

TITLE OF THE INVENTION

LOW GWP BLENDS COMPRISING 1,2-DIFLUOROETHYLENE 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 and 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 that 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 1,2-difluoroethylene, 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] Certain embodiments disclosed herein relate to a fluoroethylene composition comprising 1,2-difluoroethylene (also called HFO-1132, or HFO-1132). This compound is shown herein to have advantageous properties for its use in refrigerant applications, such as air-conditioning and heat pumps.

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

[0008] In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 56 to about 99 weight percent HFO-1132E and about 1 to about 44 weight percent HFC-32. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially

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

[0009] In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 74 to about 99 weight percent of HFO-1132E and 1 to about 26 weight percent HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 87 to about 99 weight percent of HFO-1132E and 1 to about 13 weight percent of HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 87 to about 99 weight percent of HFO-1132E and 1 to about 13 weight percent of HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 74 weight percent HFO-1132E and about 26 weight percent HFC-134.

[0010] In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 1 to about 99 weight percent of HFO-1132E and 1 to about 99 weight percent HFO-1234zeE. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 40 to about 61 weight percent of HFO-1132E and 39 to about 60 weight percent of HFO-1234zeE. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 42 to about 62 weight percent of HFO-1132E and about 38 to 58 of HFO-1234zeE.

[0011] In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 57 to about 98.5 wt-% of HFO-1132E, about 0.5 to about 26 wt-% HFC-134, and about 0.5 to about 43 wt-% HFC-32. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 79 to about 98.5 wt-% of HFO-1132E, about 0.5 to about 13 wt-% HFC-134, and about 0.5 to about 21 wt-% HFC-32. In another

embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 62 wt-% HFO-1132E, about 9 wt-% HFC-134 and about 29 wt-% HFC-32. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 86.6 wt-% HFO-1132E, about 12.9 wt-% HFC-134 and about 0.5 wt-% HFC-32. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 56.7 wt-% HFO-1132E, about 0.5 wt-% HFC-134 and about 42.8 wt-% HFC-32. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 78.6 wt-% HFO-1132E, about 0.5 wt-% HFC-134 and about 20.9 wt-% HFC-32

[0012] According to any of the foregoing embodiments, also disclosed herein are compositions comprising, consisting essentially of, or consisting of from about 6 to 58 weight percent HFO-1132E, from about 1 to 22 weight percent HFC-32, and from about 42 to 72 weight percent HFO-1234zeE. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of from about 6 to 42 weight percent HFO-1132E, from about 2 to 22 weight percent HFC-32, and from about 47 to 72 weight percent HFO-1234zeE. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of from about 8 to 60 weight percent HFO-1132E, from about 1 to 22 weight percent HFC-32, and from about 40 to 70 weight percent HFO-1234zeE. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of from about 8 to 42 weight percent HFO-1132E, from about 3 to 22 weight percent HFC-32, and from about 46 to 70 weight percent HFO-1234zeE. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of from about 29 to 30 weight percent HFO-1132E, from about 20 to 24 weight percent HFC-32, and from about 47 to 50 weight percent HFO-1234zeE.

[0013] In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 0.5 to about 98.5 wt-% HFO-1132E, about 0.5 to about 98.5 wt-% HFO-1234zeE, and about 0.5 to about 26 wt-% HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 0.5 to about 98.5 wt-% of HFO-1132E, about 0.5 to about 98.5 wt-% HFO-1234zeE, and about 0.5 to about 13 wt-% HFC-

134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 0.5 to about 98.5 wt-% of HFO-1132E, about 0.5 to about 98.5 wt-% HFO-1234zeE, and about 0.5 to about 26 wt-% HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 0.5 to about 98.5 wt-% of HFO-1132E, about 0.5 to about 98.5 wt-% HFO-1234zeE, and about 0.5 to about 13 wt-% HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 39 to about 98.5 wt-% of HFO-1132E, about 0.5 to about 60 wt-% of HFO-1234zeE, and about 0.5 to about 13 of HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 41 to about 98.5 wt-% of HFO-1132E, about 0.5 to about 57 of HFO-1234zeE, and about 0.5 to about 13 wt-% HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 39 to about 47 wt-% HFO-1132E, about 40 to about 54 wt-% HFO-1234zeE, and about 6 to about 13 wt-% HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 47 wt-% HFO-1132E, about 40 wt-% HFO-1234zeE and about 13 wt-% HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 41 to about 47 wt-% HFO-1132E, about 40 to about 50 wt-% HFO-1234zeE, and about 8 to about 13 wt-% HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 47 wt-% HFO-1132E, about 40 wt-% HFO-1234zeE and about 13 wt-% HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 39 wt-% HFO-1132E, about 49 wt-% HFO-1234zeE and about 12 wt-% HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 47 wt-% HFO-1132E, about 40 wt-% HFO-1234zeE and about 13 wt-% HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 41 wt-% HFO-1132E, about 50 wt-% HFO-1234zeE and about 9 wt-% HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 47 wt-% HFO-1132E, about 40 wt-% HFO-1234zeE and about 13 wt-% HFC-134.

