5	-39.7	101.0	76.7	6.91	1.03	0.83
0.26	0.57	0.02	0.15	124.8	-38.8	102.1	75.6	6.98	1.03	0.80
0.25	0.58	0.02	0.15	124.8	-38.8	102.2	75.6	7.05	1.03	0.80
0.25	0.56	0.03	0.16	142.7	-39.2	101.9	76.0	7.12	1.03	0.81
0.26	0.54	0.03	0.17	149.5	-39.6	101.4	76.5	7.20	1.03	0.83
0.26	0.57	0.01	0.16	120.4	-39.4	101.7	76.1	7.25	1.03	0.81
0.27	0.55	0.01	0.17	127.1	-39.9	101.2	76.6	7.32	1.03	0.83

Composition (wt fraction)				GWP (AR5)	T_bp (degC)	T_c (degC)	T_disch (degC)	avg glide (K)	COP cool (rel)	CAP cool (rel)
1252zc	1234zeE	R134	R32							
0.25	0.56	0.02	0.17	138.3	-39.7	101.4	76.5	7.37	1.03	0.83
0.23	0.57	0.03	0.17	149.5	-39.6	101.7	76.4	7.42	1.03	0.82
0.28	0.52	0.01	0.19	140.6	-40.7	100.3	77.5	7.47	1.03	0.86
0.21	0.61	0.02	0.16	131.5	-39.2	102.3	75.9	7.52	1.03	0.81
0.21	0.59	0.03	0.17	149.5	-39.6	101.9	76.3	7.57	1.03	0.82
0.26	0.54	0.01	0.19	140.6	-40.7	100.5	77.4	7.62	1.03	0.85
0.24	0.57	0.01	0.18	133.9	-40.3	101.1	76.9	7.67	1.03	0.84
0.22	0.58	0.02	0.18	145.1	-40.1	101.4	76.8	7.72	1.03	0.84
0.19	0.64	0.01	0.16	120.4	-39.3	102.4	75.8	7.78	1.03	0.81
0.23	0.57	0.01	0.19	140.6	-40.7	100.8	77.3	7.85	1.03	0.85
0.16	0.66	0.02	0.16	131.5	-39.1	102.9	75.7	7.91	1.03	0.80
0.20	0.61	0.01	0.18	133.9	-40.2	101.5	76.7	7.98	1.03	0.83
0.15	0.65	0.03	0.17	149.5	-39.5	102.7	76.1	8.04	1.03	0.81
0.17	0.63	0.02	0.18	145.1	-40.1	102.0	76.6	8.12	1.03	0.83
0.16	0.64	0.02	0.18	145.1	-40.1	102.1	76.6	8.20	1.03	0.83
0.15	0.65	0.02	0.18	145.1	-40.0	102.3	76.5	8.28	1.03	0.83
0.12	0.68	0.03	0.17	149.5	-39.4	103.2	76.0	8.28	1.04	0.81
0.11	0.69	0.03	0.17	149.5	-39.4	103.3	75.9	8.36	1.04	0.81
0.17	0.62	0.01	0.20	147.4	-41.0	101.1	77.5	8.42	1.03	0.85
0.15	0.65	0.01	0.19	140.6	-40.6	101.8	77.0	8.50	1.03	0.84
0.14	0.66	0.01	0.19	140.6	-40.6	101.9	76.9	8.58	1.03	0.84
0.10	0.72	0.01	0.17	127.1	-39.6	103.3	75.9	8.65	1.04	0.81
0.12	0.68	0.01	0.19	140.6	-40.5	102.2	76.9	8.75	1.03	0.83
0.08	0.72	0.02	0.18	145.1	-39.9	103.4	76.3	8.86	1.04	0.81
0.06	0.74	0.02	0.18	145.1	-39.8	103.7	76.2	9.02	1.04	0.81
0.04	0.76	0.02	0.18	145.1	-39.7	104.1	76.1	9.18	1.04	0.81
0.02	0.78	0.02	0.18	145.1	-39.7	104.5	76.0	9.34	1.04	0.80
0.02	0.79	0.01	0.18	133.9	-39.8	104.4	76.0	9.45	1.04	0.80
0.02	0.77	0.01	0.20	147.4	-40.7	103.6	76.9	9.71	1.04	0.83
0.00	0.80	0.01	0.19	140.6	-40.2	104.4	76.4	9.76	1.04	0.81
0.01	0.78	0.01	0.20	147.4	-40.7	103.8	76.9	9.79	1.04	0.83
0.00	0.79	0.01	0.20	147.4	-40.6	104.0	76.8	9.88	1.04	0.83

Table 1B

W_R-1252ZC	W_HFO-1234ZE(E)	W_R134	W_R32	GWP	ASHRAE FLAMMABILITY CLASS	AVG GLIDE (K)	COP DEV from 454C	CAP DEV from 454C	COP DEV from 410A	CAP DEV from 410A
0.09	0.52	0.08	0.31	300	2L	9.1	1.9	-1	6.8	-33.6
0.985	0.002	0.01	0.002	13	3	0.2	4.1	-31.7	9.1	-54.2
0.002	0.866	0.002	0.129	91	2L	8.5	4.1	-27.2	9.1	-51.2
0.002	0.985	0.01	0.002	14	2L	0.3	4.7	-48.1	9.7	-65.2
0.647	0.002	0.002	0.348	239	2	7.5	-0.9	13.4	3.8	-24.0
0.17	0.56	0.26	0.01	299	2L	1.5	4.4	-39	9.4	-59.1

W_R-1252ZC	W_HFO-1234ZE(E)	W_R134	W_R32	GWP	ASHRAE FLAMMABILITY CLASS	AVG GLIDE (K)	COP DEV from 454C	CAP DEV from 454C	COP DEV from 410A	CAP DEV from 410A
0.896	0.002	0.002	0.1	70	3	5.9	2.8	-16.8	7.7	-44.2
0.002	0.557	0.002	0.438	300	2L	8.4	0.3	10.3	5.1	-26.0
0.002	0.776	0.219	0.002	248	1	0.3	4.9	-45.7	9.9	-63.6
0.557	0.002	0.002	0.438	299	2	6	-2.4	22.3	2.3	-18.0
0.16	0.65	0.07	0.12	160	2L	8	5.4	-22.2	10.4	-47.8
0.03	0.657	0.005	0.308	215	2L	9.9	2	-2.9	6.9	-34.9
0.25	0.48	0.14	0.13	245	2L	6.9	3.3	-19.6	8.2	-46.1
0.01	0.73	0.22	0.04	274	1	3.1	4.5	-39.6	9.5	-59.5
0.49	0.43	0.06	0.02	81	2	1.9	3.7	-32.3	8.7	-54.6
0.73	0.08	0.08	0.11	164	3	5.7	2.8	-15.9	7.7	-43.6
0.826	0.005	0.08	0.09	150	3	5.1	3	-18.6	7.9	-45.4
0.002	0.955	0.002	0.04	31	2L	3.8	4.3	-41.6	9.3	-60.8
0.01	0.985	0.002	0.002	5	2L	0.4	4.7	-47.9	9.7	-65.1
0.985	0.002	0.002	0.01	10	3	0.8	4	-30.6	9.0	-53.5
0.716	0.149	0.129	0.005	148	3	0.4	4	-31.8	9.0	-54.3
0.002	0.925	0.002	0.07	51	2L	5.8	4.2	-36.6	9.2	-57.5
0.418	0.368	0.005	0.209	147	2	8.3	1.7	-5.3	6.6	-36.5
0.05	0.945	0.002	0.002	5	2L	0.6	4.6	-46.6	9.6	-64.2
0.786	0.002	0.002	0.209	144	3	8.2	1.5	-2.2	6.4	-34.4
0.14	0.73	0.12	0.01	142	2L	1.8	5	-40.8	10.0	-60.3
0.657	0.129	0.005	0.209	147	3	7.9	1.5	-2.6	6.4	-34.7
0.667	0.119	0.005	0.209	147	3	7.9	1.5	-2.5	6.4	-34.6
0.677	0.109	0.005	0.209	147	3	7.9	1.5	-2.5	6.4	-34.6
0.687	0.1	0.005	0.209	147	3	7.9	1.5	-2.4	6.4	-34.6
0.696	0.09	0.005	0.209	147	3	7.9	1.5	-2.4	6.4	-34.6
0.706	0.08	0.005	0.209	147	3	7.9	1.5	-2.4	6.4	-34.6
0.716	0.07	0.005	0.209	147	3	8	1.5	-2.3	6.4	-34.5
0.726	0.06	0.005	0.209	147	3	8	1.5	-2.3	6.4	-34.5
0.736	0.05	0.005	0.209	147	3	8	1.5	-2.3	6.4	-34.5
0.746	0.04	0.005	0.209	147	3	8.1	1.5	-2.2	6.4	-34.4
0.756	0.03	0.005	0.209	147	3	8.1	1.5	-2.2	6.4	-34.4
0.159	0.627	0.005	0.209	148	2L	9.6	2.7	-11	7.6	-40.3
0.109	0.796	0.005	0.09	67	2L	7.1	3.9	-29.9	8.9	-53.0
0.388	0.517	0.005	0.09	67	2	6.1	3.1	-23.1	8.0	-48.4
0.75	0.22	0.02	0.01	29	3	0.8	3.8	-31.3	8.8	-53.9
0.46	0.34	0.03	0.17	149	2	7.6	2.2	-9.9	7.1	-39.6
0.846	0.002	0.002	0.149	104	3	7.4	2.3	-9.8	7.2	-39.5
0.199	0.587	0.005	0.209	148	2L	9.4	2.5	-9.9	7.4	-39.6
0.75	0.05	0.03	0.17	149	3	7.4	2.1	-7.4	7.0	-37.9
0.826	0.002	0.002	0.169	117	3	7.8	2	-7.2	6.9	-37.8
0.448	0.338	0.005	0.209	147	2	8.1	1.7	-4.8	6.6	-36.2
0.816	0.03	0.005	0.149	107	3	7.3	2.3	-9.9	7.2	-39.6
0.78	0.04	0.03	0.15	135	3	7.1	2.3	-10	7.2	-39.7

W_R-1252ZC	W_HFO-1234ZE(E)	W_R134	W_R32	GWP	ASHRAE FLAMMABILITY CLASS	AVG GLIDE (K)	COP DEV from 454C	CAP DEV from 454C	COP DEV from 410A	CAP DEV from 410A
0.219	0.567	0.005	0.209	148	2L	9.3	2.4	-9.4	7.3	-39.3
0.53	0.27	0.01	0.19	140	2	7.7	1.9	-6.2	6.8	-37.1
0.637	0.179	0.005	0.179	127	3	7.5	1.9	-6.6	6.8	-37.4
0.229	0.557	0.005	0.209	148	2L	9.3	2.4	-9.2	7.3	-39.1

[0114] Broadly, for cooling mode, a composition range of 1.0% to 21.0% of R-1252ZC, 64.0% to 92.0% of HFO-1234ZE(E), 1.0% to 11.0% of HFC-134, and 1.0% to 9.0% of HFC-32 will have a GWP < 150, an ASHRAE flammability rating of 2L, an average temperature glide of no more than 6.5, a cooling capacity of 40.0% to 48.9% of the cooling capacity of R-454C evaluated with the same conditions set, and a cooling COP of 108.6% to 109.3% of the cooling COP of R-454C evaluated with the same conditions set.

Similarly but less broadly, for cooling mode, a composition range of 15.0% to 21.0% HFO-1252zc, 63.0% to 76.0% HFO-1252zeE, 1.0% to 8.0% HFC-134, and 7.0% to 9.0% HFC-32 will have a GWP < 150, an ASHRAE flammability rating of 2L, an average temperature glide of no more than 6.5, a cooling capacity of 49.1% to 53.0% of the cooling capacity of R-454C evaluated with the same conditions set, and a cooling COP of 108.6% to 108.7% of the cooling COP of R-454C evaluated with the same conditions set.

Example 2

[0115] The presently claimed compositions containing HFO-1252zc, HFO-1234zeE, HFC-32, and CO2 are compared to R-454C (ASHRAE designation for a refrigerant containing 78.5 wt% HFO-1234yf and 21.5 wt% HFC-32) and R-410A (ASHRAE designation for a refrigerant containing 50 wt% HFC-125 and 50 wt% HFC-32) under the conditions for a residential heat pump shown below. Tables 2A and 2B provide the calculated results.

Conditions:
T_condenser = 35.0ºC
T_evaporator = -5.0ºC
subcool = 8.3 K
evaporator superheat = 11.1 K
compressor efficiency = 0.7
Average Heat Exchanger Temperature Set Points
100 % of superheat is included in refrigeration effect.
Vapor Molar Quality Entering Evaporator: q_4
cooling load = 3.517 kW
compressor displacement = 0.1 (m^3 / min)

[0116] The data demonstrates that compositions comprising HFO-1252zc, HFO-1234zeE, HFC-32, and CO_2 provide higher COP (a measure of energy efficiency) higher than R-454C, and CAP (cooling capacity) within 20%, or even in some cases 15% of that for R-454C.

[0117] Broadly, for heating mode, a composition range of 0.2% to 8.0% of CARBON DIOXIDE, 0.2% to 98.5% of R-1252ZC, 0.2% to 98.5% of HFO-1234ZE(E), and 0.2% to 44.0% of HFC-32 will have a GWP less than 298, a maximum average glide of about 10.0 K, a heating capacity range that has a deviation range of -50.7% to 50.3% from the heating capacity of R-454C evaluated with the same conditions set, and the heating COP range has a deviation range from -3.6% to 2.3% than that of the heating COP of R-454C evaluated with the same conditions set. Table 2 lists example compositions within the GWP<298 range that have ASHRAE flammability classifications of 2L, 2 and 3.

[0118] Similarly, but a little less broadly for heating mode, a composition range of 0.2% to 3.0% of CARBON DIOXIDE, 0.2% to 98.5% of R-1252ZC, 0.2% to 98.5% of HFO-1234ZE(E), and 0.2% to 22.0% of HFC-32 will have a GWP less than 149, a maximum average glide of about 10.0 K, an ASHRAE flammability classification of 2, 3 and 2L, a heating capacity range has a deviation of -50.7% to 2.0% from the heating capacity of R-454C evaluated with the same conditions set, and the heating COP range has a deviation of 0.1% to 2.3% than that of the heating COP of R-454C evaluated with the same conditions set.

[0119] Preferred blend composition ranges for heating mode within a composition range of 0.2% to 2.0% of CARBON DIOXIDE, 27.9% to 84.6% of R-1252ZC, 0.2% to 51.7% of HFO-1234ZE(E), and 11.0% to 22.0% of HFC-32 will have a GWP < 149, a maximum average heat exchanger glide of 10.0 K, an ASHRAE flammability classification of 2 and 3, the minimum and maximum heating capacities are -10.0% and 2.0% than that of R-454C evaluated at the same conditions set, and the minimum and maximum heating COP efficiencies are 0.6% and 1.3% than that of R-454C evaluated at the same conditions set.

[0120] Even more preferred blend composition ranges for heating mode within a composition range of 0.5% to 1.0% of CARBON DIOXIDE, 27.9% to 64.7% of R-1252ZC, 12.9% to 51.7% of HFO-1234ZE(E), and 15.0% to 22.0% of HFC-32 will have a GWP < 149, a maximum average heat exchanger glide of 10.0 K, an ASHRAE flammability classification of 2, the minimum and maximum heating capacities are -10.0% and 1.5% than that of R-454C evaluated at the same conditions set, and the minimum and maximum heating COP efficiencies are 0.6% and 1.2% than that of R-454C evaluated at the same conditions set.

[0121] The composition for the even more preferred maximum heating capacity, which is 1.5% than that of R-454C, is 1.0 wt-% CARBON DIOXIDE, 64.0 wt-% R-1252ZC, 13.0 wt-% HFO-1234ZE(E) and 22.0 wt-% HFC-32, where the COP for heating is 0.6% than that for R-454C under the same cycle conditions, the maximum average heat exchanger glide is 9.2 K and its ASHRAE flammability classification is 2.

[0122] The composition for the even more preferred maximum heating COP efficiency, which is 1.2% than that of R-454C, is 0.5 wt-% CARBON DIOXIDE, 27.9 wt-% R-1252ZC, 51.7 wt-% HFO-1234ZE(E), and 19.9 wt-% HFC-32, where the CAP for heating is -9.5% than that for R-454C under the same cycle conditions, the maximum average heat exchanger glide is 10.0 K and its ASHRAE flammability classification is 2.

TABLE 2A

Composition (wt fraction)				GWP (AR5)	T_bp (degC)	T_c (degC)	T_disch (degC)	avg glide (K)	COP cool (rel)	CAP cool (rel)
1252zc	1234zeE	R32	CO_2							
0.30	0.56	0.13	0.01	88.9	-40.5	101.8	76.2	7.73	1.03	0.81
0.29	0.57	0.13	0.01	88.9	-40.5	101.9	76.1	7.80	1.03	0.81
0.28	0.58	0.13	0.01	88.9	-40.5	102.0	76.1	7.88	1.03	0.81
0.30	0.55	0.14	0.01	95.6	-41.0	101.4	76.6	7.90	1.03	0.82
0.27	0.59	0.13	0.01	88.9	-40.5	102.1	76.0	7.95	1.03	0.81
0.29	0.56	0.14	0.01	95.6	-41.0	101.5	76.6	7.97	1.03	0.82
0.26	0.60	0.13	0.01	88.9	-40.5	102.2	76.0	8.03	1.03	0.81
0.24	0.61	0.14	0.01	95.6	-41.0	102.0	76.4	8.37	1.03	0.82
0.23	0.62	0.14	0.01	95.6	-41.0	102.1	76.4	8.45	1.03	0.81
0.22	0.63	0.14	0.01	95.6	-41.0	102.2	76.3	8.53	1.03	0.81
0.30	0.57	0.11	0.02	75.4	-42.1	102.0	76.6	8.58	1.03	0.81
0.21	0.64	0.14	0.01	95.6	-41.0	102.3	76.3	8.61	1.03	0.81
0.29	0.58	0.11	0.02	75.4	-42.1	102.1	76.5	8.66	1.03	0.81
0.20	0.65	0.14	0.01	95.6	-41.0	102.4	76.2	8.70	1.03	0.81
0.28	0.59	0.11	0.02	75.4	-42.1	102.2	76.5	8.74	1.03	0.81
0.17	0.68	0.14	0.01	95.6	-41.0	102.8	76.1	8.95	1.03	0.81
0.25	0.62	0.11	0.02	75.4	-42.1	102.4	76.4	8.99	1.03	0.81
0.29	0.56	0.13	0.02	88.9	-42.9	101.3	77.4	8.99	1.03	0.84
0.27	0.59	0.12	0.02	82.1	-42.5	101.8	76.9	9.00	1.03	0.82
0.16	0.69	0.14	0.01	95.6	-41.0	102.9	76.1	9.04	1.03	0.81
0.30	0.54	0.14	0.02	95.6	-43.3	100.8	77.9	9.04	1.03	0.85
0.24	0.63	0.11	0.02	75.4	-42.1	102.5	76.3	9.07	1.03	0.81
0.28	0.57	0.13	0.02	88.9	-43.0	101.4	77.4	9.07	1.03	0.84
0.26	0.60	0.12	0.02	82.1	-42.5	101.9	76.9	9.09	1.03	0.82
0.22	0.65	0.11	0.02	75.4	-42.1	102.7	76.3	9.24	1.03	0.80
0.24	0.62	0.12	0.02	82.1	-42.6	102.1	76.8	9.26	1.03	0.82
0.27	0.57	0.14	0.02	95.6	-43.4	101.0	77.8	9.29	1.03	0.85
0.13	0.72	0.14	0.01	95.6	-41.0	103.3	76.0	9.30	1.03	0.80
0.29	0.60	0.08	0.03	55.1	-43.1	102.6	76.4	9.32	1.03	0.80
0.25	0.60	0.13	0.02	88.9	-43.0	101.6	77.3	9.33	1.03	0.84
0.21	0.66	0.11	0.02	75.4	-42.1	102.8	76.2	9.33	1.03	0.80
0.23	0.63	0.12	0.02	82.1	-42.6	102.2	76.8	9.34	1.03	0.82
0.26	0.58	0.14	0.02	95.6	-43.4	101.1	77.8	9.38	1.03	0.85
0.28	0.61	0.08	0.03	55.1	-43.1	102.7	76.4	9.41	1.03	0.80
0.29	0.59	0.09	0.03	61.8	-43.6	102.2	76.9	9.53	1.03	0.82
0.24	0.60	0.14	0.02	95.6	-43.4	101.3	77.7	9.55	1.03	0.85
0.22	0.63	0.13	0.02	88.9	-43.0	101.9	77.2	9.59	1.03	0.83
0.20	0.66	0.12	0.02	82.1	-42.6	102.5	76.7	9.61	1.03	0.82
0.28	0.60	0.09	0.03	61.8	-43.6	102.3	76.9	9.62	1.03	0.82
0.30	0.57	0.10	0.03	68.6	-44.0	101.7	77.4	9.63	1.03	0.83
0.23	0.61	0.14	0.02	95.6	-43.4	101.4	77.7	9.64	1.03	0.85
0.28	0.59	0.10	0.03	68.6	-44.0	101.9	77.3	9.80	1.03	0.83

Composition (wt fraction)				GWP (AR5)	T_bp (degC)	T_c (degC)	T_disch (degC)	avg glide (K)	COP cool (rel)	CAP cool (rel)
1252zc	1234zeE	R32	CO_2							
0.21	0.63	0.14	0.02	95.6	-43.4	101.6	77.6	9.82	1.03	0.84
0.19	0.66	0.13	0.02	88.9	-43.0	102.3	77.1	9.87	1.03	0.83
0.29	0.57	0.11	0.03	75.4	-44.4	101.4	77.8	9.87	1.03	0.84
0.18	0.67	0.13	0.02	88.9	-43.1	102.4	77.1	9.96	1.03	0.83
0.28	0.58	0.11	0.03	75.4	-44.4	101.5	77.8	9.96	1.03	0.84
0.24	0.64	0.09	0.03	61.8	-43.7	102.7	76.8	9.97	1.03	0.81
0.16	0.70	0.12	0.02	82.1	-42.6	103.0	76.5	9.98	1.03	0.81
0.26	0.61	0.10	0.03	68.6	-44.1	102.1	77.3	9.98	1.03	0.83

TABLE 2B

W_CARBON DIOXIDE	W_R-1252ZC	W_HFO-1234ZE(E)	W_R32	GWP	ASHRAE FLAMMABILITY CLASS	AVG GLIDE (K)	COP DEV from 454C	CAP DEV from 454C	COP DEV from 410A	CAP DEV from 410A
0.01	0.01	0.54	0.44	298	2L	9.4	-0.5	12.8	2.4	-26.6
0.08	0.42	0.06	0.44	298	2	9.7	-3.4	50	-0.6	-2.4
0.002	0.002	0.955	0.04	28	2L	4.6	2	-44.4	5.0	-63.8
0.01	0.985	0.002	0.002	2	3	2.7	1.5	-30.2	4.4	-54.6
0.002	0.002	0.567	0.428	290	2L	9.2	-0.2	8.6	2.7	-29.4
0.01	0.002	0.985	0.002	3	2L	3.3	1.5	-48.4	4.4	-66.4
0.002	0.876	0.002	0.119	81	3	7.2	1.5	-14.3	4.4	-44.3
0.02	0.53	0.01	0.44	298	2	7.2	-2.1	30.4	0.7	-15.2
0.002	0.627	0.368	0.002	2	3	1.1	2	-35.2	5.0	-57.9
0.08	0.47	0.01	0.44	298	2	9.8	-3.6	50.3	-0.8	-2.2
0.002	0.01	0.985	0.002	3	2L	1.1	2.3	-50.7	5.3	-67.9
0.002	0.002	0.866	0.129	88	2L	9.4	2.3	-29.7	5.3	-54.3
0.002	0.002	0.846	0.149	102	2L	9.9	2.3	-26.7	5.3	-52.3
0.002	0.002	0.856	0.139	95	2L	9.7	2.3	-28.2	5.3	-53.3
0.002	0.02	0.975	0.002	3	2L	1.2	2.3	-50.4	5.3	-67.7
0.08	0.478	0.005	0.438	297	2	9.8	-3.6	49.9	-0.8	-2.5
0.04	0.38	0.22	0.36	244	2	10	-1.6	25.8	1.3	-18.2
0.02	0.68	0.26	0.04	27	3	6.9	0.8	-21.8	3.7	-49.1
0.03	0.29	0.24	0.44	298	2	8.1	-2	29.9	0.8	-15.5
0.01	0.24	0.44	0.31	210	2L	10	0	5.8	2.9	-31.2
0.01	0.36	0.41	0.22	149	2	10	0.7	-2.8	3.6	-36.8
0.03	0.44	0.52	0.01	7	2	8.3	0.2	-26.9	3.1	-52.5
0.002	0.219	0.776	0.002	2	2	2.1	2.1	-43.9	5.1	-63.5
0.002	0.002	0.935	0.06	41	2L	6	2.1	-41	5.1	-61.6
0.002	0.965	0.002	0.03	20	3	2.9	1.9	-28.3	4.9	-53.4
0.01	0.75	0.02	0.22	149	3	9.5	0.6	2	3.5	-33.7
0.002	0.498	0.498	0.002	2	3	1.5	1.9	-37.2	4.9	-59.2
0.01	0.76	0.01	0.22	149	3	9.6	0.6	2	3.5	-33.7
0.03	0.965	0.002	0.002	2	3	7.3	0.1	-23	3.0	-49.9
0.01	0.36	0.43	0.2	136	2	10	0.9	-5.6	3.8	-38.6