[0014] According to any of the foregoing embodiments, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 8 to 59 weight percent HFO-1132E, about 1 to about 22 weight percent HFC-32, about 1 to about 13 weight percent HFC-134, and about 30 to about 61 weight percent HFO-1234zeE. According to any of the foregoing embodiments, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 8 to 47 weight percent HFO-1132E, about 1 to about 22 weight percent HFC-32, about 1 to about 13 weight percent HFC-134, and about 37 to about 71 weight percent HFO-1234zeE. According to any of the foregoing embodiments, also disclosed herein are compositions comprising, consisting of, or consisting essentially of 0.25 to about 98.5 wt-% of HFO-1132E, 0.25 to about 98.5 wt-% of HFO-1234zeE, 0.25 to about 26 wt-% HFC-134, and 0.25 to about 44 wt-% HFC-32. According to any of the foregoing embodiments, also disclosed herein are compositions comprising, consisting of, or consisting essentially of 0.25 to about 98.5 wt-% of HFO-1132E, 0.25 to about 98.5 wt-% of HFO-1234zeE, 0.25 to about 13 wt-% HFC-134, and 0.25 to about 21 wt-% HFC-32. According to any of the foregoing embodiments, also disclosed herein are compositions comprising, consisting of, or consisting essentially of 0.25 to about 98.5 wt-% of HFO-1132E, 0.25 to about 98.5 wt-% of HFO-1234zeE, 0.25 to about 26 wt-% HFC-134, and 0.25 to about 44 wt-% HFC-32. According to any of the foregoing embodiments, also disclosed herein are compositions comprising, consisting of, or consisting essentially of 0.25 to about 98.5 wt-% of HFO-1132E, 0.25 to about 98.5 wt-% of HFO-1234zeE, 0.25 to about 13 wt-% HFC-134, and 0.25 to about 21 wt-% HFC-32. According to any of the foregoing embodiments, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 7 to about 98.5 wt-% of HFO-1132E, 0.25 to about 72 wt-% of HFO-1234zeE, 0.25 to about 13 wt-% of HFC-134, and 0.25 to about 21 wt-% of HFC-32. According to any of the foregoing embodiments, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 10 to about 98.5 wt-% of HFO-1132E, 0.25 to about 69 wt-% of HFO-1234zeE, 0.25 to about 13 wt-% of HFC-134, and 0.25 to about 21 wt-% HFC-32. According to any of the foregoing embodiments, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 7 to about 48 wt-% HFO-1132E, about 36 to about 72 wt-% HFO-1234zeE, about 0.5 to about 13 wt-% HFC-134, and about 0.5 to about 21 wt-% HFC-32. According to any of the foregoing

embodiments, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 41.8 wt-% HFO-1132E, about 45.8 wt-% HFO-1234zeE, about 0.5 wt-% HFC-134 and about 11.9 wt-% HFC-32. According to any of the foregoing embodiments, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 7.0 wt-% HFO-1132E, about 71.6 wt-% HFO-1234zeE, about 0.5 wt-% HFC-134 and about 20.9 wt-% HFC-32. According to any of the foregoing embodiments, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 10 to about 48 wt-% HFO-1132E, about 36 to about 69 wt-% HFO-1234zeE, about 0.5 to about 13 wt-% HFC-134, and about 0.5 to about 21 wt-% HFC-32. According to any of the foregoing embodiments, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 40 wt-% HFO-1132E, about 42 wt-% HFO-1234zeE, about 4 wt-% HFC-134 and about 14 wt-% HFC-32. According to any of the foregoing embodiments, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 10.9 wt-% HFO-1132E, about 68.7 wt-% HFO-1234zeE, about 0.5 wt-% HFC-134 and about 19.9 wt-% HFC-32.

[0015] According to any of the foregoing embodiments, also disclosed herein are compositions comprising about 30 weight percent HFO-1132E, about 21 weight percent HFC-32, and about 49 weight percent HFO-1234zeE.

[0016] According to any of the foregoing embodiments, also disclosed herein are compositions comprising, consisting of, or consisting essentially of from about 1 to 79 weight percent HFO-1132Z, from about 19 to 44 weight percent HFC-32, and from about 1 to 81 weight percent HFO-1234zeE. In another embodiment, the compositions comprise, consist of, or consist essentially of from about 1 to 49 weight percent HFO-1132Z, from about 19 to 22 weight percent HFC-32, and from about 29 to 81 weight percent HFO-1234zeE. In another embodiment, the compositions comprise, consist of, or consist essentially of from about 1 to 51 weight percent HFO-1132Z, from about 21 to 22 weight percent HFC-32, and from about 27 to 79 weight percent HFO-1234zeE.

[0017] According to any of the foregoing embodiments, also disclosed herein are compositions comprising, consisting of, or consisting essentially of from about 1 to

97 weight percent HFO-1132Z, from about 1 to 97 weight percent HFO-1132E, from about 1 to 97 weight percent HFO-1234zeE, and from about 1 to 44 weight percent HFC-32. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of from about 1 to 97 weight percent HFO-1132Z, from about 1 to 97 weight percent HFO-1132E, from about 1 to 97 weight percent HFO-1234zeE, and from about 1 to 22 weight percent HFC-32. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of from about 1 to 66 weight percent HFO-1132Z, from about 6 to 64 weight percent HFO-1132E, from about 1 to 72 weight percent HFO-1234zeE, and from about 1 to 22 weight percent HFC-32. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of from about 1 to 63 weight percent HFO-1132Z, from about 8 to 65 weight percent HFO-1132E, from about 1 to 69 weight percent HFO-1234zeE, and from about 1 to 22 weight percent HFC-32. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of from about 1 to 37 weight percent HFO-1132Z, from about 8 to 42 weight percent HFO-1132E, from about 26 to 69 weight percent HFO-1234zeE, and from about 3 to 22 weight percent HFC-32.

[0018] According to any of the foregoing embodiments, also disclosed herein are compositions comprising, consisting of, or consisting essentially of:

about 30 weight percent HFO-1132E, about 21 weight percent HFC-32, and about 49 weight percent HFO-1234zeE; or

about 6 weight percent HFO-1132E, about 22 weight percent HFC-32, and about 72 weight percent HFO-1234zeE; or

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

about 45 weight percent HFO-1132E, about 10 weight percent HFC-32, and about 45 weight percent HFO-1234zeE; or

about 53 weight percent HFO-1132E, about 4 weight percent HFC-32, and about 43 weight percent HFO-1234zeE; or

about 30 weight percent HFO-1132Z, about 21 weight percent HFC-32, and about 49 weight percent HFO-1234zeE; or

about 1 weight percent HFO-1132Z, about 22 weight percent HFC-32, and about 77 weight percent HFO-1234zeE; or

about 10 weight percent HFO-1132Z, about 34 weight percent HFO-1132E, about 37 weight percent HFO-1234zeE, and about 19 weight percent HFC-32; or

about 10 weight percent HFO-1132Z, about 34 weight percent HFO-1132E, about 37 weight percent HFO-1234zeE, and about 19 weight percent HFC-32.

[0019] According to any of the foregoing embodiments, also disclosed herein are compositions further comprising at least one additional compound selected from methane, ethane, HCFC-22, HFC-23, HCC-30, HCFC-31, HCC-40, HFC-41, HFCF-22, HFO-1141, HFO-1225yeE, HFO-1225yeZ, HFO-1234yf, HFO-1243zf, HFC-161, HFC-152, HFC-143, HFC-143a, HFC-134a, HCFO-1122, HCFO-1122aE, HCFO-1122aZ, HCC-150, HCFC-151, CFO-1112E, CFO-1112Z, HCFC-142a, HCFC-132, HCFC-133, HCFC-133b, HCFC-123, HFC-236fa, HFC-245fa, HFC-245eb, HFO-1123, HFO-1132a, HCFO-1131E, HCFO-1131Z, ethylene, and acetylene.

[0020] According to any of the foregoing embodiments, also disclosed herein are compositions further comprising at least one additional compound selected from HCFC-22, HCC-40, HFO-1234yf, HFO-1243zf, HFC-245fa, and HFC-134a.

[0021] According to any of the foregoing embodiments, also disclosed herein are compositions wherein said composition further comprises from 0.1 to 200 ppm by weight of water; from about 10 ppm by volume to about 0.35 volume percent oxygen; and/or from about 100 ppm by volume to about 1.5 volume percent air or NAG.

[0022] According to any of the foregoing embodiments, also disclosed herein are compositions wherein said composition comprises a stabilizer.

[0023] According to any of the foregoing embodiments, also disclosed herein are compositions, wherein the stabilizer is selected from the group consisting of nitromethane, ascorbic acid, terephthalic acid, azoles, phenolic compounds, cyclic

monoterpenes, terpenes, phosphites, phosphates, phosphonates, thiols, and lactones.

[0024] According to any of the foregoing embodiments, also disclosed herein are compositions, wherein the stabilizer is selected from toluotriazole, benzotriazole, tocopherol, hydroquinone, t-butyl hydroquinone, 2,6-di-terbutyl-4-methylphenol, fluorinated epoxides, n-butyl glycidyl ether, hexanediol diglycidyl ether, allyl glycidyl ether, butylphenylglycidyl ether, d-limonene, α -terpinene, β -terpinene, α -pinene, β -pinene, or butylated hydroxytoluene.