W_CARBON DIOXIDE	W_R-1252ZC	W_HFO-1234ZE(E)	W_R32	GWP	ASHRAE FLAMMABILITY CLASS	AVG GLIDE (K)	COP DEV from 454C	CAP DEV from 454C	COP DEV from 410A	CAP DEV from 410A
0.005	0.766	0.109	0.119	81	3	7.3	1.3	-13.8	4.2	-43.9
0.005	0.567	0.239	0.189	128	2	8.6	1	-5.2	3.9	-38.3
0.005	0.149	0.806	0.04	28	2L	5.6	1.7	-38.5	4.7	-60.0
0.02	0.7	0.16	0.12	81	3	9.4	0.9	-8.9	3.8	-40.7
0.002	0.846	0.002	0.149	101	3	8	1.3	-10	4.2	-41.5
0.01	0.846	0.005	0.139	94	3	8.8	1.1	-8.9	4.0	-40.7
0.005	0.279	0.517	0.199	135	2	10	1.2	-9.5	4.1	-41.1
0.002	0.806	0.002	0.189	128	3	8.6	1.1	-4.5	4.0	-37.9
0.01	0.37	0.4	0.22	149	2	9.9	0.7	-2.6	3.6	-36.6
0.02	0.78	0.09	0.11	75	3	9.3	0.9	-9.9	3.8	-41.4
0.01	0.65	0.12	0.22	149	3	9.2	0.6	1.6	3.5	-33.9
0.01	0.66	0.11	0.22	149	3	9.2	0.6	1.6	3.5	-33.9
0.01	0.67	0.1	0.22	149	3	9.3	0.6	1.7	3.5	-33.8
0.01	0.68	0.09	0.22	149	3	9.3	0.6	1.7	3.5	-33.8
0.01	0.69	0.08	0.22	149	3	9.3	0.6	1.8	3.5	-33.8
0.01	0.7	0.07	0.22	149	3	9.3	0.6	1.8	3.5	-33.8
0.01	0.71	0.06	0.22	149	3	9.4	0.6	1.9	3.5	-33.7
0.01	0.72	0.05	0.22	149	3	9.4	0.6	1.9	3.5	-33.7
0.01	0.73	0.04	0.22	149	3	9.4	0.6	1.9	3.5	-33.7
0.01	0.74	0.03	0.22	149	3	9.5	0.6	2	3.5	-33.7
0.01	0.58	0.19	0.22	149	2	9.2	0.6	0.9	3.5	-34.4
0.01	0.59	0.18	0.22	149	2	9.2	0.6	1	3.5	-34.3
0.01	0.6	0.17	0.22	149	2	9.2	0.6	1.1	3.5	-34.2
0.01	0.61	0.16	0.22	149	2	9.2	0.6	1.2	3.5	-34.2
0.01	0.62	0.15	0.22	149	2	9.2	0.6	1.3	3.5	-34.1
0.01	0.63	0.14	0.22	149	2	9.2	0.6	1.4	3.5	-34.0
0.01	0.64	0.13	0.22	149	2	9.2	0.6	1.5	3.5	-34.0
0.005	0.806	0.03	0.159	108	3	8.4	1.2	-7.8	4.1	-40.0
0.01	0.47	0.33	0.19	129	2	9.4	0.9	-4.8	3.8	-38.1
0.01	0.41	0.4	0.18	122	2	9.6	1	-7.4	3.9	-39.8
0.005	0.388	0.418	0.189	128	2	9.3	1.1	-8.3	4.0	-40.4
0.005	0.647	0.129	0.219	148	2	8.7	0.7	-0.2	3.6	-35.1
0.01	0.47	0.3	0.22	149	2	9.4	0.6	-0.6	3.5	-35.3
0.01	0.52	0.32	0.15	102	2	8.8	1	-9.9	3.9	-41.4
0.01	0.36	0.46	0.17	116	2	9.9	1.1	-10	4.0	-41.5
0.005	0.318	0.488	0.189	129	2	9.7	1.2	-9.9	4.1	-41.4
0.005	0.438	0.368	0.189	128	2	9	1	-7.2	3.9	-39.6

Example 3

[0123] The presently claimed compositions containing HFO-1252zc, HFO-1234zeE, HFC-32, HFC-134, and CO2 are compared to R-454C (ASHRAE

designation for a refrigerant containing 78.5 wt% HFO-1234yf and 21.5 wt% HFC-32) and R-410A (ASHRAE designation for a refrigerant containing 50 wt% HFC-125 and 50 wt% HFC-32) under the conditions for a residential heat pump shown below. Tables 3A and 3B provide the calculated results.

Conditions:
T_condenser = 35.0°C
T_evaporator = -5.0°C
subcool = 8.3 K
evaporator superheat = 11.1 K
compressor efficiency = 0.7
Average Heat Exchanger Temperature Set Points
100 % of superheat is included in refrigeration effect.
Vapor Molar Quality Entering Evaporator: q_4
cooling load = 3.517 kW
compressor displacement = 0.1 (m^3 / min)

[0124] The data demonstrates that compositions comprising HFO-1252zc, HFO-1234zeE, HFC-134, HFC-32, and CO_2 provide higher COP (a measure of energy efficiency) than R-454C, and CAP (cooling capacity) within 20%, or 15%, or even in some cases 12% of that for R-454C.

[0125] Broadly, for heating mode, a composition range of 0.2% to 3.0% of CARBON DIOXIDE, 0.2% to 98.5% of R-1252ZC, 0.2% to 98.5% of HFO-1234ZE(E), 0.2% to 26.0% of HFC-134, and 0.2% to 43.8% of HFC-32 will have a GWP less than 300, a maximum average glide of about 10.0 K, a heating capacity range that has a deviation range of -51.3% to 33.3% from the heating capacity of R-454C evaluated with the same conditions set, and the heating COP range has a deviation range from -2.4% to 2.6% than that of the heating COP of R-454C evaluated with the same conditions set. Table 3 lists example compositions within the GWP<300 range that have ASHRAE flammability classifications of 2, 2L, 3 and 1.

[0126] Similarly, but a little less broadly for heating mode, a composition range of 0.2% to 3.0% of CARBON DIOXIDE, 0.2% to 98.5% of R-1252ZC, 0.2% to 98.5% of HFO-1234ZE(E), 0.2% to 12.9% of HFC-134, and 0.2% to 20.9% of HFC-32 will

have a GWP less than 150, a maximum average glide of about 10.0 K, an ASHRAE flammability classification of 2, 3 and 2L, a heating capacity range has a deviation of -51.3% to 0.5% from the heating capacity of R-454C evaluated with the same conditions set, and the heating COP range has a deviation of 0.1% to 2.5% than that of the heating COP of R-454C evaluated with the same conditions set.

[0127] Preferred blend composition ranges for heating mode within a composition range of 0.2% to 2.0% of CARBON DIOXIDE, 24.9% to 84.6% of R-1252ZC, 0.2% to 53.7% of HFO-1234ZE(E), 0.2% to 6.0% of HFC-134, and 11.0% to 20.9% of HFC-32 will have a GWP < 150, a maximum average heat exchanger glide of 10.0 K, an ASHRAE flammability classification of 2 and 3, the minimum and maximum heating capacities are -10.0% and 0.5% than that of R-454C evaluated at the same conditions set, and the minimum and maximum heating COP efficiencies are 0.7% and 1.3% than that of R-454C evaluated at the same conditions set.

[0128] Even more preferred blend composition ranges for heating mode within a composition range of 0.2% to 2.0% of CARBON DIOXIDE, 24.9% to 63.7% of R-1252ZC, 13.9% to 53.7% of HFO-1234ZE(E), 0.2% to 5.0% of HFC-134, and 13.0% to 20.9% of HFC-32 will have a GWP < 150, a maximum average heat exchanger glide of 10.0 K, an ASHRAE flammability classification of 2, the minimum and maximum heating capacities are -10.0% and -0.1% than that of R-454C evaluated at the same conditions set, and the minimum and maximum heating COP efficiencies are 0.7% and 1.2% than that of R-454C evaluated at the same conditions set.

[0129] The composition for the even more preferred maximum heating capacity, which is -0.1% than that of R-454C, is 1.0 wt-% CARBON DIOXIDE, 63.7 wt-% R-1252ZC, 13.9 wt-% HFO-1234ZE(E), 0.5 wt-% HFC-134, and 20.9 wt-% HFC-32, where the COP for heating is 0.7% than that for R-454C under the same cycle conditions, the maximum average heat exchanger glide is 9.2 K and its ASHRAE flammability classification is 2.

[0130] The composition for the even more preferred maximum heating COP efficiency, which is 1.2% than that of R-454C, is 0.2 wt-% CARBON DIOXIDE, 24.9 wt-% R-1252ZC, 53.7 wt-% HFO-1234ZE(E), 0.2 wt-% HFC-134, and 20.9 wt-% HFC-32, where the CAP for heating is -9.8% than that for R-454C under the same

cycle conditions, the maximum average heat exchanger glide is 9.9 K and its ASHRAE flammability classification is 2.

TABLE 3A

Composition (wt fraction)					GWP (AR5)	T_bp (degC)	T_c (degC)	T_disch (degC)	avg glide (K)	COP cool (rel)	CAP cool (rel)
1252 zc	1234zeE	R134	R32	CO_2							
0.29	0.52	0.04	0.14	0.01	140.4	-40.7	101.7	76.6	7.62	1.03	0.82
0.28	0.53	0.04	0.14	0.01	140.4	-40.7	101.8	76.6	7.69	1.03	0.82
0.26	0.55	0.04	0.14	0.01	140.4	-40.7	102.0	76.5	7.85	1.03	0.82
0.30	0.52	0.02	0.15	0.01	124.8	-41.3	101.1	77.1	7.87	1.03	0.84
0.28	0.55	0.01	0.15	0.01	113.6	-41.4	101.3	77.0	8.11	1.03	0.83
0.29	0.55	0.04	0.10	0.02	113.4	-41.3	102.6	76.1	8.15	1.03	0.80
0.29	0.50	0.02	0.18	0.01	145.1	-42.5	100.0	78.4	8.26	1.03	0.87
0.25	0.60	0.00	0.14	0.01	95.6	-41.0	101.9	76.4	8.29	1.03	0.82
0.22	0.59	0.03	0.15	0.01	136.0	-41.2	101.9	76.8	8.41	1.03	0.83
0.30	0.52	0.04	0.12	0.02	126.9	-42.2	101.7	77.0	8.43	1.03	0.83
0.28	0.53	0.00	0.18	0.01	122.7	-42.7	100.0	78.3	8.52	1.03	0.87
0.25	0.58	0.00	0.16	0.01	109.2	-41.9	101.1	77.3	8.57	1.03	0.84
0.19	0.62	0.03	0.15	0.01	136.0	-41.2	102.3	76.7	8.66	1.03	0.82
0.29	0.55	0.02	0.12	0.02	104.5	-42.4	101.7	77.0	8.67	1.03	0.83
0.30	0.53	0.02	0.13	0.02	111.3	-42.8	101.3	77.5	8.74	1.03	0.84
0.29	0.56	0.01	0.12	0.02	93.3	-42.4	101.7	77.0	8.75	1.03	0.83
0.17	0.64	0.03	0.15	0.01	136.0	-41.2	102.5	76.6	8.83	1.03	0.82
0.25	0.57	0.04	0.12	0.02	126.9	-42.3	102.2	76.9	8.84	1.03	0.82
0.29	0.55	0.01	0.13	0.02	100.1	-42.9	101.3	77.4	8.91	1.03	0.84
0.25	0.53	0.00	0.21	0.01	143.0	-43.7	99.0	79.4	8.92	1.02	0.91
0.20	0.63	0.00	0.16	0.01	109.2	-41.9	101.6	77.2	8.99	1.03	0.84
0.27	0.59	0.00	0.12	0.02	82.1	-42.5	101.8	76.9	9.00	1.03	0.82
0.23	0.56	0.00	0.20	0.01	136.2	-43.4	99.7	78.9	9.05	1.03	0.89
0.26	0.57	0.02	0.13	0.02	111.3	-42.8	101.6	77.3	9.07	1.03	0.84
0.18	0.63	0.06	0.11	0.02	142.5	-41.7	103.4	76.2	9.11	1.03	0.80
0.17	0.67	0.00	0.15	0.01	102.4	-41.5	102.4	76.6	9.11	1.03	0.82
0.27	0.58	0.00	0.13	0.02	88.9	-43.0	101.4	77.4	9.16	1.03	0.84
0.20	0.64	0.03	0.11	0.02	108.9	-41.9	103.0	76.2	9.17	1.03	0.80
0.27	0.58	0.04	0.08	0.03	99.8	-43.0	102.8	76.4	9.22	1.03	0.80
0.15	0.66	0.02	0.16	0.01	131.5	-41.7	102.4	77.0	9.24	1.03	0.83
0.15	0.69	0.00	0.15	0.01	102.4	-41.4	102.6	76.5	9.29	1.03	0.82
0.28	0.51	0.02	0.17	0.02	138.3	-44.3	99.9	79.1	9.31	1.02	0.89
0.19	0.66	0.02	0.11	0.02	97.7	-42.0	103.1	76.2	9.34	1.03	0.80
0.24	0.59	0.06	0.08	0.03	122.2	-42.9	103.1	76.3	9.35	1.03	0.80
0.28	0.57	0.03	0.09	0.03	95.4	-43.4	102.4	76.9	9.40	1.03	0.82
0.27	0.56	0.00	0.15	0.02	102.4	-43.8	100.6	78.2	9.40	1.03	0.86
0.19	0.64	0.03	0.12	0.02	115.7	-42.4	102.8	76.7	9.44	1.03	0.82
0.16	0.64	0.01	0.18	0.01	133.9	-42.6	101.4	77.9	9.45	1.03	0.86

Composition (wt fraction)					GWP (AR5)	T_bp (degC)	T_c (degC)	T_disch (degC)	avg glide (K)	COP cool (rel)	CAP cool (rel)
1252 zc	1234zeE	R134	R32	CO_2							
0.28	0.52	0.06	0.11	0.03	142.5	-44.1	101.6	77.8	9.50	1.03	0.85
0.30	0.54	0.07	0.05	0.04	113.1	-44.0	103.0	76.5	9.52	1.02	0.80
0.30	0.53	0.03	0.11	0.03	108.9	-44.2	101.4	77.9	9.55	1.03	0.85
0.15	0.65	0.06	0.12	0.02	149.3	-42.2	103.4	76.5	9.56	1.03	0.81
0.13	0.70	0.00	0.16	0.01	109.2	-41.9	102.5	76.9	9.61	1.03	0.83
0.15	0.64	0.01	0.19	0.01	140.6	-43.0	101.1	78.2	9.62	1.03	0.87
0.26	0.52	0.01	0.19	0.02	140.6	-45.0	99.2	79.8	9.66	1.02	0.91
0.22	0.57	0.03	0.16	0.02	142.7	-43.9	100.9	78.5	9.67	1.03	0.87
0.10	0.69	0.03	0.17	0.01	149.5	-42.0	102.8	77.3	9.71	1.03	0.84
0.29	0.50	0.05	0.13	0.03	144.8	-44.9	100.8	78.7	9.72	1.02	0.87
0.26	0.50	0.00	0.22	0.02	149.7	-45.9	97.9	80.9	9.76	1.02	0.95
0.08	0.72	0.03	0.16	0.01	142.7	-41.5	103.5	76.7	9.77	1.03	0.82
0.30	0.49	0.04	0.14	0.03	140.4	-45.2	100.3	79.2	9.80	1.02	0.89
0.25	0.62	0.01	0.09	0.03	73.0	-43.6	102.6	76.8	9.81	1.03	0.81
0.21	0.61	0.01	0.15	0.02	113.6	-43.7	101.3	78.0	9.85	1.03	0.86
0.24	0.56	0.06	0.11	0.03	142.5	-44.2	102.0	77.7	9.86	1.03	0.84
0.26	0.54	0.05	0.12	0.03	138.1	-44.6	101.4	78.2	9.88	1.03	0.86
0.06	0.76	0.02	0.15	0.01	124.8	-41.1	104.2	76.2	9.89	1.03	0.80
0.24	0.63	0.01	0.09	0.03	73.0	-43.6	102.7	76.8	9.90	1.03	0.81
0.13	0.69	0.04	0.12	0.02	126.9	-42.3	103.6	76.5	9.91	1.03	0.81
0.12	0.69	0.05	0.12	0.02	138.1	-42.3	103.8	76.4	9.92	1.03	0.81
0.24	0.52	0.00	0.22	0.02	149.7	-45.9	98.1	80.8	9.93	1.02	0.95
0.22	0.60	0.00	0.16	0.02	109.2	-44.2	100.7	78.5	9.94	1.03	0.87
0.23	0.60	0.04	0.10	0.03	113.4	-43.9	102.5	77.2	9.95	1.03	0.83
0.07	0.74	0.02	0.16	0.01	131.5	-41.6	103.6	76.7	9.96	1.03	0.82
0.16	0.67	0.02	0.13	0.02	111.3	-42.9	102.7	77.0	9.97	1.03	0.82
0.26	0.58	0.02	0.11	0.03	97.7	-44.4	101.8	77.8	9.98	1.03	0.84
0.11	0.68	0.01	0.19	0.01	140.6	-42.9	101.7	78.1	9.99	1.03	0.86
0.30	0.58	0.02	0.06	0.04	63.9	-44.6	102.7	76.9	10.00	1.02	0.81
0.28	0.57	0.05	0.06	0.04	97.5	-44.5	102.8	76.9	10.00	1.02	0.81

TABLE 3B

W_CARBON DIOXIDE	W_R-1252ZC	W_HFO-1234ZE(E)	W_R134	W_R32	GWP	ASHRAE CLASS	AVG GLIDE (K)	COP DEV from 454C	CAP DEV from 454C	COP DEV from 410A	CAP DEV from 410A
0.01	0.35	0.23	0.05	0.36	300	2	8.3	-0.5	14.5	2.4	-25.5
0.02	0.35	0.22	0.05	0.36	300	2	8.9	-0.8	17.8	2.1	-23.4
0.03	0.35	0.21	0.05	0.36	300	2	9.5	-1.1	21.2	1.8	-21.2
0.03	0.39	0.31	0.23	0.04	285	2	8.7	0.6	-21.5	3.5	-48.9
0.002	0.002	0.577	0.002	0.418	285	2L	9.3	0	7.2	2.9	-30.3
0.002	0.985	0.002	0.002	0.01	9	3	1.2	2.2	-31.9	5.2	-55.7

W_CARBON DIOXIDE	W_R-1252ZC	W_HFO-1234ZE(E)	W_R134	W_R32	GWP	ASHRAE CLASS	AVG GLIDE (K)	COP DEV from 454C	CAP DEV from 454C	COP DEV from 410A	CAP DEV from 410A
0.002	0.002	0.935	0.002	0.06	43	2L	5.8	2.1	-41.3	5.1	-61.8
0.002	0.01	0.985	0.002	0.002	4	2L	0.8	2.4	-51.1	5.4	-68.2
0.002	0.826	0.002	0.002	0.169	116	3	8.2	1.2	-7.5	4.1	-39.8
0.03	0.26	0.44	0.26	0.01	298	2	8.2	0.6	-29	3.5	-53.8
0.002	0.318	0.677	0.002	0.002	4	2	1.7	2.1	-41.6	5.1	-62.0
0.002	0.537	0.02	0.002	0.438	299	2	6.4	-1.6	24.7	1.3	-18.9
0.002	0.002	0.736	0.259	0.002	292	1	0.7	2.6	-48.7	5.6	-66.6
0.03	0.527	0.002	0.002	0.438	299	2	7.7	-2.4	33.3	0.4	-13.3
0.002	0.002	0.985	0.01	0.002	13	2L	0.7	2.4	-51.3	5.4	-68.3
0.002	0.002	0.746	0.249	0.002	280	1	0.7	2.6	-48.8	5.6	-66.7
0.02	0.39	0.26	0.08	0.25	259	2	10	0.3	4.7	3.2	-31.9
0.02	0.199	0.567	0.209	0.005	238	2L	6.1	1	-35.7	3.9	-58.2
0.002	0.002	0.756	0.209	0.03	255	1	3.1	2.3	-44.4	5.3	-63.8
0.01	0.29	0.44	0.21	0.05	270	2	5.9	1.5	-29.7	4.4	-54.3
0.002	0.607	0.279	0.109	0.002	125	3	1	2.1	-34.8	5.1	-57.6
0.005	0.418	0.428	0.109	0.04	150	2	4.3	1.6	-30.8	4.6	-55.0
0.03	0.59	0.28	0.09	0.01	108	3	7.4	0.3	-23.8	3.2	-50.4
0.002	0.975	0.002	0.002	0.02	15	3	2	2.1	-30.3	5.1	-54.7
0.01	0.985	0.002	0.002	0.002	3	3	2.6	1.5	-30.4	4.4	-54.7
0.02	0.002	0.975	0.002	0.002	4	2L	5.9	0.8	-45	3.7	-64.2
0.002	0.002	0.985	0.002	0.01	10	2L	1.6	2.3	-50	5.3	-67.5
0.002	0.856	0.002	0.002	0.139	96	3	7.6	1.4	-11.7	4.3	-42.6
0.03	0.736	0.1	0.129	0.005	148	3	7	0.3	-23.1	3.2	-50.0
0.002	0.696	0.298	0.002	0.002	3	3	0.7	2.1	-34.7	5.1	-57.5
0.01	0.507	0.269	0.005	0.209	147	2	9.3	0.7	-1.6	3.6	-36.0
0.002	0.796	0.199	0.002	0.002	3	3	0.6	2.2	-33.9	5.2	-57.0
0.01	0.776	0.002	0.002	0.209	144	3	9.5	0.7	0.5	3.6	-34.6
0.002	0.002	0.866	0.129	0.002	147	2L	0.8	2.5	-50	5.5	-67.5
0.002	0.002	0.876	0.119	0.002	136	2L	0.8	2.5	-50.1	5.5	-67.5
0.03	0.965	0.002	0.002	0.002	3	3	7.2	0.1	-23.1	3.0	-50.0
0.01	0.29	0.52	0.02	0.16	131	2	10	1.3	-13.2	4.2	-43.5
0.002	0.149	0.696	0.002	0.149	105	2L	9.7	1.9	-21.4	4.9	-48.9
0.02	0.27	0.62	0.05	0.04	84	2	8.2	1	-29.2	3.9	-53.9
0.002	0.876	0.08	0.002	0.04	30	3	3.5	1.8	-26.8	4.8	-52.4
0.01	0.37	0.42	0.03	0.17	149	2	9.5	1.1	-9.9	4.0	-41.4
0.02	0.67	0.15	0.03	0.13	122	3	9.4	0.9	-7.8	3.8	-40.0
0.002	0.806	0.002	0.002	0.189	130	3	8.5	1.1	-4.8	4.0	-38.1
0.01	0.846	0.002	0.002	0.139	97	3	8.7	1.1	-9	4.0	-40.8
0.002	0.249	0.537	0.002	0.209	145	2	9.9	1.2	-9.8	4.1	-41.3
0.02	0.74	0.06	0.06	0.12	149	3	9.2	0.9	-9	3.8	-40.8
0.01	0.647	0.129	0.005	0.209	147	3	9.2	0.7	0	3.6	-35.0
0.02	0.8	0.05	0.02	0.11	97	3	9.3	0.9	-10	3.8	-41.5

W_CARBON DIOXIDE	W_R-1252ZC	W_HFO-1234ZE(E)	W_R134	W_R32	GWP	ASHRAE CLASS	AVG GLIDE (K)	COP DEV from 454C	CAP DEV from 454C	COP DEV from 410A	CAP DEV from 410A
0.002	0.597	0.239	0.002	0.159	111	2	7.9	1.2	-10	4.1	-41.5
0.005	0.667	0.169	0.01	0.149	112	3	7.9	1.2	-10	4.1	-41.5
0.01	0.52	0.29	0.03	0.15	135	2	8.6	1.1	-10	4.0	-41.5
0.02	0.78	0.08	0.01	0.11	86	3	9.2	0.9	-10	3.8	-41.5
0.002	0.836	0.002	0.002	0.159	110	3	8.1	1.3	-8.9	4.2	-40.7
0.002	0.806	0.002	0.03	0.159	141	3	8	1.3	-8.9	4.2	-40.7
0.01	0.607	0.169	0.005	0.209	147	2	9.1	0.7	-0.4	3.6	-35.2
0.01	0.617	0.159	0.005	0.209	147	2	9.1	0.7	-0.3	3.6	-35.1
0.01	0.627	0.149	0.005	0.209	147	2	9.1	0.7	-0.2	3.6	-35.1
0.01	0.637	0.139	0.005	0.209	147	2	9.2	0.7	-0.1	3.6	-35.0
0.01	0.657	0.119	0.005	0.209	147	3	9.2	0.7	0	3.6	-35.0
0.01	0.667	0.109	0.005	0.209	147	3	9.2	0.7	0.1	3.6	-34.9
0.01	0.677	0.1	0.005	0.209	147	3	9.2	0.7	0.2	3.6	-34.8
0.01	0.687	0.09	0.005	0.209	147	3	9.2	0.7	0.2	3.6	-34.8
0.01	0.696	0.08	0.005	0.209	147	3	9.3	0.7	0.3	3.6	-34.8
0.01	0.706	0.07	0.005	0.209	147	3	9.3	0.7	0.3	3.6	-34.8
0.01	0.716	0.06	0.005	0.209	147	3	9.3	0.7	0.4	3.6	-34.7
0.01	0.348	0.448	0.005	0.189	134	2	10	1	-7.5	3.9	-39.8
0.01	0.776	0.005	0.01	0.199	146	3	9.4	0.8	-0.9	3.7	-35.5
0.01	0.6	0.19	0.01	0.19	140	2	9	0.8	-3.1	3.7	-37.0
0.02	0.57	0.23	0.04	0.14	140	2	9.6	0.8	-7.3	3.7	-39.7
0.002	0.438	0.378	0.002	0.179	124	2	8.6	1.1	-9.5	4.0	-41.1
0.005	0.637	0.149	0.01	0.199	146	2	8.6	0.9	-3.1	3.8	-37.0
0.02	0.52	0.28	0.05	0.13	144	2	9.5	0.9	-9.5	3.8	-41.1
0.002	0.398	0.408	0.002	0.189	131	2	8.9	1.1	-8.9	4.0	-40.7
0.002	0.627	0.159	0.002	0.209	144	2	8.4	0.9	-2.6	3.8	-36.6
0.02	0.57	0.24	0.04	0.13	133	2	9.4	0.9	-8.8	3.8	-40.7
0.01	0.488	0.289	0.005	0.209	147	2	9.3	0.7	-1.9	3.6	-36.2

Example 4

[0131] The presently claimed compositions containing HFO-1252zc, HFO-1234zeE, HFC-32, and HFC-134a are compared to R-454C (ASHRAE designation for a refrigerant containing 78.5 wt% HFO-1234yf and 21.5 wt% HFC-32) and R-410A (ASHRAE designation for a refrigerant containing 50 wt% HFC-125 and 50 wt% HFC-32) under the conditions for a residential air-conditioner shown below. Tables 4A and 4B provide the calculated results.