[0025] According to any of the foregoing embodiments, also disclosed herein are compositions, wherein the stabilizer is present in an amount from about 0.001 to 1.0 weight percent based on the weight of the refrigerant.

[0026] According to any of the foregoing embodiments, also disclosed herein are compositions, wherein the composition further comprises a lubricant.

[0027] According to any of the foregoing embodiments, also disclosed herein are compositions, wherein said lubricant is at least one selected from the group consisting of polyalkylene glycol, polyol ester, poly- α -olefin, and polyvinyl ether.

[0028] According to any of the foregoing embodiments, also disclosed herein are compositions, wherein said lubricant is a polyol ester or a polyvinyl ether.

[0029] According to any of the foregoing embodiments, also disclosed herein are compositions, wherein said lubricant has at least one property selected from the group consisting of volume resistivity of greater than 10^{10} Ω -m at 20 °C; surface tension of from about 0.02 N/m to 0.04 N/m at 20 °C; kinematic viscosity of from about 20 cSt to about 500 cSt at 40 °C; a breakdown voltage of at least 25 kV; and a hydroxy value of at most 0.1 mg KOH/g.

[0030] According to any of the foregoing embodiments, also disclosed herein are compositions, wherein the composition comprises at least one tracer.

[0031] According to any of the foregoing embodiments, also disclosed herein are compositions, wherein said tracer is present in an amount from about 1.0 ppm by weight to about 1000 ppm by weight.

[0032] According to any of the foregoing embodiments, also disclosed herein are compositions, wherein said at least one tracer is selected from the group consisting of hydrofluorocarbons, hydrofluoroolefins, hydrochlorocarbons, hydrochloroolefins, hydrochlorofluorocarbons, hydrochlorofluoroolefins, hydrochlorocarbons, hydrochloroolefins, chlorofluorocarbons, chlorofluoroolefins, hydrocarbons, perfluorocarbons, perfluoroolefins, and combinations thereof.

[0033] According to any of the foregoing embodiments, also disclosed herein are compositions, wherein said at least one tracer is selected from the group consisting of HFC-23, HCFC-31, HFC-41, HFC-161, HFC-143a, HFC-134a, HFC-125, HFC-236fa, HFC-236ea, HFC-245cb, HFC-245fa, HFC-254eb, HFC-263fb, HFC-272ca, HFC-281ea, HFC-281fa, HFC-329p, HFC-329mmz, HFC338mf, HFC-338pcc, CFC-12, CFC-11, CFC-114, CFC-114a, HCFC-22, HCFC-123, HCFC-124, HCFC-124a, HCFC-141b, HCFC-142b, HCFC-151a, HCFC-244bb, HCC-40, HFO-1141, HCFO-1130, HCFO-1130a, HCFO-1131, HCFO-1122, HFO-1123, HFO-1234yf, HFO-1234ye, HFO-1243zf, HFO-1225ye, HFO-1225zc, PFC-116, PFC-C216, PFC-218, PFC-C318, PFC-1216, PFC-31-10mc, PFC-31-10my, and combinations thereof.

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

[0035] According to any of the foregoing embodiments, also disclosed herein are methods for cooling comprising evaporating the composition 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.

[0036] According to any of the foregoing embodiments, also disclosed herein are methods for heating comprising evaporating the composition and thereafter condensing said composition in the vicinity of a body to be heated, wherein said heating is provided by a heat pump.

[0037] According to any of the foregoing embodiments, also disclosed herein are systems for cooling or heating comprising the composition. 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.

DETAILED DESCRIPTION

[0038] This invention relates to compositions comprising, consisting of, or consisting essentially of 1,2-difluoroethylene (HFO-1132), and at least one compound selected from the group difluoromethane (HFC-32), 1,1,2,2-tetrafluoroethane (R-134), and E-1,3,3,3-tetrafluoropropene (HFO-1234zeE). The compositions may potentially be candidates to replace refrigerants such as R-454C, R-410A, or propane with low Global Warming Potential (GWP), improved environmental fate characteristics, and improved energy efficiency (COP).

[0039] The compositions comprise, consist of, or consist essentially of HFO-113 and at least one compound selected from the group consisting of HFC-32, HFO-134, and HFO-1234zeE. They provide refrigerant blends with low global warming potential, improved glide as compared to other suggested refrigerant blends, and improved coefficient of performance as compared to existing refrigerants and other proposed replacements, while additionally meeting the evolving regulatory landscape.

[0040] 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.

[0041] 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.

[0042] 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.

[0043] 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.

[0044] 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).

[0045] 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).

[0046] 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).

[0047] 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.