[0132] Conditions:

Avg Evaporator temperature, C	10
Avg Condenser temperature, C	46.1
Evaporator Superheat, K	11.1
Subcool, K	8.3
Compressor efficiency	0.7

TABLE 4A

Composition, mass fraction				GWP (AR5)	Avg Glide	Discharge temp (C)	COP	CAP (kJ/m³)
R134A	R-1252zc	HFO-1234zeE	R32					
0.01	0.21	0.58	0.20	148.5	8.14	77.7	4.81	3920.5
0.01	0.20	0.59	0.20	148.5	8.18	77.6	4.81	3912.3
0.01	0.19	0.60	0.20	148.5	8.26	77.6	4.81	3906.4
0.01	0.16	0.63	0.20	148.5	8.51	77.4	4.81	3888.3
0.01	0.14	0.65	0.20	148.5	8.68	77.4	4.82	3875.7
0.01	0.13	0.66	0.20	148.5	8.77	77.3	4.82	3869.1
0.01	0.12	0.67	0.20	148.5	8.85	77.3	4.82	3862.4
0.01	0.11	0.68	0.20	148.5	8.94	77.3	4.82	3855.5
0.01	0.18	0.62	0.19	141.7	8.22	77.1	4.82	3840.5
0.01	0.17	0.63	0.19	141.7	8.38	77.1	4.82	3838.9
0.01	0.09	0.70	0.20	148.5	9.07	77.1	4.82	3838.7
0.01	0.07	0.72	0.20	148.5	9.28	77.1	4.83	3826.2
0.01	0.15	0.65	0.19	141.7	8.51	77.0	4.82	3823.9
0.01	0.14	0.66	0.19	141.7	8.59	76.9	4.82	3817.1
0.01	0.13	0.67	0.19	141.7	8.67	76.9	4.82	3810.6
0.01	0.04	0.75	0.20	148.5	9.58	77.0	4.83	3804.8
0.02	0.20	0.58	0.20	147.9	7.90	76.7	4.82	3803.9
0.01	0.12	0.68	0.19	141.7	8.72	76.8	4.82	3801.1
0.01	0.20	0.61	0.18	134.9	7.99	76.7	4.82	3796.4
0.02	0.18	0.60	0.20	147.9	8.06	76.7	4.82	3791.2
0.01	0.19	0.62	0.18	134.9	8.07	76.7	4.82	3790.1
0.01	0.02	0.77	0.20	148.5	9.75	76.9	4.84	3788.0
0.01	0.18	0.63	0.18	134.9	8.15	76.7	4.82	3784.0
0.02	0.16	0.63	0.19	147.9	8.23	76.6	4.82	3778.4
0.01	0.17	0.64	0.18	134.9	8.20	76.6	4.82	3775.4
0.02	0.15	0.64	0.19	147.9	8.31	76.5	4.82	3771.8
0.01	0.07	0.73	0.19	141.7	9.22	76.7	4.83	3769.1
0.02	0.14	0.65	0.19	147.9	8.35	76.5	4.82	3762.6
0.01	0.14	0.67	0.18	134.9	8.48	76.5	4.83	3757.9
0.02	0.12	0.68	0.18	147.9	8.56	76.4	4.83	3750.7
0.01	0.12	0.69	0.18	134.9	8.65	76.4	4.83	3743.7
0.02	0.20	0.59	0.19	141.2	7.74	76.3	4.82	3742.6
0.02	0.19	0.60	0.19	141.2	7.86	76.3	4.82	3738.4
0.01	0.20	0.62	0.17	128.2	7.86	76.3	4.82	3737.0

Composition, mass fraction				GWP (AR5)	Avg Glide	Discharge temp (C)	COP	CAP (kJ/m³)
R134A	R-1252zc	HFO-1234zeE	R32					
0.02	0.10	0.70	0.18	147.9	8.72	76.4	4.83	3736.2
0.01	0.03	0.77	0.19	141.7	9.52	76.5	4.84	3733.9
0.02	0.18	0.61	0.19	141.2	7.94	76.2	4.82	3731.9
0.01	0.18	0.64	0.17	128.2	8.06	76.2	4.83	3726.7
0.02	0.17	0.63	0.18	141.2	8.02	76.2	4.82	3725.5
0.01	0.02	0.78	0.19	141.7	9.57	76.4	4.84	3722.6
0.01	0.09	0.72	0.18	134.9	8.90	76.3	4.83	3721.6
0.02	0.08	0.72	0.18	147.9	8.89	76.3	4.83	3720.7
0.01	0.17	0.65	0.17	128.2	8.07	76.1	4.83	3715.6
0.02	0.07	0.73	0.18	147.9	9.01	76.3	4.84	3715.2
0.01	0.08	0.73	0.18	134.9	8.98	76.3	4.84	3714.0
0.01	0.16	0.66	0.17	128.2	8.18	76.1	4.83	3711.3
0.01	0.15	0.67	0.17	128.2	8.23	76.1	4.83	3702.1
0.01	0.06	0.75	0.18	134.9	9.15	76.2	4.84	3697.9
0.01	0.14	0.68	0.17	128.2	8.35	76.1	4.83	3697.6
0.03	0.20	0.59	0.18	147.4	7.55	75.9	4.82	3692.4
0.01	0.13	0.69	0.17	128.2	8.43	76.0	4.83	3690.5
0.02	0.12	0.69	0.17	141.2	8.42	76.0	4.83	3690.5
0.03	0.19	0.60	0.18	147.4	7.63	75.8	4.83	3686.0
0.02	0.11	0.70	0.17	141.2	8.54	76.0	4.83	3685.3
0.01	0.12	0.70	0.17	128.2	8.51	76.0	4.83	3683.4
0.01	0.04	0.77	0.18	134.9	9.31	76.1	4.84	3681.2
0.02	0.19	0.61	0.18	134.4	7.71	75.8	4.83	3678.5
0.02	0.10	0.71	0.17	141.2	8.62	75.9	4.84	3677.8
0.01	0.20	0.63	0.16	121.4	7.68	75.8	4.83	3674.7
0.01	0.03	0.78	0.18	134.9	9.39	76.1	4.84	3672.5
0.01	0.19	0.64	0.16	121.4	7.76	75.8	4.83	3668.2
0.02	0.09	0.72	0.17	141.2	8.67	75.9	4.84	3667.7
0.01	0.10	0.72	0.17	128.2	8.64	75.9	4.84	3665.9
0.02	0.17	0.64	0.17	134.4	7.87	75.7	4.83	3665.1
0.03	0.16	0.63	0.18	147.4	7.83	75.7	4.83	3663.3
0.02	0.01	0.79	0.18	147.9	9.46	76.0	4.85	3660.6
0.02	0.16	0.65	0.17	134.4	7.95	75.7	4.83	3658.2
0.01	0.17	0.66	0.16	121.4	7.95	75.7	4.83	3657.3
0.01	0.01	0.80	0.18	134.9	9.55	76.0	4.85	3654.3
0.01	0.08	0.74	0.17	128.2	8.84	75.8	4.84	3652.9
0.02	0.14	0.67	0.17	134.4	8.10	75.6	4.83	3643.9
0.01	0.07	0.75	0.17	128.2	8.88	75.7	4.84	3642.4
0.02	0.06	0.75	0.17	141.2	8.87	75.7	4.84	3640.8

TABLE 4B – RELATIVE PERFORMANCE

Composition, mass fraction				CAP rel to R-454C (%)	COP rel to R-454C (%)	CAP rel to R-410A (%)	COP rel to R-410A (%)
R134a	1252zc	1234zeE	R32				
0.01	0.21	0.58	0.20	-13.8	2.92	-42.2	7.84
0.01	0.20	0.59	0.20	-14.0	2.93	-42.3	7.85
0.01	0.19	0.60	0.20	-14.1	2.95	-42.4	7.87
0.01	0.16	0.63	0.20	-14.5	3.03	-42.7	7.95
0.01	0.14	0.65	0.20	-14.8	3.08	-42.9	8.01
0.01	0.13	0.66	0.20	-14.9	3.11	-43.0	8.05
0.01	0.12	0.67	0.20	-15.1	3.14	-43.1	8.08
0.01	0.11	0.68	0.20	-15.2	3.18	-43.2	8.11
0.01	0.18	0.62	0.19	-15.5	3.06	-43.4	7.99
0.01	0.17	0.63	0.19	-15.6	3.12	-43.4	8.05
0.01	0.09	0.70	0.20	-15.6	3.23	-43.4	8.17
0.01	0.07	0.72	0.20	-15.9	3.32	-43.6	8.26
0.01	0.15	0.65	0.19	-15.9	3.16	-43.6	8.09
0.01	0.14	0.66	0.19	-16.1	3.19	-43.7	8.13
0.01	0.13	0.67	0.19	-16.2	3.22	-43.8	8.16
0.01	0.04	0.75	0.20	-16.3	3.46	-43.9	8.41
0.02	0.20	0.58	0.20	-16.4	3.10	-43.9	8.03
0.01	0.12	0.68	0.19	-16.4	3.24	-44.0	8.17
0.01	0.20	0.61	0.18	-16.5	3.13	-44.0	8.06
0.02	0.18	0.60	0.20	-16.6	3.15	-44.1	8.08
0.01	0.19	0.62	0.18	-16.7	3.15	-44.1	8.09
0.01	0.02	0.77	0.20	-16.7	3.55	-44.1	8.50
0.01	0.18	0.63	0.18	-16.8	3.18	-44.2	8.11
0.02	0.16	0.63	0.19	-16.9	3.20	-44.3	8.14
0.01	0.17	0.64	0.18	-17.0	3.19	-44.3	8.12
0.02	0.15	0.64	0.19	-17.1	3.23	-44.4	8.17
0.01	0.07	0.73	0.19	-17.1	3.44	-44.4	8.39
0.02	0.14	0.65	0.19	-17.3	3.24	-44.5	8.18
0.01	0.14	0.67	0.18	-17.4	3.29	-44.6	8.23
0.02	0.12	0.68	0.18	-17.5	3.32	-44.7	8.26
0.01	0.12	0.69	0.18	-17.7	3.35	-44.8	8.29
0.02	0.20	0.59	0.19	-17.7	3.18	-44.8	8.11
0.02	0.19	0.60	0.19	-17.8	3.22	-44.9	8.15
0.01	0.20	0.62	0.17	-17.8	3.22	-44.9	8.16
0.02	0.10	0.70	0.18	-17.8	3.39	-44.9	8.33
0.01	0.03	0.77	0.19	-17.9	3.59	-44.9	8.55
0.02	0.18	0.61	0.19	-17.9	3.24	-45.0	8.18
0.01	0.18	0.64	0.17	-18.0	3.29	-45.1	8.23
0.02	0.17	0.63	0.18	-18.1	3.27	-45.1	8.21
0.01	0.02	0.78	0.19	-18.1	3.62	-45.1	8.58
0.01	0.09	0.72	0.18	-18.2	3.45	-45.1	8.40
0.02	0.08	0.72	0.18	-18.2	3.46	-45.1	8.41

Composition, mass fraction				CAP rel to R-454C (%)	COP rel to R-454C (%)	CAP rel to R-410A (%)	COP rel to R-410A (%)
R134a	1252zc	1234zeE	R32				
0.01	0.17	0.65	0.17	-18.3	3.28	-45.2	8.22
0.02	0.07	0.73	0.18	-18.3	3.51	-45.2	8.46
0.01	0.08	0.73	0.18	-18.3	3.49	-45.2	8.44
0.01	0.16	0.66	0.17	-18.4	3.32	-45.3	8.27
0.01	0.15	0.67	0.17	-18.6	3.34	-45.4	8.28
0.01	0.06	0.75	0.18	-18.7	3.56	-45.5	8.52
0.01	0.14	0.68	0.17	-18.7	3.38	-45.5	8.33
0.03	0.20	0.59	0.18	-18.8	3.25	-45.6	8.19
0.01	0.13	0.69	0.17	-18.8	3.41	-45.6	8.36
0.02	0.12	0.69	0.17	-18.8	3.41	-45.6	8.36
0.03	0.19	0.60	0.18	-18.9	3.28	-45.7	8.22
0.02	0.11	0.70	0.17	-19.0	3.46	-45.7	8.41
0.01	0.12	0.70	0.17	-19.0	3.44	-45.7	8.39
0.01	0.04	0.77	0.18	-19.0	3.65	-45.7	8.60
0.02	0.19	0.61	0.18	-19.1	3.31	-45.8	8.25
0.02	0.10	0.71	0.17	-19.1	3.49	-45.8	8.44
0.01	0.20	0.63	0.16	-19.2	3.30	-45.8	8.24
0.01	0.03	0.78	0.18	-19.2	3.69	-45.9	8.65
0.01	0.19	0.64	0.16	-19.3	3.32	-45.9	8.26
0.02	0.09	0.72	0.17	-19.3	3.51	-45.9	8.47
0.01	0.10	0.72	0.17	-19.4	3.49	-45.9	8.44
0.02	0.17	0.64	0.17	-19.4	3.35	-46.0	8.30
0.03	0.16	0.63	0.18	-19.4	3.34	-46.0	8.28
0.02	0.01	0.79	0.18	-19.5	3.75	-46.0	8.71
0.02	0.16	0.65	0.17	-19.6	3.38	-46.1	8.33
0.01	0.17	0.66	0.16	-19.6	3.38	-46.1	8.33
0.01	0.01	0.80	0.18	-19.6	3.78	-46.1	8.74
0.01	0.08	0.74	0.17	-19.7	3.58	-46.1	8.53
0.02	0.14	0.67	0.17	-19.9	3.44	-46.3	8.39
0.01	0.07	0.75	0.17	-19.9	3.60	-46.3	8.56
0.02	0.06	0.75	0.17	-19.9	3.61	-46.3	8.57

[0133] The data demonstrates that the compositions of the present invention containing HFO-1252zc, HFO-1234zeE, HFC-32, and HFC-134a provide GWP less than 150 and reasonable compressor discharge temperatures. Additionally, the compositions provide average temperature glide less than 10 K, or less than 9 K, or less than 8 K. And the compositions also provide capacity within 20% of that for R-454C and COP at least 2%, or even 30 % or more higher than that for R-454C.

Example 5

[0134] The presently claimed compositions containing HFO-1252zc, HFO-1234zeE, HFC-32, HFC-134, and CO_2 are compared to R-454C (ASHRAE designation for a refrigerant containing 78.5 wt% HFO-1234yf and 21.5 wt% HFC-32) and R-410A (ASHRAE designation for a refrigerant containing 50 wt% HFC-125 and 50 wt% HFC-32) under the conditions for a residential air-conditioner shown below. Tables 5A and 5B provide the calculated results.

[0135] Conditions:

Avg Evaporator temperature, C	10
Avg Condenser temperature, C	46.1
Evaporator Superheat, K	11.1
Subcool, K	8.3
Compressor efficiency	0.7

TABLE 5A

Composition, mass fraction					GWP (AR5)	Avg Glide	Discharge temp (C)	COP	CAP (kJ/m³)
CO_2	R134	1252zc	1234zeE	R32					
0.02	0.04	0.19	0.60	0.15	147.2	9.77	78.0	4.80	3891.3
0.02	0.03	0.18	0.55	0.22	136.0	9.99	78.0	4.80	3886.9
0.02	0.04	0.18	0.61	0.15	147.2	9.82	77.9	4.80	3882.7
0.02	0.04	0.17	0.62	0.15	147.2	9.997	78.0	4.81	3882.3
0.01	0.03	0.20	0.59	0.17	149.5	8.78	77.6	4.81	3868.7
0.01	0.03	0.19	0.60	0.17	149.5	8.87	77.5	4.81	3863.1
0.01	0.03	0.18	0.61	0.17	149.5	8.99	77.5	4.81	3859.2
0.01	0.03	0.17	0.62	0.17	149.5	9.11	77.5	4.81	3854.8
0.02	0.04	0.18	0.62	0.14	140.4	9.79	77.6	4.81	3827.7
0.02	0.03	0.18	0.56	0.21	129.2	9.83	77.5	4.81	3823.4
0.02	0.04	0.17	0.63	0.14	140.4	9.84	77.5	4.81	3818.5
0.02	0.03	0.17	0.57	0.21	129.2	9.93	77.5	4.81	3817.5
0.01	0.01	0.18	0.58	0.22	120.4	9.07	77.1	4.81	3798.4
0.01	0.03	0.18	0.62	0.16	142.7	8.84	77.0	4.82	3797.4
0.01	0.01	0.17	0.59	0.22	120.4	9.15	77.0	4.82	3791.9
0.02	0.05	0.19	0.60	0.14	144.8	9.47	77.2	4.81	3774.0
0.01	0.01	0.13	0.63	0.22	120.4	9.51	76.9	4.82	3766.2
0.02	0.04	0.18	0.63	0.13	133.6	9.61	77.1	4.81	3764.1
0.02	0.05	0.18	0.61	0.14	144.8	9.49	77.1	4.81	3763.5
0.02	0.05	0.17	0.62	0.14	144.8	9.65	77.1	4.81	3761.4
0.02	0.03	0.18	0.57	0.20	122.5	9.66	77.0	4.81	3759.7
0.01	0.01	0.12	0.64	0.22	120.4	9.60	76.9	4.82	3759.6
0.02	0.04	0.17	0.64	0.13	133.6	9.70	77.0	4.81	3757.5
0.02	0.05	0.16	0.63	0.14	144.8	9.71	77.0	4.81	3752.6

Composition, mass fraction					GWP (AR5)	Avg Glide	Discharge temp (C)	COP	CAP (kJ/m³)
CO_2	R134	1252zc	1234zeE	R32					
0.02	0.02	0.17	0.66	0.13	111.3	9.84	77.0	4.81	3752.0
0.02	0.01	0.17	0.65	0.15	100.1	9.93	77.0	4.81	3750.2
0.02	0.04	0.16	0.65	0.13	133.6	9.76	77.0	4.81	3748.9
0.01	0.03	0.19	0.62	0.15	136.0	8.69	76.7	4.82	3747.9
0.02	0.03	0.16	0.59	0.20	122.5	9.84	77.0	4.81	3747.0
0.01	0.04	0.19	0.60	0.16	147.2	8.56	76.7	4.82	3746.7
0.02	0.05	0.15	0.64	0.14	144.8	9.81	77.0	4.81	3746.3
0.01	0.01	0.10	0.66	0.22	120.4	9.79	76.8	4.82	3745.7
0.02	0.02	0.16	0.67	0.13	111.3	9.93	77.0	4.81	3745.3
0.01	0.04	0.18	0.61	0.16	147.2	8.68	76.7	4.82	3742.2
0.02	0.04	0.14	0.67	0.13	133.6	9.99	77.0	4.81	3738.4
0.01	0.01	0.18	0.59	0.21	113.6	8.94	76.6	4.82	3737.9
0.01	0.03	0.18	0.63	0.15	136.0	8.71	76.6	4.82	3737.2
0.01	0.04	0.17	0.62	0.16	147.2	8.74	76.6	4.82	3734.0
0.01	0.01	0.08	0.68	0.22	120.4	9.97	76.7	4.83	3730.7
0.01	0.04	0.16	0.63	0.16	147.2	8.86	76.6	4.82	3729.7
0.01	0.01	0.17	0.60	0.21	113.6	8.98	76.6	4.82	3728.6
0.01	0.01	0.16	0.61	0.21	113.6	9.11	76.6	4.82	3724.9
0.01	0.01	0.15	0.62	0.21	113.6	9.16	76.5	4.82	3716.0
0.01	0.01	0.14	0.63	0.21	113.6	9.32	76.5	4.82	3714.5
0.01	0.04	0.14	0.65	0.16	147.2	8.99	76.5	4.82	3713.4
0.02	0.06	0.19	0.61	0.12	149.3	9.17	76.6	4.81	3710.4
0.02	0.05	0.18	0.62	0.13	138.1	9.37	76.6	4.81	3704.0
0.01	0.01	0.13	0.64	0.21	113.6	9.33	76.4	4.82	3702.0
0.01	0.04	0.12	0.67	0.16	147.2	9.17	76.4	4.83	3699.9
0.02	0.06	0.17	0.63	0.12	149.3	9.38	76.6	4.81	3699.2
0.02	0.04	0.18	0.64	0.12	126.9	9.41	76.6	4.81	3698.9
0.02	0.05	0.17	0.63	0.13	138.1	9.46	76.6	4.81	3697.6
0.02	0.04	0.17	0.65	0.12	126.9	9.50	76.6	4.81	3692.9
0.02	0.02	0.17	0.67	0.12	104.5	9.71	76.6	4.81	3691.9
0.02	0.04	0.16	0.66	0.12	126.9	9.67	76.6	4.81	3691.7
0.02	0.06	0.15	0.65	0.12	149.3	9.59	76.6	4.81	3687.7
0.02	0.02	0.16	0.68	0.12	104.5	9.84	76.6	4.81	3687.6
0.01	0.04	0.19	0.61	0.15	140.4	8.41	76.2	4.82	3686.1
0.01	0.04	0.10	0.69	0.16	147.2	9.34	76.4	4.83	3684.5
0.01	0.03	0.19	0.63	0.14	129.2	8.47	76.2	4.82	3682.7
0.02	0.03	0.15	0.61	0.19	115.7	9.85	76.6	4.82	3682.6
0.02	0.04	0.15	0.67	0.12	126.9	9.73	76.5	4.81	3682.2
0.01	0.04	0.18	0.62	0.15	140.4	8.53	76.2	4.82	3681.6
0.02	0.02	0.15	0.69	0.12	104.5	9.90	76.5	4.81	3679.0
0.02	0.06	0.14	0.66	0.12	149.3	9.66	76.5	4.82	3678.9
0.01	0.03	0.18	0.64	0.14	129.2	8.58	76.2	4.82	3678.3
0.02	0.05	0.14	0.66	0.13	138.1	9.70	76.5	4.82	3674.8
0.01	0.03	0.17	0.65	0.14	129.2	8.70	76.2	4.82	3673.7