[0048] The net refrigeration effect is the quantity of heat that each kilogram of refrigerant absorbs in the evaporator to produce useful cooling.

[0049] 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.

[0050] 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.

[0051] 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), for those compounds listed. The GWP of HFO-1132Z has been reported by McLinden (McLinden et. al., A thermodynamic analysis of refrigerants: Possibilities and tradeoffs for Low-GWP refrigerants, Int J Refrig 38 (2014) 80) as being 1.5, and that value is used herein. The GWP of HFO-1132E is

reported by Tokuhashi (Tokuhashi, et. al., Rate Constants for the Reactions of OH Radicals with the (E)/(Z) Isomers of CFCI=CFCI and (E)-CHF=CHF, J. Phys. Chem A (2019), 123, 4834) as being 0.0056, and that value is used herein.

[0052] 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-1132Z and HFO-1132E have zero ozone depletion potential.

[0053] 1,2-difluoroethylene (HFO-1132) may be prepared by dehydrochlorination of 1-chloro-1,2-difluoroethane (HCFC-142a) in either the gas phase or liquid phase as described in U.S. Patent Publication 2022-0017438A. The reaction will produce both the E- and Z- isomers of the compound, but they are separable by distillation.

[0054] E-1,3,3,3-Tetrafluoropropene (HFO-1234zeE or HFO-1234zeE) is available commercially from Honeywell (Charlotte, North Carolina, USA). Difluoromethane (HFC-32 or R-321) and 1,1,2,2-tetrafluoroethane (HFC-134 or R-134) are available commercially from various sources worldwide.

[0055] 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.

[0056] 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.

[0057] 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.

[0058] 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.

[0059] 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

[0060] In one embodiment, compositions comprise, consist of, or consist essentially of HFO-1132 and at least one compound selected from the group consisting of HFC-32, HFC-134, and HFO-1234zeE. In another embodiment, compositions comprise, consist of, or consist essentially of HFO-1132E and HFC-32.

In another embodiment, compositions comprise, consist of, or consist essentially of HFO-1132E and HFC-134. In another embodiment, compositions comprise, consist of, or consist essentially of HFO-1132E and HFO-1234zeE. In another embodiment, compositions comprise, consist of, or consist essentially of HFO-1132E, HFC-32, and HFC-134. In another embodiment, compositions comprise, consist of, or consist essentially of HFO-1132E, HFC-32, and HFO-1234zeE. In another embodiment, compositions comprise, consist of, or consist essentially of HFO-1132E, HFC-134, and HFO-1234zeE. In another embodiment, compositions comprise, consist of, or consist essentially of HFO-1132E, HFC-32, HFC-134, and HFO-1234zeE. In another embodiment, compositions comprise, consist of, or consist essentially of HFO-1132Z, HFC-32, and HFO-1234zeE. In another embodiment, the compositions comprise, consist of, or consist essentially of HFO-1132Z, HFC-32, and HFO-1234zeE. In another embodiment, the compositions comprise, consist of, or consist essentially of HFO-1132E, HFO-1132Z, HFC-32, and HFO-1234zeE. In another embodiment, the compositions comprise, consist of, or consist essentially of HFO-1132E, HFO-1132Z, HFC-134, and HFO-1234zeE. These compositions provide low Global Warming Potential (GWP), improved environmental fate characteristics, and improved energy efficiency (COP).

[0061] In one embodiment, disclosed herein are compositions comprising, consisting essentially of, or consisting of from about 6 to 58 weight percent HFO-1132E, from about 1 to 22 weight percent HFC-32, and from about 42 to 72 weight percent HFO-1234zeE. In another embodiment, the compositions comprise, consist of, or consist essentially of from about 6 to 42 weight percent HFO-1132E, from about 2 to 22 weight percent HFC-32, and from about 47 to 72 weight percent HFO-1234zeE. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of from about 8 to 60 weight percent HFO-1132E, from about 1 to 22 weight percent HFC-32, and from about 40 to 70 weight percent HFO-1234zeE. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of from about 8 to 42 weight percent HFO-1132E, from about 3 to 22 weight percent HFC-32, and from about 46 to 70 weight percent HFO-1234zeE. In another embodiment, the compositions comprise, consist of, or consist essentially of from about 29 to 30

weight percent HFO-1132E, from about 20 to 24 weight percent HFC-32, and from about 47 to 50 weight percent HFO-1234zeE.

[0062] In another embodiment, also disclosed herein are compositions comprising about 30 weight percent HFO-1132E, about 21 weight percent HFC-32, and about 49 weight percent HFO-1234zeE.