Composition, mass fraction					GWP (AR5)	Avg Glide	Discharge temp (C)	COP	CAP (kJ/m³)
CO_2	R134	1252zc	1234zeE	R32					
0.02	0.03	0.14	0.62	0.19	115.7	9.90	76.5	4.82	3673.4
0.01	0.01	0.09	0.68	0.21	113.6	9.68	76.3	4.83	3673.1
0.01	0.04	0.17	0.63	0.15	140.4	8.58	76.1	4.82	3673.0
0.01	0.04	0.08	0.71	0.16	147.2	9.55	76.3	4.83	3671.2
0.02	0.05	0.13	0.67	0.13	138.1	9.83	76.5	4.82	3670.1
0.02	0.06	0.13	0.67	0.12	149.3	9.71	76.4	4.82	3669.5
0.01	0.01	0.17	0.61	0.20	106.8	8.85	76.1	4.82	3669.3
0.02	0.05	0.12	0.68	0.13	138.1	9.88	76.4	4.82	3660.6
0.01	0.01	0.07	0.70	0.21	113.6	9.90	76.2	4.83	3660.4
0.01	0.04	0.15	0.65	0.15	140.4	8.74	76.1	4.83	3658.9
0.01	0.04	0.06	0.73	0.16	147.2	9.69	76.2	4.83	3652.6
0.01	0.04	0.14	0.66	0.15	140.4	8.83	76.0	4.83	3652.0
0.01	0.01	0.14	0.64	0.20	106.8	9.15	76.1	4.83	3651.9
0.01	0.01	0.06	0.71	0.21	113.6	9.95	76.2	4.83	3650.1
0.02	0.06	0.18	0.63	0.11	142.5	9.11	76.2	4.81	3643.8
0.01	0.01	0.13	0.65	0.20	106.8	9.20	76.0	4.83	3642.0
0.02	0.05	0.18	0.63	0.12	131.3	9.19	76.2	4.81	3641.2

TABLE 5B – RELATIVE PERFORMANCE

Composition, mass fraction					CAP rel to R-454C (%)	COP rel to R-454C (%)	CAP rel to R-410A (%)	COP rel to R-410A (%)
CO2	R134	1252zc	1234zeE	R32				
0.02	0.04	0.19	0.60	0.15	-14.43	2.78	-42.62	7.70
0.02	0.03	0.18	0.55	0.22	-14.53	2.82	-42.69	7.74
0.02	0.04	0.18	0.61	0.15	-14.62	2.79	-42.75	7.70
0.02	0.04	0.17	0.62	0.15	-14.63	2.85	-42.76	7.77
0.01	0.03	0.20	0.59	0.17	-14.93	2.93	-42.96	7.85
0.01	0.03	0.19	0.60	0.17	-15.05	2.95	-43.04	7.88
0.01	0.03	0.18	0.61	0.17	-15.13	2.98	-43.10	7.90
0.01	0.03	0.17	0.62	0.17	-15.23	3.01	-43.16	7.93
0.02	0.04	0.18	0.62	0.14	-15.83	2.89	-43.56	7.81
0.02	0.03	0.18	0.56	0.21	-15.92	2.87	-43.63	7.79
0.02	0.04	0.17	0.63	0.14	-16.03	2.89	-43.70	7.82
0.02	0.03	0.17	0.57	0.21	-16.05	2.89	-43.71	7.81
0.01	0.01	0.18	0.58	0.22	-16.47	3.04	-43.99	7.97
0.01	0.03	0.18	0.62	0.16	-16.49	3.05	-44.01	7.98
0.01	0.01	0.17	0.59	0.22	-16.61	3.07	-44.09	8.00
0.02	0.05	0.19	0.60	0.14	-17.01	2.91	-44.35	7.84
0.01	0.01	0.13	0.63	0.22	-17.18	3.18	-44.47	8.11
0.02	0.04	0.18	0.63	0.13	-17.22	2.93	-44.50	7.85
0.02	0.05	0.18	0.61	0.14	-17.24	2.92	-44.51	7.85
0.02	0.05	0.17	0.62	0.14	-17.28	2.96	-44.54	7.88
0.02	0.03	0.18	0.57	0.20	-17.32	2.91	-44.57	7.83
0.01	0.01	0.12	0.64	0.22	-17.32	3.20	-44.57	8.14

Composition, mass fraction					CAP rel to R-454C (%)	COP rel to R-454C (%)	CAP rel to R-410A (%)	COP rel to R-410A (%)
CO2	R134	1252zc	1234zeE	R32				
0.02	0.04	0.17	0.64	0.13	-17.37	2.95	-44.60	7.88
0.02	0.05	0.16	0.63	0.14	-17.48	2.97	-44.67	7.90
0.02	0.02	0.17	0.66	0.13	-17.49	2.93	-44.68	7.85
0.02	0.01	0.17	0.65	0.15	-17.53	2.93	-44.70	7.85
0.02	0.04	0.16	0.65	0.13	-17.56	2.95	-44.72	7.88
0.01	0.03	0.19	0.62	0.15	-17.58	3.11	-44.74	8.04
0.02	0.03	0.16	0.59	0.20	-17.60	2.95	-44.75	7.88
0.01	0.04	0.19	0.60	0.16	-17.61	3.11	-44.76	8.05
0.02	0.05	0.15	0.64	0.14	-17.62	3.00	-44.76	7.92
0.01	0.01	0.10	0.66	0.22	-17.63	3.27	-44.77	8.21
0.02	0.02	0.16	0.67	0.13	-17.64	2.95	-44.78	7.88
0.01	0.04	0.18	0.61	0.16	-17.71	3.14	-44.82	8.07
0.02	0.04	0.14	0.67	0.13	-17.79	3.02	-44.88	7.95
0.01	0.01	0.18	0.59	0.21	-17.80	3.12	-44.89	8.05
0.01	0.03	0.18	0.63	0.15	-17.82	3.13	-44.90	8.06
0.01	0.04	0.17	0.62	0.16	-17.89	3.16	-44.94	8.09
0.01	0.01	0.08	0.68	0.22	-17.96	3.33	-44.99	8.28
0.01	0.04	0.16	0.63	0.16	-17.98	3.19	-45.01	8.12
0.01	0.01	0.17	0.60	0.21	-18.01	3.13	-45.02	8.06
0.01	0.01	0.16	0.61	0.21	-18.09	3.17	-45.08	8.10
0.01	0.01	0.15	0.62	0.21	-18.28	3.18	-45.21	8.11
0.01	0.01	0.14	0.63	0.21	-18.32	3.24	-45.23	8.18
0.01	0.04	0.14	0.65	0.16	-18.34	3.24	-45.25	8.17
0.02	0.06	0.19	0.61	0.12	-18.41	2.95	-45.29	7.88
0.02	0.05	0.18	0.62	0.13	-18.55	2.98	-45.39	7.91
0.01	0.01	0.13	0.64	0.21	-18.59	3.23	-45.42	8.17
0.01	0.04	0.12	0.67	0.16	-18.64	3.29	-45.45	8.23
0.02	0.06	0.17	0.63	0.12	-18.65	3.00	-45.46	7.93
0.02	0.04	0.18	0.64	0.12	-18.66	2.96	-45.46	7.89
0.02	0.05	0.17	0.63	0.13	-18.69	3.00	-45.48	7.93
0.02	0.04	0.17	0.65	0.12	-18.79	2.98	-45.55	7.91
0.02	0.02	0.17	0.67	0.12	-18.81	3.00	-45.56	7.93
0.02	0.04	0.16	0.66	0.12	-18.82	3.04	-45.57	7.97
0.02	0.06	0.15	0.65	0.12	-18.90	3.05	-45.63	7.98
0.02	0.02	0.16	0.68	0.12	-18.91	3.04	-45.63	7.97
0.01	0.04	0.19	0.61	0.15	-18.94	3.18	-45.65	8.12
0.01	0.04	0.10	0.69	0.16	-18.98	3.35	-45.67	8.29
0.01	0.03	0.19	0.63	0.14	-19.02	3.17	-45.70	8.11
0.02	0.03	0.15	0.61	0.19	-19.02	3.06	-45.70	7.99
0.02	0.04	0.15	0.67	0.12	-19.03	3.04	-45.71	7.97
0.01	0.04	0.18	0.62	0.15	-19.04	3.20	-45.72	8.14
0.02	0.02	0.15	0.69	0.12	-19.10	3.04	-45.76	7.97
0.02	0.06	0.14	0.66	0.12	-19.10	3.06	-45.76	7.99

Composition, mass fraction					CAP rel to R-454C (%)	COP rel to R-454C (%)	CAP rel to R-410A (%)	COP rel to R-410A (%)
CO2	R134	1252zc	1234zeE	R32				
0.01	0.03	0.18	0.64	0.14	-19.11	3.20	-45.77	8.13
0.02	0.05	0.14	0.66	0.13	-19.19	3.06	-45.82	7.99
0.01	0.03	0.17	0.65	0.14	-19.21	3.22	-45.83	8.16
0.02	0.03	0.14	0.62	0.19	-19.22	3.07	-45.84	8.00
0.01	0.01	0.09	0.68	0.21	-19.23	3.35	-45.84	8.30
0.01	0.04	0.17	0.63	0.15	-19.23	3.22	-45.84	8.16
0.01	0.04	0.08	0.71	0.16	-19.27	3.42	-45.87	8.36
0.02	0.05	0.13	0.67	0.13	-19.29	3.09	-45.89	8.02
0.02	0.06	0.13	0.67	0.12	-19.31	3.08	-45.90	8.02
0.01	0.01	0.17	0.61	0.20	-19.31	3.21	-45.90	8.15
0.02	0.05	0.12	0.68	0.13	-19.50	3.11	-46.03	8.04
0.01	0.01	0.07	0.70	0.21	-19.51	3.44	-46.03	8.38
0.01	0.04	0.15	0.65	0.15	-19.54	3.27	-46.05	8.21
0.01	0.04	0.06	0.73	0.16	-19.68	3.48	-46.14	8.43
0.01	0.04	0.14	0.66	0.15	-19.69	3.30	-46.15	8.24
0.01	0.01	0.14	0.64	0.20	-19.69	3.31	-46.15	8.25
0.01	0.01	0.06	0.71	0.21	-19.73	3.45	-46.18	8.40
0.02	0.06	0.18	0.63	0.11	-19.87	3.02	-46.27	7.95
0.01	0.01	0.13	0.65	0.20	-19.91	3.32	-46.30	8.26
0.02	0.05	0.18	0.63	0.12	-19.93	3.02	-46.31	7.95

[0136] The data demonstrates that the compositions of the present invention containing HFO-1252zc, HFO-1234zeE, HFC-32, HFC-134, and CO_2 provide GWP less than 150 and reasonable compressor discharge temperatures. Additionally, the compositions provide average temperature glide less than 10 K, or less than 9 K. And the compositions also provide capacity within 20% of that for R-454C and COP at least 2%, or even 30 % or more higher than that for R-454C.

[0137] The presently claimed compositions may be lower in capacity than R-410A, but the improved COP (at least 7% higher, or even 8% higher than R-410A) may be worth a small redesign to allow use in systems similar to R-410A systems with the presently claimed lower capacity refrigerants.

Example 6

[0138] The presently claimed compositions containing HFO-1252zc, HFO-1234zeE, HFC-134, HFC-134a and HFC-32 are compared to R-454C (ASHRAE designation for a refrigerant containing 78.5 wt% HFO-1234yf and 21.5 wt% HFC-32) and R-410A (ASHRAE designation for a refrigerant containing 50 wt% HFC-125 and 50 wt% HFC-32) under the conditions for a residential heat pump in both cooling

and heating mode shown below. Table 6a provides the calculated results for cooling mode while Table 6b provides the calculated results for heating mode.

Cooling Mode Conditions:
T_condenser = 47 ºC
T_evaporator = 7 ºC
subcool = 12 K
evaporator superheat = 3 K
compressor efficiency = 0.7
Heating Mode Conditions:
T_condenser = 35 ºC
T_evaporator = -5 ºC
subcool = 8.3 K
superheat = 11.1 K
compressor efficiency = 0.7

[0139] Broadly, for cooling mode, a composition range of 1.0% to 96.0% of R-1252ZC, 1.0% to 96.0% of HFO-1234ZE(E), 1.0% to 24.0% of HFC-134, 1.0% to 21.0% of HFC-134A, and 1.0% to 40.0% of HFC-32 will have a GWP less than 300, a maximum average glide of about 10.0 K, a cooling capacity range that has a deviation range of -47.2% to 20.1% from the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range has a deviation range from -1.1% to 4.7% than that of the cooling COP of R-454C evaluated with the same conditions set. Table 6a lists example compositions within the GWP<300 range that have ASHRAE flammability classifications of 2L, 2, 3 and 1.

[0140] Similarly, but a little less broadly for cooling mode, a composition range of 1.0% to 96.0% of R-1252ZC, 1.0% to 96.0% of HFO-1234ZE(E), 1.0% to 11.0% of HFC-134, 1.0% to 10.0% of HFC-134A, and 1.0% to 18.0% of HFC-32 will have a GWP less than 150, a maximum average glide of about 9.6 K, an ASHRAE flammability classification of 2L, 2 and 3, a cooling capacity range has a deviation of -47.2% to -5.2% from the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range has a deviation of 1.7% to 4.4% than that of the cooling COP of R-454C evaluated with the same conditions set.

[0141] Preferred blend composition ranges for cooling mode within a composition range of 36.0% to 82.0% of R-1252ZC, 1.0% to 44.0% of HFO-1234ZE(E), 1.0% to

3.0% of HFC-134, 1.0% to 2.0% of HFC-134A, and 15.0% to 18.0% of HFC-32 will have a GWP < 150, a maximum average heat exchanger glide of 8.2 K, an ASHRAE flammability classification of 3 and 2, the minimum and maximum cooling capacities are -10.0% and -5.2% than that of R-454C evaluated at the same conditions set, and the minimum and maximum cooling COP efficiencies are 2.2% and 2.6% than that of R-454C evaluated at the same conditions set.

[0142] Even more preferred blend composition ranges for cooling mode within a composition range of 36.0% to 63.0% of R-1252ZC, 17.0% to 44.0% of HFO-1234ZE(E), 1.0% to 2.0% of HFC-134, 1.0% to 2.0% of HFC-134A, and 16.0% to 18.0% of HFC-32 will have a GWP < 150, a maximum average heat exchanger glide of 8.2 K, an ASHRAE flammability classification of 2, the minimum and maximum cooling capacities are -10.0% and -6.0% than that of R-454C evaluated at the same conditions set, and the minimum and maximum cooling COP efficiencies are 2.2% and 2.4% than that of R-454C evaluated at the same conditions set.

[0143] The composition for the even more preferred maximum cooling capacity, which is -6.0% than that of R-454C, is 63.0 wt-% R-1252ZC, 17.0 wt-% HFO-1234ZE(E), 1.0 wt-% HFC-134, 1.0 wt-% HFC-134A, and 18.0 wt-% HFC-32, where the COP for cooling is 2.2% than that for R-454C under the same cycle conditions, the maximum average heat exchanger glide is 7.4 K and its ASHRAE flammability classification is 2.

[0144] The composition for the even more preferred maximum cooling COP efficiency, which is 2.4% than that of R-454C, is 53.0 wt-% R-1252ZC, 28.0 wt-% HFO-1234ZE(E), 2.0 wt-% HFC-134, 1.0 wt-% HFC-134A, and 16.0 wt-% HFC-32, where the CAP for cooling is -9.9% than that for R-454C under the same cycle conditions, the maximum average heat exchanger glide is 7.2 K and its ASHRAE flammability classification is 2.

[0145] Broadly, for heating mode, a composition range of 1.0% to 96.0% of R-1252ZC, 1.0% to 96.0% of HFO-1234ZE(E), 1.0% to 25.0% of HFC-134, 1.0% to 21.0% of HFC-134A, and 1.0% to 40.0% of HFC-32 will have a GWP less than 300, a maximum average glide of about 10.0 K, a heating capacity range that has a deviation range of -50.1% to 19.7% from the heating capacity of R-454C evaluated with the same conditions set, and the heating COP range has a deviation range from

-1.3% to 2.8% than that of the heating COP of R-454C evaluated with the same conditions set. Table 6b lists example compositions within the GWP<300 range that have ASHRAE flammability classifications of 2L, 3, 1 and 2.

[0146] Similarly, but a little less broadly for heating mode, a composition range of 1.0% to 96.0% of R-1252ZC, 1.0% to 96.0% of HFO-1234ZE€, 1.0% to 11.0% of HFC-134, 1.0% to 10.0% of HFC-134A, and 1.0% to 18.0% of HFC-32 will have a GWP less than 150, a maximum average glide of about 10.0 K, an ASHRAE flammability classification of 2, 3 and 2L, a heating capacity range has a deviation of -50.1% to -6.5% from the heating capacity of R-454C evaluated with the same conditions set, and the heating COP range has a deviation of 1.1% to 2.7% than that of the heating COP of R-454C evaluated with the same conditions set.

[0147] Preferred blend composition ranges for heating mode within a composition range of 45.0% to 81.0% of R-1252ZC, 1.0% to 35.0% of HFO-1234ZE€, 1.0% to 2.0% of HFC-134, 1.0% to 2.0% of HFC-134A, and 16.0% to 18.0% of HFC-32 will have a GWP < 150, a maximum average heat exchanger glide of 8.3 K, an ASHRAE flammability classification of 2 and 3, the minimum and maximum heating capacities are -10.0% and -6.5% than that of R-454C evaluated at the same conditions set, and the minimum and maximum heating COP efficiencies are 1.1% and 1.2% than that of R-454C evaluated at the same conditions set.

[0148] Even more preferred blend composition ranges for heating mode within a composition range of 45.0% to 63.0% of R-1252ZC, 17.0% to 35.0% of HFO-1234ZE€, 1.0% to 1.0% of HFC-134, 1.0% to 1.0% of HFC-134A, and 17.0% to 18.0% of HFC-32 will have a GWP < 150, a maximum average heat exchanger glide of 8.3 K, an ASHRAE flammability classification of 2, the minimum and maximum heating capacities are -9.9% and -7.4% than that of R-454C evaluated at the same conditions set, and the minimum and maximum heating COP efficiencies are 1.1% and 1.1% than that of R-454C evaluated at the same conditions set.

[0149] The compositionn for the even more preferred maximum heating capacity, which is–7.4% than that of R-454C, is 63.0 wt-% R-1252ZC, 17.0 wt-% HFO-1234ZE€, 1.0 wt-% HFC-134, 1.0 wt-% HFC-134A, and 18.0 wt-% HFC-32, where the COP for heating is 1.1% than that for R-454C under the same cycle conditions,

the maximum average heat exchanger glide is 7.8 K and its ASHRAE flammability classification is 2.

[0150] The composition for the even more preferred maximum heating COP efficiency, which is 1.1% than that of R-454C, is 54.0 wt-% R-1252ZC, 27.0 wt-% HFO-1234ZE€, 1.0 wt-% HFC-134, 1.0 wt-% HFC-134A, and 17.0 wt-% HFC-32, where the CAP for heating is -9.9% than that for R-454C under the same cycle conditions, the maximum average heat exchanger glide is 7.8 K and its ASHRAE flammability classification is 2.

TABLE 6A

W_R-1252ZC	W_HFO-1234ZE€	W_R134	W_R134A	W_R32	GWP	ASHRAE CLASS	AVG GLIDE (K)	COP DEV from 454C	CAP DEV from 454C	COP DEV from 410A	CAP DEV from 410A
0.01	0.62	0.04	0.05	0.28	300	2L	9.4	2.7	-6.4	6.6	-38.3
0.02	0.61	0.04	0.05	0.28	300	2L	9.3	2.6	-6.1	6.5	-38.1
0.03	0.6	0.04	0.05	0.28	300	2L	9.3	2.5	-5.7	6.4	-37.9
0.04	0.59	0.04	0.05	0.28	300	2L	9.3	2.5	-5.3	6.4	-37.6
0.05	0.58	0.04	0.05	0.28	300	2L	9.2	2.4	-4.9	6.3	-37.3
0.06	0.57	0.04	0.05	0.28	300	2L	9.2	2.3	-4.6	6.2	-37.1
0.07	0.56	0.04	0.05	0.28	300	2L	9.2	2.3	-4.2	6.2	-36.9
0.08	0.55	0.04	0.05	0.28	300	2L	9.1	2.2	-3.9	6.1	-36.7
0.09	0.54	0.04	0.05	0.28	300	2L	9.1	2.2	-3.5	6.1	-36.4
0.1	0.53	0.04	0.05	0.28	300	2L	9	2.1	-3.2	6.0	-36.2
0.11	0.52	0.04	0.05	0.28	300	2L	9	2.1	-2.8	6.0	-35.9
0.12	0.51	0.04	0.05	0.28	300	2L	8.9	2	-2.5	5.9	-35.7
0.13	0.5	0.04	0.05	0.28	300	2L	8.9	1.9	-2.2	5.8	-35.5
0.14	0.49	0.04	0.05	0.28	300	2L	8.8	1.9	-1.9	5.8	-35.4
0.15	0.48	0.04	0.05	0.28	300	2L	8.8	1.9	-1.6	5.8	-35.2
0.16	0.47	0.04	0.05	0.28	300	2L	8.7	1.8	-1.3	5.7	-35.0
0.17	0.46	0.04	0.05	0.28	300	2L	8.7	1.7	-1	5.6	-34.8
0.18	0.45	0.04	0.05	0.28	300	2L	8.6	1.7	-0.7	5.6	-34.6
0.19	0.44	0.04	0.05	0.28	300	2L	8.5	1.7	-0.4	5.6	-34.4
0.2	0.43	0.04	0.05	0.28	300	2L	8.5	1.6	-0.1	5.5	-34.2
0.21	0.42	0.04	0.05	0.28	300	2L	8.4	1.6	0.2	5.5	-34.0
0.22	0.41	0.04	0.05	0.28	300	2L	8.3	1.5	0.5	5.4	-33.8
0.23	0.4	0.04	0.05	0.28	300	2L	8.3	1.5	0.8	5.4	-33.6
0.24	0.39	0.04	0.05	0.28	300	2L	8.2	1.5	1	5.4	-33.4
0.25	0.38	0.04	0.05	0.28	300	2L	8.2	1.4	1.3	5.3	-33.2
0.26	0.37	0.04	0.05	0.28	300	2L	8.1	1.4	1.5	5.3	-33.1
0.27	0.36	0.04	0.05	0.28	300	2L	8	1.3	1.8	5.2	-32.9
0.28	0.35	0.04	0.05	0.28	300	2L	8	1.3	2	5.2	-32.8

W_R-1252ZC	W_HFO-1234ZE€	W_R134	W_R134A	W_R32	GWP	ASHRAE CLASS	AVG GLIDE (K)	COP DEV from 454C	CAP DEV from 454C	COP DEV from 410A	CAP DEV from 410A
0.29	0.34	0.04	0.05	0.28	300	2L	7.9	1.3	2.3	5.2	-32.6
0.3	0.33	0.04	0.05	0.28	300	2	7.9	1.2	2.5	5.1	-32.5
0.31	0.32	0.04	0.05	0.28	300	2	7.8	1.2	2.8	5.1	-32.3
0.32	0.31	0.04	0.05	0.28	300	2	7.8	1.2	3	5.1	-32.1
0.33	0.3	0.04	0.05	0.28	300	2	7.7	1.2	3.2	5.1	-32.0
0.34	0.29	0.04	0.05	0.28	300	2	7.6	1.1	3.4	5.0	-31.9
0.35	0.28	0.04	0.05	0.28	300	2	7.6	1.1	3.6	5.0	-31.7
0.36	0.27	0.04	0.05	0.28	300	2	7.5	1.1	3.9	5.0	-31.5
0.37	0.26	0.04	0.05	0.28	300	2	7.5	1.1	4.1	5.0	-31.4
0.38	0.25	0.04	0.05	0.28	300	2	7.5	1.1	4.3	5.0	-31.3
0.39	0.24	0.04	0.05	0.28	300	2	7.4	1.1	4.4	5.0	-31.2
0.4	0.23	0.04	0.05	0.28	300	2	7.4	1	4.6	4.9	-31.1
0.41	0.22	0.04	0.05	0.28	300	2	7.3	1	4.8	4.9	-30.9
0.42	0.21	0.04	0.05	0.28	300	2	7.3	1	5	4.9	-30.8
0.43	0.2	0.04	0.05	0.28	300	2	7.3	1	5.1	4.9	-30.7
0.44	0.19	0.04	0.05	0.28	300	2	7.2	1	5.3	4.9	-30.6
0.45	0.18	0.04	0.05	0.28	300	2	7.2	1	5.5	4.9	-30.5
0.46	0.17	0.04	0.05	0.28	300	2	7.2	1	5.6	4.9	-30.4
0.47	0.16	0.04	0.05	0.28	300	2	7.2	0.9	5.8	4.8	-30.3
0.48	0.15	0.04	0.05	0.28	300	2	7.2	0.9	5.9	4.8	-30.2
0.49	0.14	0.04	0.05	0.28	300	2	7.1	0.9	6	4.8	-30.1
0.5	0.13	0.04	0.05	0.28	300	2	7.1	0.9	6.1	4.8	-30.1
0.51	0.12	0.04	0.05	0.28	300	2	7.1	0.9	6.3	4.8	-29.9
0.52	0.11	0.04	0.05	0.28	300	2	7.1	0.9	6.4	4.8	-29.9
0.53	0.1	0.04	0.05	0.28	300	2	7.1	0.9	6.5	4.8	-29.8
0.54	0.09	0.04	0.05	0.28	300	2	7.1	0.9	6.6	4.8	-29.7
0.55	0.08	0.04	0.05	0.28	300	2	7.1	0.9	6.7	4.8	-29.7
0.56	0.07	0.04	0.05	0.28	300	2	7.1	0.9	6.7	4.8	-29.7
0.57	0.06	0.04	0.05	0.28	300	2	7.2	0.9	6.8	4.8	-29.6
0.58	0.05	0.04	0.05	0.28	300	2	7.2	0.9	6.9	4.8	-29.6
0.59	0.04	0.04	0.05	0.28	300	2	7.2	0.8	7	4.7	-29.5
0.6	0.03	0.04	0.05	0.28	300	2	7.2	0.8	7	4.7	-29.5
0.61	0.02	0.04	0.05	0.28	300	2	7.3	0.8	7.1	4.7	-29.4
0.62	0.01	0.04	0.05	0.28	300	2	7.3	0.8	7.1	4.7	-29.4
0.96	0.01	0.01	0.01	0.01	32	3	0.9	3.6	-30.4	7.6	-54.1
0.01	0.7	0.02	0.06	0.21	243	2L	9.3	3.3	-15.1	7.3	-44.1
0.01	0.96	0.01	0.01	0.01	32	2L	1.2	3.6	-47.2	7.6	-65.2
0.82	0.01	0.05	0.04	0.08	163	3	4.7	3.1	-19	7.1	-46.6
0.65	0.09	0.24	0.01	0.01	289	3	0.7	3.6	-31.1	7.6	-54.6
0.22	0.51	0.01	0.14	0.12	275	2L	6.8	2.8	-19.7	6.7	-47.1
0.1	0.67	0.01	0.21	0.01	292	2L	1.8	3.4	-39.9	7.4	-60.4