[0063] In one embodiment, disclosed herein are compositions comprising, consisting of, or consisting essentially of HFO-1132 and at least one compound selected from the group consisting of HFC-32, HFC-134, and HFO-1234zeE. In another embodiment, the compositions comprise, consist of, or consist essentially of HFO-1132 and HFC-32. In another embodiment, the compositions comprise, consist of, or consist essentially of HFO-1132 and HFC-134. In another embodiment, the compositions comprise, consist of, or consist essentially of HFO-1132 and HFO-1234zeE. In another embodiment, the compositions comprise, consist of, or consist essentially of HFO-1132, HFC-32, and HFC-134. In another embodiment, the compositions comprise, consist of, or consist essentially of HFO-1132, HFC-32, and HFO-1234zeE. In another embodiment, the compositions comprise, consist of, or consist essentially of HFO-1132, HFC-134, and HFO-1234zeE. In another embodiment, the compositions comprise, consist of, or consist essentially of HFO-1132E, HFC-32, HFC-134, and HFO-1234zeE. In another embodiment, the compositions comprise, consist of, or consist essentially of HFO-1132Z, HFC-32, and HFO-1234zeE. In another embodiment, the compositions comprise, consist of, or consist essentially of HFO-1132E, HFO-1132Z, HFC-32, and HFO-1234zeE. In another embodiment, the compositions comprise, consist of, or consist essentially of HFO-1132E, HFO-1132Z, HFC-134, and HFO-1234zeE.

[0064] In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 56 to about 99 weight percent HFO-1132E and about 1 to about 44 weight percent HFC-32. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 78 to about 99 weight percent HFO-1132E and about 1 to about 22 weight percent HFC-32. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 56 to about 60 weight percent of HFO-1132E and about 40 to about 44 weight percent of HFC-32. In

another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 56 weight percent HFO-1132E and about 44 weight percent HFC-32.

[0065] In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 74 to about 99 weight percent of HFO-1132E and 1 to about 26 weight percent HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 87 to about 99 weight percent of HFO-1132E and 1 to about 13 weight percent of HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 87 to about 99 weight percent of HFO-1132E and 1 to about 13 weight percent of HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 74 weight percent HFO-1132E and about 26 weight percent HFC-134.

[0066] In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 1 to about 99 weight percent of HFO-1132E and 1 to about 99 weight percent HFO-1234zeE. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 40 to about 61 weight percent of HFO-1132E and 39 to about 60 weight percent of HFO-1234zeE. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 42 to about 62 weight percent of HFO-1132E and about 38 to 58 of HFO-1234zeE.

[0067] In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 57 to about 98.5 wt-% of HFO-1132E, about 0.5 to about 26 wt-% HFC-134, and about 0.5 to about 43 wt-% HFC-32. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 79 to about 98.5 wt-% of HFO-1132E, about 0.5 to about 13 wt-% HFC-134, and about 0.5 to about 21 wt-% HFC-32. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 62 wt-% HFO-1132E, about 9 wt-% HFC-134 and about 29 wt-% HFC-32. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 86.6 wt-% HFO-1132E,

about 12.9 wt-% HFC-134 and about 0.5 wt-% HFC-32. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 56.7 wt-% HFO-1132E, about 0.5 wt-% HFC-134 and about 42.8 wt-% HFC-32. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 78.6 wt-% HFO-1132E, about 0.5 wt-% HFC-134 and about 20.9 wt-% HFC-32

[0068] According to any of the foregoing embodiments, also disclosed herein are compositions comprising, consisting essentially of, or consisting of from about 6 to 58 weight percent HFO-1132E, from about 1 to 22 weight percent HFC-32, and from about 42 to 72 weight percent HFO-1234zeE. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of from about 6 to 42 weight percent HFO-1132E, from about 2 to 22 weight percent HFC-32, and from about 47 to 72 weight percent HFO-1234zeE. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of from about 8 to 60 weight percent HFO-1132E, from about 1 to 22 weight percent HFC-32, and from about 40 to 70 weight percent HFO-1234zeE. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of from about 8 to 42 weight percent HFO-1132E, from about 3 to 22 weight percent HFC-32, and from about 46 to 70 weight percent HFO-1234zeE. In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of from about 29 to 30 weight percent HFO-1132E, from about 20 to 24 weight percent HFC-32, and from about 47 to 50 weight percent HFO-1234zeE.

[0069] In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 0.5 to about 98.5 wt-% HFO-1132E, about 0.5 to about 98.5 wt-% HFO-1234zeE, and about 0.5 to about 26 wt-% HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 0.5 to about 98.5 wt-% of HFO-1132E, about 0.5 to about 98.5 wt-% HFO-1234zeE, and about 0.5 to about 13 wt-% HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 0.5 to about 98.5 wt-% of HFO-1132E, about 0.5 to about 98.5 wt-% HFO-1234zeE, and about 0.5 to about 26 wt-% HFC-134. In another embodiment, disclosed herein are compositions, comprising,

consisting, or consisting essentially of about 0.5 to about 98.5 wt-% of HFO-1132E, about 0.5 to about 98.5 wt-% HFO-1234zeE, and about 0.5 to about 13 wt-% HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 39 to about 98.5 wt-% of HFO-1132E, about 0.5 to about 60 wt-% of HFO-1234zeE, and about 0.5 to about 13 of HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 41 to about 98.5 wt-% of HFO-1132E, about 0.5 to about 57 of HFO-1234zeE, and about 0.5 to about 13 wt-% HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 39 to about 47 wt-% HFO-1132E, about 40 to about 54 wt-% HFO-1234zeE, and about 6 to about 13 wt-% HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 47 wt-% HFO-1132E, about 40 wt-% HFO-1234zeE and about 13 wt-% HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 41 to about 47 wt-% HFO-1132E, about 40 to about 50 wt-% HFO-1234zeE, and about 8 to about 13 wt-% HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 47 wt-% HFO-1132E, about 40 wt-% HFO-1234zeE and about 13 wt-% HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 39 wt-% HFO-1132E, about 49 wt-% HFO-1234zeE and about 12 wt-% HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 47 wt-% HFO-1132E, about 40 wt-% HFO-1234zeE and about 13 wt-% HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 41 wt-% HFO-1132E, about 50 wt-% HFO-1234zeE and about 9 wt-% HFC-134. In another embodiment, disclosed herein are compositions, comprising, consisting, or consisting essentially of about 47 wt-% HFO-1132E, about 40 wt-% HFO-1234zeE and about 13 wt-% HFC-134.

[0070] In another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 8 to 59 weight percent HFO-1132E, about 1 to about 22 weight percent HFC-32, about 1 to about 13 weight percent HFC-134, and about 30 to about 61 weight percent HFO-1234zeE. According to

another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 8 to 47 weight percent HFO-1132E, about 1 to about 22 weight percent HFC-32, about 1 to about 13 weight percent HFC-134, and about 37 to about 71 weight percent HFO-1234zeE. According to another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of 0.25 to about 98.5 wt-% of HFO-1132E, 0.25 to about 98.5 wt-% of HFO-1234zeE, 0.25 to about 26 wt-% HFC-134, and 0.25 to about 44 wt-% HFC-32. According to another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of 0.25 to about 98.5 wt-% of HFO-1132E, 0.25 to about 98.5 wt-% of HFO-1234zeE, 0.25 to about 13 wt-% HFC-134, and 0.25 to about 21 wt-% HFC-32. According to another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of 0.25 to about 98.5 wt-% of HFO-1132E, 0.25 to about 98.5 wt-% of HFO-1234zeE, 0.25 to about 26 wt-% HFC-134, and 0.25 to about 44 wt-% HFC-32. According to another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of 0.25 to about 98.5 wt-% of HFO-1132E, 0.25 to about 98.5 wt-% of HFO-1234zeE, 0.25 to about 13 wt-% HFC-134, and 0.25 to about 21 wt-% HFC-32. According to another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 7 to about 98.5 wt-% of HFO-1132E, 0.25 to about 72 wt-% of HFO-1234zeE, 0.25 to about 13 wt-% of HFC-134, and 0.25 to about 21 wt-% of HFC-32. According to another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 10 to about 98.5 wt-% of HFO-1132E, 0.25 to about 69 wt-% of HFO-1234zeE, 0.25 to about 13 wt-% of HFC-134, and 0.25 to about 21 wt-% HFC-32. According to another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 7 to about 48 wt-% HFO-1132E, about 36 to about 72 wt-% HFO-1234zeE, about 0.5 to about 13 wt-% HFC-134, and about 0.5 to about 21 wt-% HFC-32. According to another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 41.8 wt-% HFO-1132E, about 45.8 wt-% HFO-1234zeE, about 0.5 wt-% HFC-134 and about 11.9 wt-% HFC-32. According to another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 7.0 wt-% HFO-1132E, about 71.6 wt-% HFO-1234zeE, about 0.5 wt-% HFC-134 and about 20.9 wt-% HFC-32. According to

another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 10 to about 48 wt-% HFO-1132E, about 36 to about 69 wt-% HFO-1234zeE, about 0.5 to about 13 wt-% HFC-134, and about 0.5 to about 21 wt-% HFC-32. According to another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 40 wt-% HFO-1132E, about 42 wt-% HFO-1234zeE, about 4 wt-% HFC-134 and about 14 wt-% HFC-32. According to another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of about 10.9 wt-% HFO-1132E, about 68.7 wt-% HFO-1234zeE, about 0.5 wt-% HFC-134 and about 19.9 wt-% HFC-32.

[0071] According to another embodiment, also disclosed herein are compositions comprising about 30 weight percent HFO-1132E, about 21 weight percent HFC-32, and about 49 weight percent HFO-1234zeE.