W_R-1252ZC	W_HFO-1234ZE€	W_R134	W_R134A	W_R32	GWP	ASHRAE CLASS	AVG GLIDE (K)	COP DEV from 454C	CAP DEV from 454C	COP DEV from 410A	CAP DEV from 410A
0.21	0.53	0.18	0.01	0.07	263	2L	4.9	3.4	-29.5	7.4	-53.5
0.32	0.26	0.01	0.01	0.4	296	2	6.8	-0.6	16.8	3.2	-23.0
0.18	0.7	0.02	0.09	0.01	147	2L	2	3.4	-39.8	7.4	-60.3
0.57	0.01	0.01	0.01	0.4	296	2	6.5	-1.1	20.1	2.7	-20.9
0.28	0.53	0.06	0.08	0.05	206	2	4.6	4.7	-29	8.7	-53.2
0.04	0.7	0.01	0.01	0.24	187	2L	10	3	-10.7	7.0	-41.2
0.01	0.76	0.17	0.05	0.01	263	1	1.1	3.8	-44.6	7.8	-63.5
0.15	0.75	0.02	0.02	0.06	90	2L	5.3	3.4	-33.7	7.4	-56.3
0.36	0.42	0.06	0.1	0.06	239	2	4.2	2.9	-26.3	6.9	-51.4
0.78	0.08	0.04	0.01	0.09	120	3	5.2	3	-18.2	7.0	-46.1
0.01	0.83	0.05	0.03	0.08	150	2L	5.9	3.8	-34.6	7.8	-56.9
0.02	0.82	0.05	0.03	0.08	150	2L	6	3.8	-34.3	7.8	-56.7
0.03	0.81	0.05	0.03	0.08	150	2L	6	3.8	-33.9	7.8	-56.4
0.04	0.8	0.05	0.03	0.08	150	2L	6	3.7	-33.5	7.7	-56.2
0.05	0.79	0.05	0.03	0.08	150	2L	6	3.7	-33.2	7.7	-56.0
0.06	0.78	0.05	0.03	0.08	150	2L	6.1	3.7	-32.9	7.7	-55.8
0.07	0.77	0.05	0.03	0.08	150	2L	6.1	3.7	-32.5	7.7	-55.5
0.08	0.76	0.05	0.03	0.08	150	2L	6.1	3.6	-32.2	7.6	-55.3
0.09	0.75	0.05	0.03	0.08	150	2L	6.1	3.6	-31.9	7.6	-55.1
0.1	0.74	0.05	0.03	0.08	150	2L	6.1	3.6	-31.5	7.6	-54.9
0.11	0.73	0.05	0.03	0.08	150	2L	6.1	3.6	-31.2	7.6	-54.7
0.12	0.72	0.05	0.03	0.08	150	2L	6.1	3.5	-30.9	7.5	-54.5
0.13	0.71	0.05	0.03	0.08	150	2L	6.1	3.5	-30.6	7.5	-54.3
0.14	0.7	0.05	0.03	0.08	150	2L	6.1	3.5	-30.3	7.5	-54.1
0.15	0.69	0.05	0.03	0.08	150	2L	6.1	3.5	-30	7.5	-53.9
0.16	0.68	0.05	0.03	0.08	150	2L	6.1	3.4	-29.7	7.4	-53.7
0.17	0.67	0.05	0.03	0.08	150	2L	6	3.4	-29.4	7.4	-53.5
0.18	0.66	0.05	0.03	0.08	150	2L	6	3.4	-29.1	7.4	-53.3
0.19	0.65	0.05	0.03	0.08	150	2L	6	3.3	-28.9	7.3	-53.1
0.2	0.64	0.05	0.03	0.08	150	2L	6	3.3	-28.6	7.3	-52.9
0.21	0.63	0.05	0.03	0.08	150	2L	6	3.3	-28.3	7.3	-52.7
0.22	0.62	0.05	0.03	0.08	150	2L	5.9	3.3	-28	7.3	-52.6
0.23	0.61	0.05	0.03	0.08	150	2	5.9	3.2	-27.8	7.2	-52.4
0.24	0.6	0.05	0.03	0.08	150	2	5.9	3.2	-27.5	7.2	-52.2
0.25	0.59	0.05	0.03	0.08	150	2	5.8	3.2	-27.3	7.2	-52.1
0.26	0.58	0.05	0.03	0.08	150	2	5.8	3.2	-27	7.2	-51.9
0.27	0.57	0.05	0.03	0.08	150	2	5.8	3.1	-26.7	7.1	-51.7
0.28	0.56	0.05	0.03	0.08	150	2	5.7	3.1	-26.5	7.1	-51.6
0.29	0.55	0.05	0.03	0.08	150	2	5.7	3.1	-26.3	7.1	-51.4
0.3	0.54	0.05	0.03	0.08	150	2	5.6	3.1	-26	7.1	-51.2
0.31	0.53	0.05	0.03	0.08	150	2	5.6	3.1	-25.8	7.1	-51.1

W_R-1252ZC	W_HFO-1234ZE€	W_R134	W_R134A	W_R32	GWP	ASHRAE CLASS	AVG GLIDE (K)	COP DEV from 454C	CAP DEV from 454C	COP DEV from 410A	CAP DEV from 410A
0.32	0.52	0.05	0.03	0.08	150	2	5.6	3.1	-25.6	7.1	-51.0
0.33	0.51	0.05	0.03	0.08	150	2	5.5	3	-25.3	7.0	-50.8
0.34	0.5	0.05	0.03	0.08	150	2	5.5	3	-25.1	7.0	-50.6
0.35	0.49	0.05	0.03	0.08	150	2	5.4	3	-24.9	7.0	-50.5
0.36	0.48	0.05	0.03	0.08	150	2	5.4	3	-24.7	7.0	-50.4
0.37	0.47	0.05	0.03	0.08	150	2	5.4	3	-24.5	7.0	-50.2
0.38	0.46	0.05	0.03	0.08	150	2	5.3	3	-24.3	7.0	-50.1
0.39	0.45	0.05	0.03	0.08	150	2	5.3	2.9	-24	6.9	-49.9
0.4	0.44	0.05	0.03	0.08	150	2	5.2	2.9	-23.8	6.9	-49.8
0.41	0.43	0.05	0.03	0.08	150	2	5.2	2.9	-23.7	6.9	-49.7
0.42	0.42	0.05	0.03	0.08	150	2	5.2	2.9	-23.5	6.9	-49.6
0.43	0.41	0.05	0.03	0.08	150	2	5.1	2.9	-23.3	6.9	-49.5
0.44	0.4	0.05	0.03	0.08	150	2	5.1	2.9	-23.1	6.9	-49.3
0.45	0.39	0.05	0.03	0.08	150	2	5	2.9	-22.9	6.9	-49.2
0.46	0.38	0.05	0.03	0.08	150	2	5	2.9	-22.7	6.9	-49.1
0.47	0.37	0.05	0.03	0.08	150	2	5	2.9	-22.6	6.9	-49.0
0.48	0.36	0.05	0.03	0.08	150	2	4.9	2.9	-22.4	6.9	-48.9
0.49	0.35	0.05	0.03	0.08	150	2	4.9	2.9	-22.2	6.9	-48.7
0.5	0.34	0.05	0.03	0.08	150	2	4.9	2.9	-22.1	6.9	-48.7
0.51	0.33	0.05	0.03	0.08	150	2	4.8	2.9	-21.9	6.9	-48.5
0.52	0.32	0.05	0.03	0.08	150	2	4.8	2.9	-21.8	6.9	-48.5
0.53	0.31	0.05	0.03	0.08	150	2	4.8	2.9	-21.6	6.9	-48.3
0.54	0.3	0.05	0.03	0.08	150	2	4.8	2.9	-21.5	6.9	-48.3
0.55	0.29	0.05	0.03	0.08	150	2	4.7	2.9	-21.3	6.9	-48.1
0.56	0.28	0.05	0.03	0.08	150	2	4.7	2.9	-21.2	6.9	-48.1
0.57	0.27	0.05	0.03	0.08	150	2	4.7	2.9	-21.1	6.9	-48.0
0.58	0.26	0.05	0.03	0.08	150	2	4.7	2.9	-20.9	6.9	-47.9
0.59	0.25	0.05	0.03	0.08	150	2	4.7	2.9	-20.8	6.9	-47.8
0.6	0.24	0.05	0.03	0.08	150	3	4.6	2.9	-20.7	6.9	-47.7
0.61	0.23	0.05	0.03	0.08	150	3	4.6	2.9	-20.6	6.9	-47.7
0.62	0.22	0.05	0.03	0.08	150	3	4.6	2.9	-20.5	6.9	-47.6
0.63	0.21	0.05	0.03	0.08	150	3	4.6	2.9	-20.4	6.9	-47.5
0.64	0.2	0.05	0.03	0.08	150	3	4.6	2.9	-20.3	6.9	-47.5
0.65	0.19	0.05	0.03	0.08	150	3	4.6	2.9	-20.2	6.9	-47.4
0.66	0.18	0.05	0.03	0.08	150	3	4.6	2.9	-20.1	6.9	-47.3
0.67	0.17	0.05	0.03	0.08	150	3	4.6	2.9	-20	6.9	-47.3
0.68	0.16	0.05	0.03	0.08	150	3	4.6	2.9	-19.9	6.9	-47.2
0.69	0.15	0.05	0.03	0.08	150	3	4.6	3	-19.8	7.0	-47.1
0.7	0.14	0.05	0.03	0.08	150	3	4.6	3	-19.8	7.0	-47.1
0.71	0.13	0.05	0.03	0.08	150	3	4.6	3	-19.7	7.0	-47.1
0.72	0.12	0.05	0.03	0.08	150	3	4.6	3	-19.6	7.0	-47.0

W_R-1252ZC	W_HFO-1234ZE€	W_R134	W_R134A	W_R32	GWP	ASHRAE CLASS	AVG GLIDE (K)	COP DEV from 454C	CAP DEV from 454C	COP DEV from 410A	CAP DEV from 410A
0.73	0.11	0.05	0.03	0.08	150	3	4.6	3	-19.6	7.0	-47.0
0.74	0.1	0.05	0.03	0.08	150	3	4.6	3	-19.5	7.0	-46.9
0.75	0.09	0.05	0.03	0.08	150	3	4.6	3	-19.4	7.0	-46.9
0.76	0.08	0.05	0.03	0.08	150	3	4.6	3	-19.4	7.0	-46.9
0.77	0.07	0.05	0.03	0.08	150	3	4.6	3	-19.3	7.0	-46.8
0.78	0.06	0.05	0.03	0.08	150	3	4.7	3	-19.3	7.0	-46.8
0.79	0.05	0.05	0.03	0.08	150	3	4.7	3	-19.3	7.0	-46.8
0.8	0.04	0.05	0.03	0.08	150	3	4.7	3.1	-19.2	7.1	-46.8
0.81	0.03	0.05	0.03	0.08	150	3	4.7	3.1	-19.2	7.1	-46.8
0.82	0.02	0.05	0.03	0.08	150	3	4.7	3.1	-19.2	7.1	-46.8
0.83	0.01	0.05	0.03	0.08	150	3	4.7	3.1	-19.1	7.1	-46.7
0.01	0.86	0.07	0.04	0.02	145	2L	2	3.6	-44.2	7.6	-63.2
0.92	0.01	0.01	0.02	0.04	65	3	2.9	3.3	-25.3	7.3	-50.8
0.21	0.66	0.11	0.01	0.01	144	2L	1.7	3.5	-39.9	7.5	-60.4
0.59	0.28	0.01	0.06	0.06	131	3	3.9	2.8	-23.4	6.7	-49.5
0.3	0.58	0.01	0.1	0.01	149	2	1.9	3.1	-36.3	7.1	-58.0
0.37	0.52	0.05	0.01	0.05	104	2	4.1	3.1	-29.8	7.1	-53.7
0.07	0.73	0.01	0.01	0.18	147	2L	9.5	3.4	-17.7	7.4	-45.8
0.27	0.63	0.03	0.06	0.01	119	2	1.9	3.3	-37.9	7.3	-59.1
0.79	0.01	0.01	0.01	0.18	147	3	7.7	2.3	-5.2	6.2	-37.5
0.34	0.54	0.02	0.04	0.06	116	2	5.1	4.4	-27.3	8.4	-52.1
0.35	0.53	0.03	0.04	0.05	120	2	3.8	1.7	-30.7	5.6	-54.3
0.02	0.78	0.01	0.01	0.18	147	2L	9.6	3.6	-19.5	7.6	-46.9
0.18	0.67	0.06	0.01	0.08	135	2L	6.1	3.4	-29.5	7.4	-53.5
0.24	0.65	0.03	0.04	0.04	114	2	3.9	3.2	-34	7.2	-56.5
0.62	0.25	0.06	0.01	0.06	122	3	3.8	3	-24.1	7.0	-50.0
0.67	0.14	0.03	0.01	0.15	149	3	6.9	2.5	-9.9	6.4	-40.6
0.68	0.13	0.03	0.01	0.15	149	3	6.9	2.5	-9.9	6.4	-40.6
0.69	0.12	0.03	0.01	0.15	149	3	6.9	2.5	-9.8	6.4	-40.6
0.7	0.11	0.03	0.01	0.15	149	3	6.9	2.6	-9.8	6.5	-40.6
0.71	0.1	0.03	0.01	0.15	149	3	6.9	2.6	-9.7	6.5	-40.5
0.72	0.09	0.03	0.01	0.15	149	3	6.9	2.6	-9.6	6.5	-40.4
0.73	0.08	0.03	0.01	0.15	149	3	6.9	2.6	-9.6	6.5	-40.4
0.74	0.07	0.03	0.01	0.15	149	3	7	2.6	-9.6	6.5	-40.4
0.75	0.06	0.03	0.01	0.15	149	3	7	2.6	-9.5	6.5	-40.4
0.76	0.05	0.03	0.01	0.15	149	3	7	2.6	-9.5	6.5	-40.4
0.77	0.04	0.03	0.01	0.15	149	3	7	2.6	-9.4	6.5	-40.3
0.78	0.03	0.03	0.01	0.15	149	3	7	2.6	-9.4	6.5	-40.3
0.79	0.02	0.03	0.01	0.15	149	3	7.1	2.6	-9.4	6.5	-40.3
0.8	0.01	0.03	0.01	0.15	149	3	7.1	2.6	-9.4	6.5	-40.3
0.82	0.01	0.01	0.01	0.15	127	3	7.2	2.6	-9.2	6.5	-40.2

W_R-1252ZC	W_HFO-1234ZE€	W_R134	W_R134A	W_R32	GWP	ASHRAE CLASS	AVG GLIDE (K)	COP DEV from 454C	CAP DEV from 454C	COP DEV from 410A	CAP DEV from 410A
0.36	0.44	0.01	0.01	0.18	147	2	8.2	2.4	-9.9	6.3	-40.6
0.8	0.01	0.01	0.02	0.16	146	3	7.3	2.5	-7.7	6.4	-39.2
0.52	0.28	0.01	0.01	0.18	147	2	7.6	2.2	-7.2	6.1	-38.8
0.65	0.16	0.01	0.02	0.16	146	3	7.1	2.4	-8.4	6.3	-39.6
0.66	0.16	0.01	0.01	0.16	133	3	7.2	2.4	-8.5	6.3	-39.7
0.37	0.43	0.01	0.01	0.18	147	2	8.2	2.3	-9.7	6.2	-40.5
0.69	0.14	0.01	0.01	0.15	127	3	7	2.5	-9.7	6.4	-40.5
0.63	0.19	0.01	0.02	0.15	140	3	6.9	2.4	-10	6.3	-40.7
0.81	0.01	0.02	0.01	0.15	138	3	7.2	2.6	-9.3	6.5	-40.2
0.53	0.27	0.01	0.01	0.18	147	2	7.6	2.2	-7	6.1	-38.7
0.54	0.26	0.01	0.01	0.18	147	2	7.5	2.2	-6.9	6.1	-38.6
0.55	0.25	0.01	0.01	0.18	147	2	7.5	2.2	-6.8	6.1	-38.6
0.56	0.24	0.01	0.01	0.18	147	2	7.5	2.2	-6.7	6.1	-38.5
0.57	0.23	0.01	0.01	0.18	147	2	7.5	2.2	-6.6	6.1	-38.4
0.58	0.22	0.01	0.01	0.18	147	2	7.5	2.2	-6.4	6.1	-38.3
0.59	0.21	0.01	0.01	0.18	147	2	7.5	2.2	-6.3	6.1	-38.3
0.6	0.2	0.01	0.01	0.18	147	2	7.5	2.2	-6.2	6.1	-38.2
0.61	0.19	0.01	0.01	0.18	147	2	7.4	2.2	-6.1	6.1	-38.1
0.62	0.18	0.01	0.01	0.18	147	2	7.4	2.2	-6	6.1	-38.1
0.63	0.17	0.01	0.01	0.18	147	2	7.4	2.2	-6	6.1	-38.1
0.64	0.16	0.01	0.01	0.18	147	3	7.4	2.2	-5.9	6.1	-38.0
0.65	0.15	0.01	0.01	0.18	147	3	7.5	2.2	-5.8	6.1	-37.9
0.48	0.32	0.01	0.01	0.18	147	2	7.7	2.2	-7.8	6.1	-39.2
0.38	0.42	0.01	0.01	0.18	147	2	8.1	2.3	-9.5	6.2	-40.4
0.39	0.41	0.01	0.01	0.18	147	2	8.1	2.3	-9.3	6.2	-40.2
0.4	0.4	0.01	0.01	0.18	147	2	8	2.3	-9.2	6.2	-40.2
0.41	0.39	0.01	0.01	0.18	147	2	8	2.3	-9	6.2	-40.0
0.42	0.38	0.01	0.01	0.18	147	2	7.9	2.3	-8.8	6.2	-39.9
0.43	0.37	0.01	0.01	0.18	147	2	7.9	2.3	-8.6	6.2	-39.8
0.44	0.36	0.01	0.01	0.18	147	2	7.9	2.3	-8.4	6.2	-39.6
0.45	0.35	0.01	0.01	0.18	147	2	7.8	2.2	-8.2	6.1	-39.5
0.46	0.34	0.01	0.01	0.18	147	2	7.8	2.2	-8.1	6.1	-39.4
0.47	0.33	0.01	0.01	0.18	147	2	7.7	2.2	-7.9	6.1	-39.3
0.49	0.31	0.01	0.01	0.18	147	2	7.7	2.2	-7.6	6.1	-39.1
0.5	0.3	0.01	0.01	0.18	147	2	7.6	2.2	-7.5	6.1	-39.0
0.51	0.29	0.01	0.01	0.18	147	2	7.6	2.2	-7.3	6.1	-38.9
0.61	0.2	0.02	0.01	0.16	145	2	7.1	2.4	-9	6.3	-40.0
0.62	0.19	0.01	0.02	0.16	146	2	7.1	2.3	-8.7	6.2	-39.8
0.58	0.23	0.02	0.01	0.16	145	2	7.1	2.4	-9.3	6.3	-40.2
0.55	0.26	0.01	0.02	0.16	146	2	7.2	2.3	-9.4	6.2	-40.3
0.51	0.3	0.01	0.02	0.16	146	2	7.3	2.3	-10	6.2	-40.7

W_R-1252ZC	W_HFO-1234ZE€	W_R134	W_R134A	W_R32	GWP	ASHRAE CLASS	AVG GLIDE (K)	COP DEV from 454C	CAP DEV from 454C	COP DEV from 410A	CAP DEV from 410A
0.53	0.28	0.02	0.01	0.16	145	2	7.2	2.4	-9.9	6.3	-40.6
0.54	0.27	0.02	0.01	0.16	145	2	7.2	2.4	-9.8	6.3	-40.6
0.62	0.19	0.02	0.01	0.16	145	2	7.1	2.4	-8.9	6.3	-40.0
0.61	0.2	0.01	0.01	0.17	140	2	7.3	2.3	-7.5	6.2	-39.0

TABLE 6B

W_R-1252ZC	W_HFO-1234ZE(E)	W_R134	W_R134A	W_R32	GWP	ASHRAE CLASS	AVG GLIDE (K)	COP DEV	CAP DEV	COP DEV from 410A	CAP DEV from 410A
0.22	0.44	0.03	0.09	0.22	300	2L	8.7	1	-8.6	3.9	-40.5
0.22	0.5	0.22	0.02	0.04	300	2L	3.6	1.9	-36.2	4.9	-58.5
0.96	0.01	0.01	0.01	0.01	31	3	0.9	1.9	-32.5	4.9	-56.1
0.01	0.7	0.21	0.01	0.07	296	1	4.9	2.2	-38.7	5.2	-60.1
0.01	0.96	0.01	0.01	0.01	32	2L	1.2	2.1	-50.1	5.1	-67.5
0.75	0.01	0.09	0.08	0.07	252	3	4.1	1.5	-21.9	4.4	-49.2
0.63	0.1	0.25	0.01	0.01	300	2	0.8	1.9	-33.6	4.9	-56.8
0.18	0.69	0.01	0.06	0.06	131	2L	5.6	1.8	-34.6	4.8	-57.5
0.73	0.03	0.01	0.21	0.02	298	3	1.5	1.6	-26.9	4.6	-52.5
0.47	0.24	0.07	0.01	0.21	234	2	7.9	1	-5.7	3.9	-38.7
0.44	0.14	0.01	0.01	0.4	295	2	6.7	-1.1	18.4	1.8	-23.0
0.59	0.26	0.11	0.03	0.01	169	3	1	1.8	-34	4.8	-57.1
0.57	0.01	0.01	0.01	0.4	295	2	6.9	-1.3	19.7	1.6	-22.1
0.32	0.53	0.04	0.06	0.05	157	2	4.9	2.8	-31.2	5.8	-55.2
0.03	0.62	0.01	0.06	0.28	279	2L	10	1.1	-8	4.0	-40.2
0.16	0.61	0.09	0.06	0.08	234	2L	6	1.9	-31.6	4.9	-55.5
0.02	0.75	0.13	0.09	0.01	270	1	1.3	2.2	-46.9	5.2	-65.5
0.56	0.21	0.01	0.14	0.08	248	2	4.5	1.3	-20.6	4.2	-48.4
0.69	0.1	0.06	0.03	0.12	188	3	6.2	1.4	-15.6	4.3	-45.1
0.33	0.52	0.08	0.02	0.05	150	2	4.4	1.7	-32.6	4.7	-56.2
0.01	0.87	0.01	0.01	0.1	93	2L	7.8	2.2	-34.7	5.2	-57.5
0.9	0.01	0.03	0.02	0.04	87	3	3	1.7	-27.4	4.7	-52.8
0.67	0.19	0.11	0.01	0.02	150	3	1.6	1.8	-32	4.8	-55.8
0.07	0.8	0.01	0.01	0.11	99	2L	8.3	2.1	-30.9	5.1	-55.1
0.71	0.17	0.01	0.1	0.01	148	3	1	1.7	-31.3	4.7	-55.3
0.62	0.3	0.05	0.01	0.02	83	3	1.7	1.7	-32.8	4.7	-56.3
0.17	0.63	0.01	0.01	0.18	147	2L	9.8	1.6	-17	4.6	-46.0
0.51	0.4	0.02	0.06	0.01	108	2	1.4	1.7	-35	4.7	-57.7
0.79	0.01	0.01	0.01	0.18	146	3	8.1	1.1	-6.5	4.0	-39.2
0.32	0.54	0.03	0.06	0.05	146	2	4.9	2.7	-31.4	5.7	-55.4
0.52	0.28	0.01	0.01	0.18	146	2	8	1.1	-8.7	4.0	-40.6

W_R-1252ZC	W_HFO-1234ZE(E)	W_R134	W_R134A	W_R32	GWP	ASHRAE CLASS	AVG GLIDE (K)	COP DEV	CAP DEV	COP DEV from 410A	CAP DEV from 410A
0.53	0.27	0.01	0.01	0.18	146	2	8	1.1	-8.6	4.0	-40.5
0.54	0.26	0.01	0.01	0.18	146	2	7.9	1.1	-8.4	4.0	-40.4
0.55	0.25	0.01	0.01	0.18	146	2	7.9	1.1	-8.3	4.0	-40.4
0.56	0.24	0.01	0.01	0.18	146	2	7.9	1.1	-8.1	4.0	-40.2
0.57	0.23	0.01	0.01	0.18	146	2	7.9	1.1	-8	4.0	-40.2
0.58	0.22	0.01	0.01	0.18	146	2	7.9	1.1	-7.9	4.0	-40.1
0.59	0.21	0.01	0.01	0.18	146	2	7.9	1.1	-7.8	4.0	-40.0
0.6	0.2	0.01	0.01	0.18	146	2	7.8	1.1	-7.7	4.0	-40.0
0.61	0.19	0.01	0.01	0.18	146	2	7.8	1.1	-7.6	4.0	-39.9
0.62	0.18	0.01	0.01	0.18	146	2	7.8	1.1	-7.5	4.0	-39.8
0.63	0.17	0.01	0.01	0.18	146	2	7.8	1.1	-7.4	4.0	-39.8
0.64	0.16	0.01	0.01	0.18	146	3	7.8	1.1	-7.3	4.0	-39.7
0.65	0.15	0.01	0.01	0.18	146	3	7.8	1.1	-7.2	4.0	-39.6
0.66	0.14	0.01	0.01	0.18	146	3	7.8	1.1	-7.1	4.0	-39.6
0.67	0.13	0.01	0.01	0.18	146	3	7.9	1.1	-7	4.0	-39.5
0.68	0.12	0.01	0.01	0.18	146	3	7.9	1.1	-7	4.0	-39.5
0.69	0.11	0.01	0.01	0.18	146	3	7.9	1.1	-6.9	4.0	-39.4
0.7	0.1	0.01	0.01	0.18	146	3	7.9	1.1	-6.9	4.0	-39.4
0.71	0.09	0.01	0.01	0.18	146	3	7.9	1.1	-6.8	4.0	-39.4
0.72	0.08	0.01	0.01	0.18	146	3	7.9	1.1	-6.8	4.0	-39.4
0.12	0.68	0.01	0.01	0.18	147	2L	10	1.8	-18.6	4.8	-47.1
0.11	0.8	0.05	0.02	0.02	96	2L	2.7	2	-44.3	5.0	-63.8
0.26	0.64	0.04	0.04	0.02	111	2	2.8	1.8	-39.3	4.8	-60.5
0.78	0.1	0.08	0.02	0.02	129	3	1.6	1.8	-31	4.8	-55.1
0.45	0.35	0.01	0.01	0.18	146	2	8.3	1.1	-9.9	4.0	-41.4
0.81	0.01	0.01	0.01	0.16	133	3	7.8	1.2	-9.3	4.1	-41.0
0.8	0.01	0.01	0.02	0.16	146	3	7.7	1.2	-9.1	4.1	-40.9
0.76	0.05	0.02	0.01	0.16	144	3	7.6	1.2	-9.5	4.1	-41.1
0.65	0.16	0.01	0.02	0.16	146	3	7.4	1.2	-9.9	4.1	-41.4
0.69	0.12	0.01	0.02	0.16	146	3	7.5	1.2	-9.6	4.1	-41.2
0.77	0.04	0.02	0.01	0.16	144	3	7.6	1.2	-9.5	4.1	-41.1
0.68	0.13	0.02	0.01	0.16	144	3	7.5	1.2	-9.9	4.1	-41.4
0.67	0.14	0.02	0.01	0.16	144	3	7.5	1.2	-10	4.1	-41.5
0.79	0.02	0.02	0.01	0.16	144	3	7.7	1.2	-9.4	4.1	-41.1
0.8	0.01	0.02	0.01	0.16	144	3	7.7	1.2	-9.4	4.1	-41.1
0.46	0.34	0.01	0.01	0.18	146	2	8.2	1.1	-9.7	4.0	-41.3
0.6	0.21	0.01	0.01	0.17	140	2	7.7	1.1	-9.1	4.0	-40.9
0.54	0.27	0.01	0.01	0.17	140	2	7.8	1.1	-9.9	4.0	-41.4

Example 7

[0151] The presently claimed compositions containing HFO-1252zc, HFO-1234zeE, HFC-134a, HFC-32 and CO2 are compared to R-454C (ASHRAE designation for a refrigerant containing 78.5 wt% HFO-1234yf and 21.5 wt% HFC-32) and R-410A (ASHRAE designation for a refrigerant containing 50 wt% HFC-125 and 50 wt% HFC-32) under the conditions for a residential heat pump in both cooling and heating mode shown below. Table 7a provides the calculated results for cooling mode while Table 7b provides the results for heating mode.

[0152]

Cooling Mode Conditions:
T_condenser = 47 ºC
T_evaporator = 7 ºC
subcool = 12 K
evaporator superheat = 3 K
compressor efficiency = 0.7
Heating Mode Conditions:
T_condenser = 35 ºC
T_evaporator = -5 ºC
subcool = 8.3 K
superheat = 11.1 K
compressor efficiency = 0.7

[0153] Broadly, for cooling mode, a composition range of 2.0% to 78.0% of CARBON DIOXIDE, 2.0% to 92.0% of R-1252ZC, 2.0% to 92.0% of HFO-1234ZE(E), 2.0% to 22.0% of HFC-134A, and 2.0% to 40.0% of HFC-32 will have a GWP less than 300, a maximum average glide of about 10.0 K, a cooling capacity range that has a deviation range of -37.7% to 218.6% from the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range has a deviation range from -35.0% to 3.2% than that of the cooling COP of R-454C evaluated with the same conditions set. Table 7a lists example compositions within the GWP<300 range that have ASHRAE flammability classifications of 2, 1, 3 and 2L.

[0154] Similarly, but a little less broadly for cooling mode, a composition range of 2.0% to 78.0% of CARBON DIOXIDE, 2.0% to 92.0% of R-1252ZC, 2.0% to 92.0% of HFO-1234ZE(E), 2.0% to 10.0% of HFC-134A, and 2.0% to 18.0% of HFC-32 will

have a GWP less than 149, a maximum average glide of about 10.0 K, an ASHRAE flammability classification of 1, 3, 2L and 2, a cooling capacity range has a deviation of -37.7% to 213.4% from the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range has a deviation of -35.0% to 3.1% than that of the cooling COP of R-454C evaluated with the same conditions set.

[0155] Preferred blend composition ranges for cooling mode within a composition range of 2.0% to 2.0% of CARBON DIOXIDE, 34.0% to 84.0% of R-1252ZC, 2.0% to 46.0% of HFO-1234ZE(E), 2.0% to 6.0% of HFC-134A, and 10.0% to 18.0% of HFC-32 will have a GWP < 149, a maximum average heat exchanger glide of 10.0 K, an ASHRAE flammability classification of 2 and 3, the minimum and maximum cooling capacities are -10.0% and 1.3% than that of R-454C evaluated at the same conditions set, and the minimum and maximum cooling COP efficiencies are 1.5% and 2.3% than that of R-454C evaluated at the same conditions set.

[0156] Even more preferred blend composition ranges for cooling mode within a composition range of 2.0% to 2.0% of CARBON DIOXIDE, 34.0% to 62.0% of R-1252ZC, 16.0% to 46.0% of HFO-1234ZE(E), 2.0% to 4.0% of HFC-134A, and 12.0% to 18.0% of HFC-32 will have a GWP < 149, a maximum average heat exchanger glide of 10.0 K, an ASHRAE flammability classification of 2, the minimum and maximum cooling capacities are -9.9% and 0.6% than that of R-454C evaluated at the same conditions set, and the minimum and maximum cooling COP efficiencies are 1.5% and 2.1% than that of R-454C evaluated at the same conditions set.

[0157] The composition for the even more preferred maximum cooling capacity, which is 0.6% than that of R-454C, is 2.0 wt-% CARBON DIOXIDE, 62.0 wt-% R-1252ZC, 16.0 wt-% HFO-1234ZE(E), 2.0 wt-% HFC-134A, and 18.0 wt-% HFC-32, where the COP for cooling is 1.5% than that for R-454C under the same cycle conditions, the maximum average heat exchanger glide is 9.5 K and its ASHRAE flammability classification is 2.

[0158] The composition for the even more preferred maximum cooling COP efficiency, which is 2.1% than that of R-454C, is 2.0 wt-% CARBON DIOXIDE, 46.0 wt-% R-1252ZC, 38.0 wt-% HFO-1234ZE(E), 2.0 wt-% HFC-134A, and 12.0 wt-% HFC-32, where the CAP for cooling is -9.9% than that for R-454C under the same

cycle conditions, the maximum average heat exchanger glide is 9.3 K and its ASHRAE flammability classification is 2.

[0159] Broadly, for heating mode, a composition range of 2.0% to 92.0% of CARBON DIOXIDE, 2.0% to 92.0% of R-1252ZC, 2.0% to 92.0% of HFO-1234ZE(E), 2.0% to 22.0% of HFC-134A, and 2.0% to 40.0% of HFC-32 will have a GWP less than 300, a maximum average glide of about 10.0 K, a heating capacity range that has a deviation range of -40.4% to 348.8% from the heating capacity of R-454C evaluated with the same conditions set, and the heating COP range has a deviation range from -22.6% to 1.4% than that of the heating COP of R-454C evaluated with the same conditions set. Table 7b lists example compositions within the GWP<300 range that have ASHRAE flammability classifications of 2, 1, 2L and 3.

[0160] Similarly, but a little less broadly for heating mode, a composition range of 2.0% to 92.0% of CARBON DIOXIDE, 2.0% to 92.0% of R-1252ZC, 2.0% to 92.0% of HFO-1234ZE(E), 2.0% to 22.0% of HFC-134A, and 2.0% to 40.0% of HFC-32 will have a GWP less than 300, a maximum average glide of about 10.0 K, an ASHRAE flammability classification of 2, 1, 3 and 2L, a heating capacity range has a deviation of -40.4% to 348.8% from the heating capacity of R-454C evaluated with the same conditions set, and the heating COP range has a deviation of -22.6% to 1.4% than that of the heating COP of R-454C evaluated with the same conditions set.

[0161] Preferred blend composition ranges for heating mode within a composition range of 2.0% to 4.0% of CARBON DIOXIDE, 28.0% to 82.0% of R-1252ZC, 2.0% to 40.0% of HFO-1234ZE(E), 2.0% to 20.0% of HFC-134A, and 4.0% to 28.0% of HFC-32 will have a GWP < 300, a maximum average heat exchanger glide of 10.0 K, an ASHRAE flammability classification of 2 and 3, the minimum and maximum heating capacities are -10.0% and 10.0% than that of R-454C evaluated at the same conditions set, and the minimum and maximum heating COP efficiencies are -0.4% and 0.9% than that of R-454C evaluated at the same conditions set.

[0162] Even more preferred blend composition ranges for heating mode within a composition range of 2.0% to 4.0% of CARBON DIOXIDE, 28.0% to 66.0% of R-1252ZC, 2.0% to 40.0% of HFO-1234ZE(E), 2.0% to 20.0% of HFC-134A, and 4.0% to 28.0% of HFC-32 will have a GWP < 300, a maximum average heat exchanger

glide of 10.0 K, an ASHRAE flammability classification of 2, the minimum and maximum heating capacities are -10.0% and 10.0% than that of R-454C evaluated at the same conditions set, and the minimum and maximum heating COP efficiencies are -0.4% and 0.8% than that of R-454C evaluated at the same conditions set.

[0163] The composition for the even more preferred maximum heating capacity, which is 10.0% than that of R-454C, is 2.0 wt-% CARBON DIOXIDE, 52.0 wt-% R-1252ZC, 14.0 wt-% HFO-1234ZE(E), 6.0 wt-% HFC-134A, and 26.0 wt-% HFC-32, where the COP for heating is -0.3% than that for R-454C under the same cycle conditions, the maximum average heat exchanger glide is 9.3 K and its ASHRAE flammability classification is 2.

[0164] The composition for the even more preferred maximum heating COP efficiency, which is 0.8% than that of R-454C, is 2.0 wt-% CARBON DIOXIDE, 58.0 wt-% R-1252ZC, 26.0 wt-% HFO-1234ZE(E), 2.0 wt-% HFC-134A, and 12.0 wt-% HFC-32, where the CAP for heating is -9.5% than that for R-454C under the same cycle conditions, the maximum average heat exchanger glide is 9.5 K and its ASHRAE flammability classification is 2.

TABLE 7A

W_CARBON DIOXIDE	W_R-1252ZC	W_HFO-1234ZE(E)	W_R134A	W_R32	GWP	ASHRAE CLASS	AVG GLIDE (K)	COP DEV from 454C	CAP DEV from 454C	COP DEV from 410A	CAP DEV from 410A
0.04	0.34	0.38	0.22	0.02	300	2	9.5	1.4	-16	5.3	-44.6
0.02	0.34	0.4	0.22	0.02	300	2	6	1.9	-23.7	5.8	-49.7
0.78	0.02	0.16	0.02	0.02	40	1	9.6	-34.2	200.6	-31.7	98.1
0.02	0.32	0.44	0.08	0.14	199	2	9.7	2	-8.5	5.9	-39.7
0.02	0.92	0.02	0.02	0.02	40	3	5.8	2.3	-21.7	6.2	-48.4
0.7	0.02	0.08	0.06	0.14	174	1	9.5	-27.9	203.8	-25.1	100.2
0.02	0.02	0.92	0.02	0.02	40	2L	7.2	2.7	-37.7	6.6	-58.9
0.04	0.74	0.02	0.16	0.04	235	3	9.3	1.5	-8.7	5.4	-39.8
0.02	0.6	0.14	0.22	0.02	300	2	5	1.9	-18.9	5.8	-46.6
0.66	0.02	0.06	0.02	0.24	189	1	8.6	-24.7	205.4	-21.8	101.3
0.04	0.3	0.24	0.02	0.4	297	2	8.7	-1.9	29.1	1.9	-14.9
0.72	0.16	0.08	0.02	0.02	40	1	9.8	-33.1	186.3	-30.5	88.7
0.72	0.02	0.02	0.02	0.22	176	1	5.1	-28.3	218.6	-25.5	110.0
0.02	0.02	0.8	0.08	0.08	159	2L	9.9	3.2	-26.3	7.2	-51.4
0.76	0.08	0.12	0.02	0.02	40	1	8.2	-35	192.4	-32.5	92.7
0.04	0.62	0.28	0.02	0.04	53	3	10	1.7	-12.9	5.6	-42.6

W_CARBON DIOXIDE	W_R-1252ZC	W_HFO-1234ZE(E)	W_R134A	W_R32	GWP	ASHRAE CLASS	AVG GLIDE (K)	COP DEV from 454C	CAP DEV from 454C	COP DEV from 410A	CAP DEV from 410A
0.04	0.66	0.08	0.2	0.02	274	3	8.5	1.3	-11.3	5.2	-41.5
0.7	0.06	0.1	0.02	0.12	108	1	9.6	-28.7	199.5	-26.0	97.4
0.02	0.44	0.44	0.06	0.04	106	2	7	2.2	-22	6.1	-48.6
0.02	0.2	0.6	0.08	0.1	172	2L	9.9	2.6	-17.4	6.5	-45.6
0.72	0.02	0.06	0.02	0.18	149	1	6.9	-28.6	213.4	-25.9	106.5
0.7	0.02	0.08	0.02	0.18	149	1	8.4	-27.4	208.2	-24.6	103.1
0.68	0.02	0.1	0.02	0.18	149	1	9.8	-26.3	202.4	-23.5	99.3
0.02	0.72	0.14	0.02	0.1	94	3	8.5	2.2	-10	6.1	-40.7
0.72	0.02	0.08	0.02	0.16	135	1	7.8	-28.8	210.4	-26.1	104.6
0.7	0.14	0.02	0.08	0.06	145	1	8.6	-31.1	191.7	-28.5	92.2
0.02	0.32	0.54	0.1	0.02	144	2	6.6	2.2	-27	6.1	-51.9
0.02	0.66	0.28	0.02	0.02	40	3	5.6	2.2	-23.2	6.1	-49.4
0.64	0.12	0.04	0.02	0.18	149	1	9.3	-25.7	192.9	-22.8	93.0
0.02	0.58	0.34	0.04	0.02	66	3	5.7	2.1	-23.6	6.0	-49.7
0.02	0.02	0.88	0.02	0.06	68	2L	9.4	3.1	-30.7	7.1	-54.3
0.04	0.58	0.26	0.08	0.04	131	3	9.7	1.6	-11.9	5.5	-41.9
0.66	0.08	0.08	0.02	0.16	135	1	9.9	-26.4	195.1	-23.6	94.5
0.02	0.52	0.38	0.04	0.04	80	2	6.8	2.2	-21.2	6.1	-48.1
0.02	0.14	0.78	0.02	0.04	54	2L	8.4	2.7	-30.3	6.6	-54.1
0.02	0.42	0.36	0.02	0.18	148	2	10	1.6	-2	5.5	-35.4
0.02	0.6	0.22	0.02	0.14	121	3	9.2	1.9	-5.1	5.8	-37.5
0.02	0.76	0.04	0.02	0.16	134	3	9.6	1.8	-1.3	5.7	-35.0
0.02	0.84	0.02	0.02	0.1	94	3	8.7	2.3	-9.5	6.2	-40.4
0.02	0.34	0.46	0.04	0.14	147	2	10	2.1	-8.8	6.0	-39.9
0.02	0.78	0.02	0.04	0.14	147	3	9.2	1.9	-3.6	5.8	-36.5
0.02	0.74	0.08	0.06	0.1	146	3	8.2	2.1	-9	6.0	-40.0
0.02	0.48	0.34	0.02	0.14	121	2	9.5	2	-6.6	5.9	-38.4
0.02	0.62	0.16	0.02	0.18	148	2	9.5	1.5	0.6	5.4	-33.7
0.02	0.74	0.1	0.04	0.1	120	3	8.4	2.2	-9.4	6.1	-40.3
0.02	0.76	0.02	0.02	0.18	148	3	9.8	1.6	1.3	5.5	-33.2
0.02	0.82	0.04	0.02	0.1	94	3	8.7	2.3	-9.5	6.2	-40.4
0.02	0.7	0.08	0.02	0.18	148	3	9.6	1.5	1.1	5.4	-33.4
0.02	0.68	0.1	0.02	0.18	148	3	9.5	1.5	1	5.4	-33.4
0.02	0.66	0.12	0.02	0.18	148	3	9.5	1.5	0.9	5.4	-33.5
0.02	0.64	0.14	0.02	0.18	148	3	9.5	1.5	0.8	5.4	-33.6
0.02	0.6	0.18	0.02	0.18	148	2	9.5	1.5	0.5	5.4	-33.8
0.02	0.58	0.2	0.02	0.18	148	2	9.5	1.5	0.3	5.4	-33.9
0.02	0.56	0.22	0.02	0.18	148	2	9.5	1.5	0.1	5.4	-34.0
0.02	0.54	0.24	0.02	0.18	148	2	9.5	1.5	-0.2	5.4	-34.2
0.02	0.52	0.26	0.02	0.18	148	2	9.6	1.5	-0.4	5.4	-34.4
0.02	0.4	0.4	0.02	0.16	135	2	10	1.9	-5.1	5.8	-37.5

W_CARBON DIOXIDE	W_R-1252ZC	W_HFO-1234ZE(E)	W_R134A	W_R32	GWP	ASHRAE CLASS	AVG GLIDE (K)	COP DEV from 454C	CAP DEV from 454C	COP DEV from 410A	CAP DEV from 410A
0.02	0.38	0.42	0.04	0.14	147	2	9.8	2	-8	5.9	-39.4
0.02	0.46	0.36	0.02	0.14	121	2	9.6	2	-7	5.9	-38.7
0.02	0.58	0.24	0.04	0.12	134	2	8.7	2	-7.8	5.9	-39.2
0.02	0.44	0.36	0.04	0.14	147	2	9.4	1.9	-6.9	5.8	-38.6
0.02	0.56	0.24	0.02	0.16	135	2	9.4	1.8	-2.7	5.7	-35.9
0.02	0.48	0.3	0.02	0.18	148	2	9.7	1.6	-1	5.5	-34.8
0.02	0.46	0.38	0.02	0.12	108	2	9.3	2.1	-9.9	6.0	-40.6
0.02	0.5	0.32	0.02	0.14	121	2	9.4	1.9	-6.3	5.8	-38.3

TABLE 7B

W_CARBON DIOXIDE	W_R-1252ZC	W_HFO-1234ZE(E)	W_R134A	W_R32	GWP	ASHRAE CLASS	AVG GLIDE (K)	COP DEV from 454C	CAP DEV from 454C	COP DEV from 410A	CAP DEV from 410A
0.02	0.34	0.4	0.22	0.02	300	2	6.5	0.6	-25.7	3.5	-51.7
0.92	0.02	0.02	0.02	0.02	40	1	3.4	-22.5	348.8	-20.2	191.9
0.02	0.12	0.7	0.12	0.04	184	2L	8.7	1.1	-31.2	4.0	-55.2
0.02	0.92	0.02	0.02	0.02	40	3	6.2	0.6	-23.3	3.5	-50.1
0.82	0.02	0.04	0.1	0.02	144	1	9.9	-21.3	294.2	-19.0	156.4
0.02	0.02	0.92	0.02	0.02	40	2L	7.7	1	-40.4	3.9	-61.2
0.02	0.74	0.02	0.16	0.06	249	3	7.1	0.7	-14.2	3.6	-44.2
0.04	0.5	0.22	0.22	0.02	300	2	9.2	0	-14	2.9	-44.1
0.02	0.18	0.72	0.02	0.06	67	2	9.9	1.2	-28	4.1	-53.2
0.02	0.3	0.26	0.02	0.4	297	2	8.3	-1.5	22.2	1.4	-20.5
0.02	0.72	0.06	0.18	0.02	248	3	5.5	0.6	-20.2	3.5	-48.1
0.02	0.02	0.86	0.04	0.06	94	2L	10	1.4	-33	4.3	-56.4
0.9	0.02	0.04	0.02	0.02	40	1	5.1	-22.6	334.5	-20.4	182.6
0.66	0.04	0.02	0.02	0.26	203	1	10	-15.3	254.9	-12.8	130.8
0.02	0.58	0.34	0.02	0.04	53	3	7.2	0.7	-22.5	3.6	-49.6
0.02	0.46	0.14	0.04	0.34	282	2	8.5	-1.1	18.7	1.8	-22.8
0.02	0.1	0.82	0.02	0.04	54	2L	9.1	1.1	-34	4.0	-57.1
0.8	0.02	0.06	0.02	0.1	95	1	8.8	-19.9	294.3	-17.6	156.5
0.02	0.56	0.18	0.14	0.1	250	2	8.1	0.7	-10.2	3.6	-41.6
0.02	0.02	0.9	0.02	0.04	54	2L	9	1.2	-36.8	4.1	-58.9
0.82	0.04	0.02	0.04	0.08	107	1	7	-20.3	306.9	-18.0	164.7
0.02	0.66	0.28	0.02	0.02	40	3	6.1	0.6	-24.8	3.5	-51.1
0.02	0.46	0.1	0.02	0.4	297	2	7.7	-1.7	25.5	1.2	-18.4
0.04	0.62	0.26	0.06	0.02	92	3	9.9	0.1	-16.3	3.0	-45.6
0.02	0.8	0.06	0.1	0.02	144	3	5.9	0.6	-21.6	3.5	-49.0
0.02	0.3	0.32	0.06	0.3	281	2	9.7	-0.5	10.7	2.4	-28.0

W_CARBON DIOXIDE	W_R-1252ZC	W_HFO-1234ZE(E)	W_R134A	W_R32	GWP	ASHRAE CLASS	AVG GLIDE (K)	COP DEV from 454C	CAP DEV from 454C	COP DEV from 410A	CAP DEV from 410A
0.04	0.24	0.3	0.02	0.4	297	2L	9.9	-1.9	27.5	0.9	-17.1
0.72	0.04	0.04	0.02	0.18	149	1	9.7	-17.3	270.9	-14.9	141.3
0.02	0.28	0.34	0.08	0.28	294	2	10	-0.3	8	2.6	-29.8
0.04	0.64	0.08	0.18	0.06	275	3	10	0.2	-6.8	3.1	-39.4
0.02	0.62	0.06	0.08	0.22	253	2	9.4	0.1	6.1	3.0	-31.0
0.02	0.82	0.02	0.02	0.12	107	3	9.7	0.9	-7.8	3.8	-40.0
0.02	0.3	0.4	0.14	0.14	277	2	9.9	0.7	-9.4	3.6	-41.1
0.02	0.76	0.02	0.08	0.12	185	3	9.1	0.7	-6.8	3.6	-39.4
0.04	0.68	0.04	0.2	0.04	287	3	9.6	0.1	-9.1	3.0	-40.9
0.02	0.7	0.12	0.02	0.14	121	3	9.7	0.8	-5.4	3.7	-38.5
0.02	0.32	0.3	0.08	0.28	294	2	9.7	-0.4	9.1	2.5	-29.0
0.04	0.7	0.04	0.18	0.04	261	3	9.7	0.1	-9.4	3.0	-41.1
0.02	0.52	0.14	0.06	0.26	254	2	9.3	-0.3	10	2.6	-28.4
0.04	0.68	0.08	0.16	0.04	235	3	9.8	0.1	-10	3.0	-41.5
0.02	0.34	0.28	0.08	0.28	294	2	9.5	-0.4	9.6	2.5	-28.7
0.04	0.6	0.12	0.18	0.06	275	2	10	0.2	-7.2	3.1	-39.6
0.02	0.66	0.1	0.04	0.18	174	3	9.8	0.5	0.4	3.4	-34.7
0.02	0.4	0.3	0.16	0.12	290	2	8.8	0.6	-9.6	3.5	-41.2
0.04	0.6	0.12	0.2	0.04	287	2	9.5	0.1	-9.9	3.0	-41.4
0.02	0.34	0.3	0.06	0.28	268	2	9.8	-0.3	9.2	2.6	-29.0
0.02	0.66	0.04	0.12	0.16	264	2	8.9	0.4	-0.9	3.3	-35.5
0.02	0.32	0.4	0.12	0.14	251	2	10	0.7	-9.3	3.6	-41.0
0.02	0.66	0.02	0.08	0.22	253	2	9.5	0	6.4	2.9	-30.8
0.02	0.56	0.26	0.02	0.14	121	2	9.8	0.8	-6.7	3.7	-39.3
0.02	0.4	0.28	0.02	0.28	216	2	9.9	-0.3	9.8	2.6	-28.6
0.02	0.4	0.32	0.14	0.12	264	2	9	0.7	-10	3.6	-41.5
0.02	0.58	0.26	0.02	0.12	108	2	9.5	0.8	-9.5	3.7	-41.1
0.02	0.56	0.28	0.02	0.12	108	2	9.5	0.8	-9.8	3.7	-41.3
0.02	0.42	0.34	0.08	0.14	199	2	9.7	0.7	-7.8	3.6	-40.0

Example 8

[0165] The presently claimed compositions containing HFO-1252zc, HFO-1234zeE, HFC-134, and HFC-32 are compared to R-410A (ASHRAE designation for a refrigerant containing 50 wt% HFC-125 and 50 wt% HFC-32) under the conditions for a residential air-conditioner shown below. Tables 8A and 8B provide the calculated results.

Conditions:
T_condenser = 46.1ºC
T_evaporator = 10.0ºC
subcool = 8.3 K
evaporator superheat = 11.1 K
compressor efficiency = 0.7

[0166] Broadly, for cooling mode, a composition range of 1.0% to 21.0% of R-1252zc, 64.0% to 92.0% of HFO-1234ze(E), 1.0% to 11.0% of HFC-134, and 1.0% to 9.0% of HFC-32 will have a GWP < 150, an ASHRAE flammability rating of 2L, an average temperature glide of no more than 6.5, a cooling capacity of 40.0% to 48.9% of the cooling capacity of R-410A evaluated with the same conditions set, and a cooling COP of 108.6% to 109.3% of the cooling COP of R-410A evaluated with the same conditions set.

[0167] Similarly but less broadly, for cooling mode, a composition range of 15.0% to 21.0% HFO-1252zc, 63.0% to 76.0% HFO-1234zeE, 1.0% to 8.0% HFC-134, and 7.0% to 9.0% HFC-32 will have a GWP < 150, an ASHRAE flammability rating of 2L, an average temperature glide of no more than 6.5, a cooling capacity of 49.1% to 53.0% of the cooling capacity of R-410A evaluated with the same conditions set, and a cooling COP of 108.6% to 108.7% of the cooling COP of R-410A evaluated with the same conditions set.

TABLE 8A

% wt R32	% wt 1252 zc	% wt R134	% wt R1234 zeE	GWP	$P_{suction}$ (bar)	$T_{discharge}$ (°C)	$P_{discharge}$ (bar)	Ave T Glide (K)	ASHRAE Flammability Class	CAP dev from R410A (%)	COP dev from R410A (%)
0.01	0.2	0.11	0.68	132.6	3.7	67.2	10.6	1.7	2L	-59.5	9.3
0.02	0.2	0.11	0.67	139.3	3.8	68.1	10.9	2.4	2L	-58.4	9.1
0.02	0.19	0.11	0.68	139.3	3.8	68.0	10.9	2.4	2L	-58.6	9.1
0.02	0.17	0.09	0.72	128.4	3.8	67.8	10.8	2.5	2L	-59.0	9.2
0.02	0.18	0.07	0.73	95.4	3.8	67.7	10.8	2.5	2L	-59.1	9.1
0.02	0.15	0.1	0.73	128.5	3.7	67.6	10.7	2.4	2L	-59.4	9.2

0.02	0.17	0.03	0.78	62.5	3.7	67.5	10.7	2.6	2L	-59.4	9.1
0.02	0.14	0.08	0.76	106.6	3.7	67.4	10.6	2.5	2L	-59.7	9.2
0.02	0.15	0.03	0.8	51.6	3.7	67.3	10.5	2.6	2L	-59.9	9.2
0.02	0.12	0.1	0.76	128.7	3.6	67.2	10.5	2.4	2L	-60.0	9.3
0.03	0.21	0.11	0.65	145.9	3.9	69.0	11.3	3.1	2L	-57.2	9.0
0.03	0.2	0.08	0.69	113.0	3.9	68.8	11.2	3.2	2L	-57.5	9.0
0.03	0.17	0.05	0.75	80.2	3.8	68.4	11.0	3.3	2L	-58.2	9.0
0.03	0.17	0.04	0.76	69.2	3.8	68.4	11.0	3.3	2L	-58.3	9.0
0.03	0.17	0.03	0.77	58.2	3.8	68.4	11.0	3.4	2L	-58.4	9.0
0.03	0.16	0.04	0.77	69.2	3.8	68.3	10.9	3.3	2L	-58.5	9.0
0.03	0.14	0.05	0.78	80.3	3.8	68.1	10.8	3.3	2L	-58.8	9.1
0.03	0.14	0.04	0.79	69.3	3.8	68.1	10.8	3.3	2L	-58.9	9.1
0.03	0.13	0.07	0.77	102.4	3.7	68.1	10.8	3.2	2L	-58.9	9.1
0.03	0.12	0.1	0.75	135.4	3.7	68.1	10.8	3.1	2L	-58.9	9.2
0.03	0.13	0.06	0.78	91.4	3.7	68.1	10.8	3.2	2L	-58.9	9.1
0.03	0.11	0.08	0.78	113.4	3.7	67.9	10.7	3.1	2L	-59.2	9.2
0.03	0.1	0.1	0.77	135.5	3.7	67.9	10.7	3.1	2L	-59.3	9.2
0.03	0.12	0.02	0.83	47.5	3.7	67.8	10.7	3.3	2L	-59.4	9.1
0.03	0.11	0.04	0.82	69.5	3.7	67.8	10.7	3.3	2L	-59.5	9.2
0.03	0.12	0	0.85	25.5	3.7	67.8	10.7	3.4	2L	-59.5	9.1
0.03	0.09	0.09	0.79	124.5	3.7	67.7	10.6	3.1	2L	-59.5	9.3
0.03	0.09	0.06	0.82	91.6	3.6	67.6	10.6	3.2	2L	-59.7	9.2
0.03	0.08	0.09	0.8	124.6	3.6	67.6	10.6	3.0	2L	-59.8	9.3
0.03	0.1	0.02	0.85	47.6	3.6	67.6	10.6	3.3	2L	-59.8	9.2
0.03	0.1	0.01	0.86	36.6	3.6	67.6	10.6	3.3	2L	-59.9	9.1
0.03	0.07	0.09	0.81	124.6	3.6	67.5	10.5	3.0	2L	-60.0	9.3
0.04	0.2	0.07	0.69	108.7	4.0	69.6	11.5	3.9	2L	-56.5	8.9
0.04	0.18	0.08	0.7	119.8	4.0	69.4	11.4	3.9	2L	-56.8	9.0
0.04	0.17	0.1	0.69	141.8	4.0	69.4	11.3	3.8	2L	-56.8	9.0
0.04	0.18	0.05	0.73	86.8	4.0	69.3	11.3	4.0	2L	-56.9	8.9
0.04	0.17	0.01	0.78	42.9	3.9	69.2	11.2	4.2	2L	-57.3	8.9
0.04	0.15	0.07	0.74	108.9	3.9	69.1	11.2	3.9	2L	-57.4	9.0
0.04	0.14	0.1	0.72	142.0	3.9	69.1	11.2	3.8	2L	-57.4	9.1
0.04	0.14	0.06	0.76	98.0	3.9	69.0	11.1	3.9	2L	-57.6	9.0

0.04	0.14	0.03	0.79	65.0	3.9	68.9	11.1	4.1	2L	-57.8	9.0
0.04	0.14	0.01	0.81	43.1	3.8	68.9	11.1	4.2	2L	-57.9	9.0
0.04	0.13	0.04	0.79	76.1	3.8	68.8	11.1	4.0	2L	-57.9	9.0
0.04	0.12	0.06	0.78	98.1	3.8	68.8	11.0	3.9	2L	-58.0	9.1
0.04	0.1	0.1	0.76	142.2	3.8	68.7	11.0	3.7	2L	-58.2	9.2
0.04	0.08	0.1	0.78	142.3	3.7	68.4	10.9	3.7	2L	-58.6	9.2
0.04	0.1	0.01	0.85	43.3	3.7	68.4	10.9	4.1	2L	-58.7	9.1
0.04	0.07	0.1	0.79	142.3	3.7	68.3	10.8	3.7	2L	-58.8	9.3
0.04	0.09	0.02	0.85	54.3	3.7	68.4	10.8	4.0	2L	-58.9	9.1
0.04	0.06	0.04	0.86	76.4	3.7	68.0	10.7	3.9	2L	-59.4	9.2
0.04	0.06	0.03	0.87	65.4	3.7	68.0	10.7	3.9	2L	-59.4	9.2
0.05	0.18	0.04	0.73	93.5	4.1	70.1	11.6	4.6	2L	-55.8	8.9
0.05	0.17	0.06	0.72	104.5	4.0	70.0	11.6	4.6	2L	-55.9	8.9
0.05	0.15	0.05	0.75	93.7	4.0	69.8	11.5	4.6	2L	-56.4	8.9
0.05	0.16	0.01	0.78	49.6	4.0	69.9	11.5	4.8	2L	-56.4	8.9
0.05	0.15	0.02	0.78	60.7	4.0	69.8	11.4	4.8	2L	-56.5	8.9
0.05	0.13	0.02	0.8	60.8	3.9	69.6	11.3	4.8	2L	-56.9	8.9
0.05	0.1	0.08	0.77	126.9	3.9	69.4	11.2	4.4	2L	-57.2	9.1
0.05	0.09	0.1	0.76	148.9	3.9	69.3	11.2	4.3	2L	-57.3	9.2
0.05	0.08	0.09	0.78	138.0	3.8	69.2	11.1	4.4	2L	-57.5	9.2
0.05	0.09	0.05	0.81	94.0	3.8	69.2	11.2	4.6	2L	-57.6	9.1
0.05	0.07	0.08	0.8	127.0	3.8	69.0	11.1	4.4	2L	-57.8	9.2
0.05	0.07	0.03	0.85	72.1	3.8	68.9	11.0	4.6	2L	-58.1	9.1
0.05	0.05	0.1	0.8	149.1	3.8	68.9	11.0	4.3	2L	-58.1	9.3
0.05	0.04	0.08	0.83	127.2	3.7	68.7	10.9	4.3	2L	-58.5	9.3
0.05	0.04	0.07	0.84	116.2	3.7	68.7	10.9	4.3	2L	-58.5	9.3
0.05	0.03	0.06	0.86	105.2	3.7	68.5	10.8	4.3	2L	-58.8	9.3
0.05	0.02	0.09	0.84	138.3	3.7	68.5	10.8	4.2	2L	-58.8	9.3
0.05	0.04	0	0.91	39.3	3.7	68.6	10.8	4.7	2L	-58.9	9.1
0.05	0.02	0.07	0.86	116.3	3.7	68.4	10.8	4.3	2L	-59.0	9.3
0.05	0.02	0.06	0.87	105.3	3.7	68.4	10.8	4.3	2L	-59.0	9.3
0.05	0	0.05	0.9	94.4	3.6	68.1	10.6	4.2	2L	-59.5	9.3
0.05	0	0.04	0.91	83.4	3.6	68.1	10.6	4.3	2L	-59.6	9.3
0.06	0.19	0.04	0.71	89.2	4.2	70.9	12.0	5.2	2L	-54.6	8.8

0.06	0.18	0.05	0.71	100.2	4.2	70.8	11.9	5.2	2L	-54.7	8.8
0.06	0.17	0.06	0.71	111.2	4.1	70.7	11.9	5.1	2L	-54.8	8.8
0.06	0.17	0	0.77	45.3	4.1	70.7	11.8	5.5	2L	-55.1	8.8
0.06	0.16	0.04	0.74	89.3	4.1	70.6	11.8	5.2	2L	-55.1	8.8
0.06	0.14	0.01	0.79	56.4	4.1	70.4	11.7	5.5	2L	-55.6	8.9
0.06	0.12	0.05	0.77	100.5	4.0	70.3	11.6	5.2	2L	-55.8	9.0
0.06	0.11	0.09	0.74	144.5	4.0	70.2	11.6	5.0	2L	-55.9	9.0
0.06	0.1	0.09	0.75	144.6	4.0	70.1	11.5	5.0	2L	-56.1	9.1
0.06	0.1	0.06	0.78	111.6	4.0	70.1	11.5	5.1	2L	-56.2	9.0
0.06	0.03	0.09	0.82	144.9	3.8	69.3	11.1	4.8	2L	-57.5	9.3
0.06	0.03	0.07	0.84	122.9	3.8	69.3	11.1	4.9	2L	-57.6	9.3
0.06	0.03	0.04	0.87	90.0	3.8	69.3	11.1	5.1	2L	-57.8	9.2
0.06	0.03	0	0.91	46.0	3.8	69.2	11.1	5.4	2L	-57.9	9.2
0.06	0.02	0.05	0.87	101.0	3.8	69.1	11.0	5.0	2L	-58.0	9.3
0.06	0	0.06	0.88	112.1	3.7	68.9	10.9	4.8	2L	-58.4	9.3
0.07	0.19	0.04	0.7	95.8	4.3	71.6	12.2	5.7	2L	-53.5	8.7
0.07	0.18	0.08	0.67	139.9	4.3	71.6	12.2	5.5	2L	-53.5	8.8
0.07	0.17	0.03	0.73	85.0	4.2	71.4	12.1	5.8	2L	-53.9	8.7
0.07	0.16	0.05	0.72	107.0	4.2	71.3	12.1	5.7	2L	-54.0	8.8
0.07	0.15	0.03	0.75	85.1	4.2	71.2	12.0	5.9	2L	-54.3	8.8
0.07	0.15	0	0.78	52.1	4.2	71.2	12.0	6.1	2L	-54.3	8.8
0.07	0.12	0.06	0.75	118.2	4.1	71.0	11.9	5.7	2L	-54.7	8.9
0.07	0.12	0.03	0.78	85.2	4.1	70.9	11.9	5.9	2L	-54.8	8.9
0.07	0.1	0.04	0.79	96.3	4.1	70.8	11.8	5.8	2L	-55.2	9.0
0.07	0.09	0.08	0.76	140.3	4.1	70.7	11.8	5.5	2L	-55.2	9.1
0.07	0.09	0	0.84	52.4	4.0	70.6	11.7	6.1	2L	-55.5	9.0
0.07	0.08	0	0.85	52.4	4.0	70.5	11.6	6.1	2L	-55.7	9.0
0.07	0.06	0.04	0.83	96.5	4.0	70.3	11.6	5.7	2L	-56.0	9.1
0.07	0.05	0.01	0.87	63.6	3.9	70.2	11.5	5.9	2L	-56.4	9.1
0.07	0.03	0.05	0.85	107.6	3.9	70.0	11.4	5.6	2L	-56.7	9.2
0.07	0.03	0.04	0.86	96.6	3.9	70.0	11.4	5.7	2L	-56.7	9.2
0.08	0.2	0.08	0.64	146.4	4.4	72.4	12.6	5.9	2L	-52.1	8.7
0.08	0.19	0.06	0.67	124.5	4.4	72.3	12.5	6.1	2L	-52.3	8.7
0.08	0.17	0.03	0.72	124.6	4.4	72.1	12.4	6.1	2L	-52.7	8.7

0.08	0.17	0.01	0.74	102.6	4.3	72.1	12.4	6.2	2L	-52.8	8.7
0.08	0.16	0	0.76	91.7	4.3	72.0	12.4	6.3	2L	-53.0	8.7
0.08	0.14	0.07	0.71	135.8	4.3	71.8	12.3	6.1	2L	-53.2	8.8
0.08	0.14	0.04	0.74	102.8	4.3	71.8	12.3	6.3	2L	-53.3	8.8
0.08	0.13	0.07	0.72	135.8	4.3	71.7	12.2	6.1	2L	-53.4	8.9
0.08	0.13	0.05	0.74	113.8	4.3	71.7	12.2	6.2	2L	-53.5	8.9
0.08	0.13	0.04	0.75	102.8	4.3	71.7	12.2	6.3	2L	-53.5	8.8
0.08	0.1	0.08	0.74	146.9	4.2	71.5	12.1	6.0	2L	-54.0	9.0
0.08	0.1	0.02	0.8	81.0	4.2	71.4	12.0	6.5	2L	-54.2	8.9
0.08	0.08	0.05	0.79	114.1	4.1	71.2	12.0	6.2	2L	-54.5	9.0
0.08	0.08	0.04	0.8	103.1	4.1	71.2	11.9	6.3	2L	-54.5	9.0
0.08	0.07	0.05	0.8	114.1	4.1	71.1	11.9	6.2	2L	-54.7	9.1
0.08	0.07	0.02	0.83	81.2	4.1	71.1	11.9	6.4	2L	-54.8	9.0
0.08	0.06	0.02	0.84	81.2	4.1	71.0	11.8	6.4	2L	-55.0	9.1
0.08	0.01	0.04	0.87	103.4	4.0	70.4	11.5	6.1	2L	-56.1	9.2
0.08	0.01	0.02	0.89	81.5	3.9	70.4	11.5	6.3	2L	-56.1	9.2
0.08	0	0.02	0.9	81.5	3.9	70.3	11.5	6.2	2L	-56.4	9.3
0.08	0	0	0.92	59.5	3.9	70.3	11.4	6.4	2L	-56.4	9.2
0.09	0.2	0.06	0.65	131.2	4.5	73.0	12.9	6.5	2L	-51.1	8.6

TABLE 8B

% wt R32	% wt 1252zc	% wt R134	% wt R1234zeE	GWP	$P_{suction}$ (bar)	$T_{discharge}$ (°C)	$P_{discharge}$ (bar)	Ave Temp Glide (K)	ASHRAE Flammability Class	CAP dev from R410A (%)	COP dev from R410A (%)
0	0.21	0.07	0.6	142	4.55	73.1	12.9	6.4	2L	-50.9	8.6
0.07	0.21	0.08	0.6	140	4.35	71.8	12.4	5.4	2L	-53.0	8.7
0.08	0.21	0.08	0.6	146	4.45	72.5	12.6	5.9	2L	-51.9	8.6
0.08	0.2	0.08	0.6	146	4.43	72.4	12.6	5.9	2L	-52.1	8.7
0.08	0.2	0.07	0.7	135	4.43	72.4	12.6	6.0	2L	-52.1	8.7
0.08	0.19	0.08	0.7	146	4.41	72.3	12.6	5.9	2L	-52.3	8.7
0.08	0.2	0.06	0.7	124	4.42	72.4	12.6	6.0	2L	-52.2	8.6
0.08	0.19	0.07	0.7	136	4.40	72.3	12.5	6.0	2L	-52.3	8.7

% wt R32	% wt 1252zc	% wt R134	% wt R1234zeE	GWP	$P_{suction}$ (bar)	$T_{discharge}$ (°C)	$P_{discharge}$ (bar)	Ave Temp Glide (K)	ASHRAE Flammability Class	CAP dev from R410A (%)	COP dev from R410A (%)
0.08	0.2	0.05	0.7	113	4.42	72.3	12.6	6.1	2L	-52.2	8.6
0.08	0.19	0.06	0.7	125	4.40	72.3	12.5	6.1	2L	-52.3	8.7
0.08	0.19	0.05	0.7	114	4.40	72.3	12.5	6.1	2L	-52.4	8.7
0.08	0.19	0.04	0.7	103	4.39	72.3	12.5	6.2	2L	-52.4	8.6
0.08	0.18	0.05	0.7	147	4.38	72.2	12.5	6.0	2L	-52.4	8.7
0.08	0.15	0.08	0.7	147	4.32	71.9	12.4	6.0	2L	-53.0	8.8
0.08	0.19	0.03	0.7	92	4.39	72.3	12.5	6.3	2L	-52.4	8.6
0.08	0.18	0.04	0.7	36	4.38	72.2	12.5	6.0	2L	-52.5	8.7
0.08	0.17	0.05	0.7	147	4.36	72.1	12.5	6.0	2L	-52.6	8.8
0.08	0.18	0.03	0.7	125	4.38	72.2	12.5	6.1	2L	-52.5	8.7
0.08	0.17	0.04	0.7	136	4.36	72.1	12.4	6.0	2L	-52.7	8.7
0.08	0.16	0.05	0.7	147	4.34	72.0	12.4	6.0	2L	-52.8	8.8
0.08	0.18	0.02	0.7	114	4.37	72.2	12.5	6.2	2L	-52.5	8.7
0.08	0.17	0.03	0.7	125	4.36	72.1	12.4	6.1	2L	-52.7	8.7
0.08	0.16	0.04	0.7	136	4.34	72.0	12.4	6.1	2L	-52.8	8.8
0.08	0.18	0.01	0.7	103	4.37	72.2	12.5	6.2	2L	-52.6	8.7
0.08	0.17	0.02	0.7	114	4.35	72.1	12.4	6.2	2L	-52.7	8.7
0.08	0.16	0.03	0.7	125	4.33	72.0	12.4	6.1	2L	-52.9	8.8
0.08	0.18	0	0.7	92	4.37	72.2	12.5	6.3	2L	-52.6	8.7
0.08	0.17	0.01	0.7	103	4.35	72.1	12.4	6.2	2L	-52.8	8.7
0.08	0.16	0.02	0.7	114	4.33	72.0	12.4	6.2	2L	-52.9	8.8
0.08	0.17	0	0.8	92	4.35	72.1	12.4	6.3	2L	-52.8	8.7
0.08	0.16	0.01	0.8	103	4.33	72.0	12.4	6.3	2L	-52.9	8.7
0.08	0.16	0	0.8	92	4.32	72.0	12.4	6.3	2L	-53.0	8.7
0.09	0.2	0.07	0.6	142	4.53	73.0	12.9	6.4	2L	-51.1	8.6
0.09	0.2	0.06	0.7	131	4.53	73.0	12.9	6.5	2L	-51.1	8.6
0.09	0.19	0.07	0.7	142	4.51	72.9	12.8	6.4	2L	-51.2	8.6
0.09	0.19	0.06	0.7	131	4.50	72.9	12.8	6.5	2L	-51.3	8.6
0.09	0.18	0.07	0.7	142	4.48	72.8	12.8	6.4	2L	-51.4	8.7

% wt R32	% wt 1252zc	% wt R134	% wt R1234zeE	GWP	$P_{suction}$ (bar)	$T_{discharge}$ (°C)	$P_{discharge}$ (bar)	Ave Temp Glide (K)	ASHRAE Flammability Class	CAP dev from R410A (%)	COP dev from R410A (%)
0.09	0.17	0.07	0.7	142	4.46	72.7	12.7	6.5	2L	-51.6	8.7
0.09	0.16	0.07	0.7	142	4.44	72.7	12.7	6.5	2L	-51.8	8.7
0.09	0.15	0.07	0.7	142	4.42	72.6	12.6	6.5	2L	-52.0	8.8

CLAIMS

What is claimed is:

1. A composition comprising HFO-1252zc, HFO-1234zeE, HFC-32, and at least one of HFC-134, HFC-134a, or CO_2.

2. The composition of claim 1 comprising:

HFO-1252zc, HFO-1234zeE, HFC-32, and HFC-134; or

HFO-1252zc, HFO-1234zeE, HFC-32, and CO_2; or

HFO-1252zc, HFO-1234zeE, HFC-32, HFC-134, and CO2; or

HFO-1252zc, HFO-1234zeE, HFC-32, and HFC-134a; or

HFO-1252zc, HFO-1234zeE, HFC-32, HFC-134, and HFC-134a; or

HFO-1252zc, HFO-1234zeE, HFC-32, HFC-134a, and CO_2.

3. The composition of claim 1 or 2, comprising:

1-30 weight percent HFO-1252zc, 48-82 weight percent HFO-1234zeE, 15-22 weight percent HFC-32, and 1-4 weight percent HFC-134; or

0.2-98.5 weight percent HFO-1252zc, 0.2-98.5 weight percent of HFO-1234zeE, 0.2-26.0% HFC-134, and 0.2-43.8% HFC-32; or

0.2-98.5% of HFO-1252zc, 0.2%-98.5% of HFO-1234ze(E), 0.2-12.9% of HFC-134, and 0.2%-20.9% of HFC-32; or

19.9-84.6% of HFO-1252zc, 0.2-58.7% of HFO-1234ze(E), 0.2-3.0% of HFC-134, and 14.9%-20.9% of HFC-32; or

19.9-22.9% of HFO-1252zc, 55.7-58.7% of HFO-1234ze(E), about 0.5% of HFC-134, and about 20.9% of HFC-32; or

about 22.9 weight percent HFO-1252zc, about 55.7 weight percent HFO-1234ze(E), about 0.5 weight percent HFC-134 and about 20.9 weight percent HFC-32; or

about 19.9 wt-% HFO-1252zc, about 58.7 wt-% HFO-1234ze(E), about 0.5 wt-% HFC-134, and about 20.9 wt-% HFC-32; or

1.0-21.0% HFO-1252zc, 64.0-92.0% HFO-1234ze(E), 1.0-11.0% HFC-134, and 1.0-9.0% HFC-32; or

15.0-21.0% HFO-1252zc, 63.0-76.0% HFO-1234zeE, 1.0-8.0% HFC-134, and 7.0-9.0% HFC-32; or

15.0-19.0% HFO-1252zc, 68.0-72.0% HFO-1234ze(E), 3.0-7.0% HFC-134, and 6.0-10.0% HFC-32; or

about 17.0% HFO-1252zc, about 70.0% HFO-1234ze(E), about 5.0% HFC-134, and about 8.0% HFC-32.

4. The composition of claim 3, wherein the composition has an average temperature glide of no more than 9.9 K, or no more than 9.6 K, or no more than 9.4 K, no more than 9.3 K, or no more than 6.5, or in a range of 6.0-6.5, or in a range of 5.1-6.1.

5. The composition of claim 3 or claim 4, wherein the composition has a volumetric cooling capacity, relative to R-454C, in a range of:

from 51.9% to 122.3% of the volumetric cooling capacity of R-454C; or

from 51.9% to 97.8% of the volumetric cooling capacity of R-454C; or

from 90.0% to 97.8% of the volumetric cooling capacity of R-454C; or

from 90.1% to 90.2% of the volumetric cooling capacity of R-454C; or

from 40.0% to 48.9% of the volumetric cooling capacity of R-454C; or

from 49.1% to 53.0% of the volumetric cooling capacity of R-454C; or

from 47.3% to 45.2% of the volumetric cooling capacity of R-454C; or

from 47.2% to 48.2% of the volumetric cooling capacity of R-454C.

6. The composition of any one of claims 3-5, wherein the composition has a cooling COP in a range of:

97.6 to 105.4% the cooling COP of R-454C; or

101.5% to 105.0% of the cooling COP of R-454C; or

101.5% to 102.5% of the cooling COP of R-454C; or

102.4% to 102.5% of the cooling COP of R-454C; or

108.6% to 109.3% of the cooling COP of R-454C; or

108.6% to 108.7% of the cooling COP of R-454C; or

108.6% to 108.8% of the cooling COP of R-454C

7. The composition of any one of claims 3-6, wherein the composition has a GWP of less than 300 or less than 150 or less than 125 or in a range of 89-125 or in a range of 92-147.

8. The composition of any one of claims 3-7, wherein the composition has an ASHRAE flammability classification of 2L, 2 or 1.

9. The composition of claim 1 or 2, comprising:

about 13 to about 30 weight percent HFO-1252zc, about 54 to about 72 weight percent HFO-1234zeE, about 8 to about 14 weight percent HFC-32, and about 1 to about 4 weight percent CO_2; or

0.2-98.5% of HFO-1252zc, 0.2-98.5% of HFO-1234ze(E), 0.2-44.0% of HFC-32, and 0.2%-8.0% of CO_2 ; or

0.2-98.5% of HFO-1252zc, 0.2-98.5% of HFO-1234ze(E), 0.2-22.0% of HFC-32, and 0.2-3.0% of CO_2; or

27.9-84.6% of HFO-1252zc, 0.2-51.7% of HFO-1234ze(E), 11.0-22.0% of HFC-32, and 0.2-2.0% of CO_2; or

27.9-64.7% of HFO-1252zc, 12.9-51.7% of HFO-1234ze(E), 15.0-22.0% of HFC-32, and 0.5-1.0% of CO_2; or

about 64.0 wt-% HFO-1252zc, about 13.0 wt-% HFO-1234ze(E), about 22.0 wt-% HFC-32, and about 1.0 wt-% CO_2; or

about 27.9 wt-% HFO-1252zc, about 51.7 wt-% HFO-1234ze(E), about 19.9 wt-% HFC-32, and about 0.5 wt-% CO_2.

10. The composition of claim 9, wherein the composition has a GWP less than 298 or a GWP less than 149.

11. The composition of claim 9 or claim 10, wherein the composition has an average temperature glide of no more than 10.0 K or no more than 9.2 K.

12. The composition of any one of claims 9-11, wherein the composition exhibits a volumetric heating capacity, relative to R-454C, in a range of:

49.3-150.3% of the volumetric heating capacity of R-454C; or

49.3-102.0% of the volumetric heating capacity of R-454C; or

90.0-102.0% of the volumetric heating capacity of R-454C; or

90.0-101.5% of the volumetric heating capacity of R-454C; or

about 101.5% of the volumetric heating capacity of R-454C; or

about 101.2% of the volumetric heating capacity of R-454C.

13. The composition of an one of claims 9-12, wherein the composition exhibits a heating COP, relative to R-454C, in a range of:

96.4-102.3% of the heating COP of R-454C; or

100.1-102.3% of the heating COP of R-454C; or

100.6-101.3% of the heating COP of R-454C; or

100.6-101.2% of the heating COP of R-454C; or

about 100.6% of the heating COP of R-454C; or

about 99.5% of the heating COP of R-454C.

14. The composition of any one of claims 9-13, wherein the composition has an ASHRAE flammability classifications of 2L or 2.

15. The composition of claim 1 or 2, comprising:

0.2-98.5% of HFO-1252zc, 0.2-98.5% of HFO-1234ze(E), 0.2026.0% of HFC-134, 0.2-43.8% of HFC-32, and 0.2-3.0% of CO_2; or

0.2-98.5% of HFO-1252zc, 0.2-98.5% of HFO-1234ze(E), 0.2-12.9% of HFC-134, 0.2-20.9% of HFC-32, and 0.2-3.0% of CO_2; or

24.9-84.6% of HFO-1252zc, 0.2-53.7% of HFO-1234ze(E), 0.2-6.0% of HFC-134, 11.0-20.9% of HFC-32, and 0.2-2.0% of CO_2; or

24.9-63.7% of HFO-1252zc, 13.9-53.7% of HFO-1234ze(E), 0.2-5.0% of HFC-134, 13.0-20.9% of HFC-32, and 0.2-2.0% of CO_2; or

6.0-20.0 weight percent of HFO-1252zc, 55.0-73.0 weight percent of HFO-1234zeE, 11.0-22.0 weight percent of HFC-32, and 1.0-2.0 weight percent of CO_2; or

5 to 30 weight percent HFO-1252zc, 46 to about 77 weight percent HFO-1234zeE, about 5 to about 22 weight percent HFC-32, about 1 to about 10 weight percent HFC-134, and about 1 to about 4 weight percent CO_2; or

1-21 weight percent HFO-1252zc, 42-82 weight percent HFO-1234zeE, 11-22 weight percent HFC-32, 1-6 weight percent HFC-134, and 1-3 weight percent CO_2; or

about 63.7 wt-% HFO-1252zc, about 13.9 wt-% HFO-1234ze(E), about 0.5 wt-% HFC-134, about 20.9 wt-% HFC-32, and about 1.0 wt-% CO_2; or

about 24.9 wt-% HFO-1252zc, about 53.7 wt-% HFO-1234ze(E), about 0.2 wt-% HFC-134, about 20.9 wt-% HFC-32, and about 0.2 wt-% CO_2.

16. The composition of claim 15, wherein the composition has a GWP of less than 300 or less than 150.

17. The composition of claim 15 or claim 16, wherein the composition wherein the composition has an average temperature glide of no more than 10.0 K, or no more than 9.9 K, or no more than 9.2 K.

18. The composition of any one of claims 15-17, wherein the composition exhibits a volumetric heating capacity, relative to R-454C, in a range of:

48.7-133.3% of the volumetric heating capacity of R-454C; or

48.7-100.5% of the volumetric heating capacity of R-454C; or

90.0-100.5% of the volumetric heating capacity of R-454C; or

90.0-100.1% of the volumetric heating capacity of R-454C; or

about 99.9% of the volumetric heating capacity of R-454C; or

about 101.2 of the volumetric heating capacity of R-454C.

19. The composition of any one of claims 15-18, wherein the composition exhibits a heating COP, relative to R-454C, in a range of:

97.6-102.6% of the heating COP of R-454C; or

100.1-102.5% of the heating COP of R-454C; or

100.7-101.3% of the heating COP of R-454C; or

100.7-101.2% of the heating COP of R-454C; or

about 100.7% of the heating COP of R-454C; or

about 1.2% of the heating COP of R-454C.

20. The composition of any one of claims 15-19, wherein the composition has an ASHRAE flammability classifications of 1 or 2 or 2L.

21. The composition of any one of claims 15-20, wherein the composition exhibits a volumetric cooling capacity, relative to R-454C, of 85.57-80.07% of the cooling capacity of R-454C.

22. The composition of any one of claims 15-21, wherein the composition exhibits a heating COP, relative to R-454C, of 53.69-57.38% of the heating COP of R-454C.

23. The composition of claim 1 or claim 2, comprising:

1-21 weight percent HFO-1252zc, 57-82 weight percent HFO-1234zeE, 16-22 weight percent HFC-32, and 1-3 weight percent HFC-134a; or

0.1-21.0 weight percent HFO-1252zc, 58.0-80.0 weight percent HFO-1234zeE, 16.0-20.0 weight percent HFC-32, and 1.0-3.0 weight percent HFC-134a.

24. The composition of claim 23, wherein the composition has an average temperature glide of no more than 9.55 K, or no more than 8.94 K, or no more than 7.95 K.

25. The composition of claim 23 or claim 24, wherein the composition has a volumetric cooling capacity, relative to R-454C, in a range of 80.1-86.2% of the volumetric cooling capacity of R-454C.

26. The composition of any one of claims 23-25, wherein the composition has a cooling COP, relative to R-454C, in a range of 102.92-103.61 % the cooling COP of R-454C.

27. The composition of any one of claims 23-26, wherein the composition has a GWP of less than 300 or less than 150.

28. The composition of claim 1 or 2, comprising:

1.0-96.0% of HFO-1252zc, 1.0-96.0% of HFO-1234ze(E), 1.0-40.0% of HFC-32, 1.0-24.0% of HFC-134, and 1.0-21.0% of HFC-134a; or

1.0% to 96.0% of HFO-1252zc, 1.0% to 96.0% of HFO-1234ze(E), 1.0% to 18.0% of HFC-32, 1.0% to 11.0% of HFC-134, 1.0% to 10.0% of HFC-134a; or

36.0% to 82.0% of HFO-1252zc, 1.0% to 44.0% of HFO-1234ze(E), 15.0% to 18.0% of HFC-32, 1.0% to 3.0% of HFC-134, 1.0% to 2.0% of HFC-134a; or

36.0% to 63.0% of HFO-1252zc, 17.0% to 44.0% of HFO-1234ze(E), 16.0% to 18.0% of HFC-32, 1.0% to 2.0% of HFC-134, 1.0% to 2.0% of HFC-134a; or

63.0 wt-% HFO-1252zc, 17.0 wt-% HFO-1234ze(E), 1.0 wt-% HFC-134, 1.0 wt-% HFC-134a, and 18.0 wt-% HFC-32; or

53.0 wt-% HFO-1252ZC, 28.0 wt-% HFO-1234ze(E), 16.0 wt-% HFC-32, 2.0 wt-% HFC-134, 1.0 wt-% HFC-134a; or

1.0% to 96.0% of HFO-1252zc, 1.0% to 96.0% of HFO-1234ze(E), 1.0% to 40.0% of HFC-32, 1.0% to 25.0% of HFC-134, and 1.0% to 21.0% of HFC-134a; or \

1.0% to 96.0% of HFO-1252zc, 1.0% to 96.0% of HFO-1234ze(E), 1.0% to 18.0% of HFC-32, 1.0% to 11.0% of HFC-134, and 1.0% to 10.0% of HFC-134a; or

45.0% to 81.0% of HFO-1252zc, 1.0% to 35.0% of HFO-1234zeE, 16.0% to 18.0% of HFC-32 1.0% to 2.0% of HFC-134, 1.0% to 2.0% of HFC-134a; or

45.0% to 63.0% of HFO-1252zc, 17.0% to 35.0% of HFO-1234zeE, 17.0% to 18.0% of HFC-32, 1.0% to 1.0% of HFC-134, and 1.0% to 1.0% of HFC-134a; or

63.0 wt-% HFO-1252zc, 17.0 wt-% HFO-1234zeE, 18.0 wt-% HFC-32, 1.0 wt-% HFC-134, 1.0 wt-% HFC-134a; or

54.0 wt-% HFO-1252zc, 27.0 wt-% HFO-1234zeE, 17.0 wt-% HFC-32, 1.0 wt-% HFC-134, and 1.0 wt-% HFC-134a.

29. The composition of claim 28, wherein the composition has a GWP of less than 300 or less than 150.

30. The composition of claim 28 or claim 29, wherein the composition exhibits an average temperature glide of no more than 10.0 K, or no more than 9.6 K, or no more than 8.3, or no more than 8.2, or no more than 7.8 K, or no more than 7.4 K, or no more than 7.2 K.

31. The composition of any one of claims 28-30, wherein the composition exhibits a volumetric cooling capacity, relative to R-454C, in the range of:

52.8-79.9.1% of the volumetric cooling capacity of R-454C; or

52.8-94.8% of the volumetric cooling capacity of R-454C; or

90.0-94.8.2% of the volumetric cooling capacity of R-454C; or

90.0%-94.0% of the volumetric cooling capacity of R-454C; or

about 94.0% of the volumetric cooling capacity of R-454C; or

about 90.1% of the volumetric cooling capacity of R-454C.

32. The composition of any one of claims 28-31, wherein the composition exhibits a cooling COP, relative to R-454C, in the range of:

98.9-104.7% of the cooling COP of R-454C; or

101.7-104.4% of the cooling COP of R-454C; or

102.2-102.6% of the cooling COP of R-454C; or

102.2-102.4% of the cooling COP of R-454C; or

about 102.2% of the cooling COP of R-454C; or

about 102.4% of the cooling COP of R-454C.

33. The composition of any one of claims 28-32, wherein the composition exhibits a volumetric heating capacity, relative to R-454C, in a range of:

49.9-80.3% of the volumetric heating capacity of R-454C; or

49.9-93.5% of the volumetric heating capacity of R-454C; or

90.0-93.5% of the volumetric heating capacity of R-454C; or

90.1-92.6% of the volumetric heating capacity of R-454C; or

about 92.6% of the volumetric heating capacity of R-454C; or

about 90.1% of the volumetric heating capacity of R-454C.

34. The composition of any one of claims 28-33, wherein the composition exhibits a heating COP, relative to R-454C, in the range of:

98.7-102.8% of the heating COP of R-454C; or

101.1-102.7% of the heating COP of R-454C; or

101.1-101.2% of the heating COP of R-454C; or

about 101.1% of the heating COP of R-454C; or

35. The composition of any one of claims 28-34, wherein the composition has an ASHRAE flammability rating of 1 or 2 or 2L.

36. The composition of claim 1 or 2, comprising:

2.0% to 92.0% of HFO-1252zc, 2.0% to 92.0% of HFO-1234ze(E), 2.0% to 40.0% of HFC-32. 2.0% to 22.0% of HFC-134a, and 2.0% to 78.0% of CO_2; or

2.0% to 92.0% of HFO-1252zc, 2.0% to 92.0% of HFO-1234ze(E), 2.0% to 18.0% of HFC-32, 2.0% to 10.0% of HFC-134a, and 2.0% to 78.0% of CO_2; or

34.0% to 84.0% of HFO-1252zc, 2.0% to 46.0% of HFO-1234ze(E), 10.0% to 18.0% of HFC-32, 2.0% to 6.0% of HFC-134a, and 2.0% to 2.0% of CO_2; or

34.0% to 62.0% of HFO-1252zc, 16.0% to 46.0% of HFO-1234ze(E), 12.0% to 18.0% of HFC-32, 2.0% to 4.0% of HFC-134a, and 2.0% to 2.0% of CO_2; or

62.0 wt-% HFO-1252zc, 16.0 wt-% HFO-1234ze(E), 18.0 wt-% HFC-32, 2.0 wt-% HFC-134a, and 2.0 wt-% CO_2; or

46.0 wt-% HFO-1252zc, 38.0 wt-% HFO-1234ze(E), 12.0 wt-% HFC-32, 2.0 wt-% HFC-134a, and 2.0 wt-% CO_2; or

2.0% to 92.0% of HFO-1252zc, 2.0% to 92.0% of HFO-1234ze(E), 2.0% to 40.0% of HFC-32, and 2.0% to 22.0% of HFC-134a, and 2.0% to 92.0% of CO_2; or

28.0% to 82.0% of HFO-1252zc, 2.0% to 40.0% of HFO-1234ze(E), 4.0% to 28.0% of HFC-32, 2.0% to 20.0% of HFC-134a, and 2.0% to 4.0% of CO_2; or

28.0% to 66.0% of HFO-1252zc, 2.0% to 40.0% of HFO-1234ze(E), 4.0% to 28.0% of HFC-32, 2.0% to 20.0% of HFC-134a, and 2.0% to 4.0% of CO_2; or

52.0 wt-% HFO-1252zc, 14.0 wt-% HFO-1234ze(E), 26.0 wt-% HFC-32, 6.0 wt-% HFC-134a, and 2.0 wt-% CO_2; or

58.0 wt-% HFO-1252zc, 26.0 wt-% HFO-1234ze(E), 12.0 wt-% HFC-32, 2.0 wt-% HFC-134a, and 2.0 wt-% CO_2.

37. The composition of claim 36, wherein the composition exhibits an AGW of less than 300 or less than 149.

38. The composition of claim 36 or claim 37, wherein the composition exhibits a volumetric cooling capacity, relative to R-454C, in a range of:

62.3-218.6% of the volumetric cooling capacity of R-454C; or

62.3-213.4% of the volumetric cooling capacity of R-454C; or

90.0-101.3% of the volumetric cooling capacity of R-454C; or

90.1- 100.6% of the volumetric cooling capacity of R-454C; or

about 100.6% of the volumetric cooling capacity of R-454C; or

about 90.1 of the volumetric cooling capacity of R-454C.

39. The composition of any one of claims 36-38, wherein the composition exhibits a cooling COP, relative to R-454C, in a range of:

65.0-103.2% of the cooling COP of R-454C; or

65.0-103.1% of the cooling COP of R-454C; or

101.5-102.3% of the cooling COP of R-454C; or

101.5-102.1% of the cooling COP of R-454C; or

about 101.5% of the cooling COP of R-454C; or

about 2.1% of the cooling COP of R-454C.

40. The composition of any one of claims 36-39, wherein the composition exhibits a volumetric heating capacity, relative to R-454C, in a range of:

59.6-348.8% of the volumetric heating capacity of R-454C; or

90.0-110.0% of the volumetric heating capacity of R-454C; or

about 110.0% of the volumetric heating capacity of R-454C; or

about 90.5 of the volumetric heating capacity of R-454C.

41. The composition of any one of claims 36-40, wherein the composition exhibits a heating COP, relative to R-454C, in a range of:

77.4-101.4% of the heating COP of R-454C; or

77.4-101.4% of the heating COP of R-454C; or

99.6-100.9% of the heating COP of R-454C; or

99.6-100.8% of the heating COP of R-454C; or

about 99.7% of the heating COP of R-454C; or

about 100.8% of the heating COP of R-454C; or

42. The composition of any one of claims 36-41, wherein the composition exhibits an average temperature glide of no more than 10.0 K, or no more than 9.5, or no more than 9.3 K.

43. The composition of any one of claims 36-42, wherein the composition has an ASHRAE flammability rating of 1 or 2 or 2L.

44. The composition of any of claims 1 to 43, further comprising at least one additional compound selected from HCFC-22, HFC-23, HCC-30, HCFC-31, HCC-40, HFC-41, methane, HFC-125, HFC-134a, HFC-143, HFC-143a, HFC-152a, HFC-245cb, HCFC-253dc, HFC-254fb, HCC-260fb, HCFC-261fc, HCFC-262fc, HFC-263fb, HFC-272fb, propane, HFO-374, n-butane, allene, 2-butene, cyclobutene, 2-methyl propene, HCFO-1122, HFO-1132, HFO-1132a, HFO-1141, ethylene, HCFO-1233xf, HFO-1234yf, HCFO-1242zf, HFO-1243zf, HCFO-1251, HCO-1260zf, HFO-1261zf, propylene, HFO-1345, HFO-1252ze, HFO-1252yf, HFO-1252zf, HFO-1252ye, and E/Z-t-BuO-CF=CH-CH_3.

45. The composition of any of claims 1 to 44, further comprising at least one additional compound selected from HCFC-22, HCC-40, HFO-1234yf, HFO-1243zf, HFC-263fb, HFO-1252ze, HFO-1252yf, HFO-1252zf, and HFO-1252ye.

46. The composition of any of claims 1 to 45, 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.

47. The composition of any of claims 1 to 46, wherein said composition comprises a stabilizer.

48. The composition of claim 47, wherein the stablilizer is selected from the group consisting of nitromethane, ascorbic acid, terephthalic acid, azoles, phenolic compounds, cyclic monoterpenes, terpenes, phosphites, phosphates, phosphonates, thiols, and lactones.

49. The composition of any of claims 47 or 49, 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.

50. The composition of any of claims 47 to 49, wherein the stabilizer is present in an amount from about 0.001 to 1.0 weight percent based on the weight of the refrigerant.

51. The composition of any of claims 1 to 50, wherein the composition further comprises a lubricant.

52. The composition of claim 51, wherein said lubricant is at least one selected from the group consisting of polyalkylene glycol, polyol ester, poly-α-olefin, and polyvinyl ether.

53. The composition of claim 51 or 52, wherein said lubricant is a polyol ester or a polyvinyl ether.

54. The composition of any of claims 51 to 53, 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 ºC; surface tension of from about 0.02 N/m to about 0.04 N/m at 20 ºC; kinematic viscosity of from about 20 cSt to about 500 cSt at 40 ºC; a breakdown voltage of at least 25 kV; and a hydroxy value of at most 0.1 mg KOH/g.

55. The composition of any of claims 1 to 54, wherein the composition comprises at least one tracer.

56. The composition of claim 55, wherein said tracer is present in an amount from about 1.0 ppm by weight to about 1000 ppm by weight.

57. The composition of any of claims 55 or 56, 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.

58. The composition of any of claims 55 to 57, 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.

59. The composition of any of claims 1 to 58, 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.

60. A method for cooling comprising evaporating a composition of any of claims 1 to 59 in the vicinity of a body to be cooled and thereafter condensing said composition, wherein said cooling is provided by an air-conditioner or heat pump.

61. A method for heating comprising evaporating a composition of any of claims 1 to 50 and thereafter condensing said composition in the vicinity of a body to be heated, wherein said heating is provided by a heat pump.

62. A system for cooling or heating comprising a composition of any of claims 1 to 50.

63. The system of claim 62, comprising an evaporator, compressor, condenser, and expansion device, each operably connected to perform a vapor compression cycle.

64. The system of claim 62 or 63, wherein said air-conditioner or heat pump is a residential, light commercial, or industrial air-conditioner or heat pump.

65. The system of any of claims 62 to 64, wherein said system is a secondary loop system.

66. A method of replacing R-454C, propane, or R-410A in air-conditioning or heat pump systems comprising providing the composition of any of claims 1 to 50 to the system in place of R-454C, propane, or R-410A.

67. Use of the composition of any of claims 1 to 50 as refrigerant in air-conditioning or heat pump systems.