[0072] According to another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of from about 1 to 79 weight percent HFO-1132Z, from about 19 to 44 weight percent HFC-32, and from about 1 to 81 weight percent HFO-1234zeE. According to another embodiment, the compositions comprise, consist of, or consist essentially of from about 1 to 49 weight percent HFO-1132Z, from about 19 to 22 weight percent HFC-32, and from about 29 to 81 weight percent HFO-1234zeE. According to another embodiment, the compositions comprise, consist of, or consist essentially of from about 1 to 51 weight percent HFO-1132Z, from about 21 to 22 weight percent HFC-32, and from about 27 to 79 weight percent HFO-1234zeE.

[0073] According to another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of from about 1 to 97 weight percent HFO-1132Z, from about 1 to 97 weight percent HFO-1132E, from about 1 to 97 weight percent HFO-1234zeE, and from about 1 to 44 weight percent HFC-32. According to another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of from about 1 to 97 weight percent HFO-1132Z, from about 1 to 97 weight percent HFO-1132E, from about 1 to 97 weight percent HFO-1234zeE, and from about 1 to 22 weight percent HFC-32. According to another embodiment, also disclosed herein are compositions

comprising, consisting of, or consisting essentially of from about 1 to 66 weight percent HFO-1132Z, from about 6 to 64 weight percent HFO-1132E, from about 1 to 72 weight percent HFO-1234zeE, and from about 1 to 22 weight percent HFC-32.

According to another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of from about 1 to 63 weight percent HFO-1132Z, from about 8 to 65 weight percent HFO-1132E, from about 1 to 69 weight percent HFO-1234zeE, and from about 1 to 22 weight percent HFC-32.

According to another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of from about 1 to 37 weight percent HFO-1132Z, from about 8 to 42 weight percent HFO-1132E, from about 26 to 69 weight percent HFO-1234zeE, and from about 3 to 22 weight percent HFC-32.

[0074] According to another embodiment, also disclosed herein are compositions comprising, consisting of, or consisting essentially of:

about 30 weight percent HFO-1132E, about 21 weight percent HFC-32, and about 49 weight percent HFO-1234zeE; or

about 6 weight percent HFO-1132E, about 22 weight percent HFC-32, and about 72 weight percent HFO-1234zeE; or

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

about 45 weight percent HFO-1132E, about 10 weight percent HFC-32, and about 45 weight percent HFO-1234zeE; or

about 53 weight percent HFO-1132E, about 4 weight percent HFC-32, and about 43 weight percent HFO-1234zeE; or

about 30 weight percent HFO-1132Z, about 21 weight percent HFC-32, and about 49 weight percent HFO-1234zeE; or

about 1 weight percent HFO-1132Z, about 22 weight percent HFC-32, and about 77 weight percent HFO-1234zeE; or

about 10 weight percent HFO-1132Z, about 34 weight percent HFO-1132E, about 37 weight percent HFO-1234zeE, and about 19 weight percent HFC-32;
or

about 10 weight percent HFO-1132Z, about 34 weight percent HFO-1132E, about 37 weight percent HFO-1234zeE, and about 19 weight percent HFC-32.

[0075] 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.

[0076] In order for a refrigerant to be classified by ANSI/ASHRAE as low flammability (class 2L), it must: 1) exhibit flame propagation when tested at 140°F (60°C) and 14.7 psia (101.3 kPa); 2) have an LFL >0.0062 lb/ft³ (0.10 kg/m³); 3) have a heat of combustion <8169 Btu/lb (19,000 kJ/kg); and 4) have a maximum burning velocity of ≤3.9 in./s (10 cm/s) when tested at 73.4°F (23.0°C) and 14.7 psia (101.3 kPa) in dry air.

[0077] In order for a refrigerant to be classified by ANSI/ASHRAE as flammable (class 2), it must: 1) exhibit flame propagation when tested at 140°F (60°C) and 14.7 psia (101.3 kPa); 2) have an LFL >0.0062 lb/ft³ (0.10 kg/m³); and 3) have a heat of combustion <8169 Btu/lb (19,000 kJ/kg).

[0078] 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.

[0079] The above-disclosed compositions can provide estimated 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 air conditioning and heat pump systems. Specific applications may have different requirements, with regards to flammability.

[0080] Any one or more of the above-disclosed compositions may further comprise at least one additional compound selected from the group consisting of methane, ethane, HCFC-22 (dichlorodifluoromethane), HFC-23 (trifluoromethane), HCC-30 (dichloromethane), HCFC-31 (chlorofluoromethane), HCC-40 (chloromethane), HFC-41 (fluoromethane), HFO-1141 (fluoroethylene), HFO-1225yeE (E-1,2,3,3,3-pentafluoropropene), HFO-1225yeZ (Z-1,2,3,3,3-pentafluoropropene), HFO-1234yf (2,3,3,3-tetrafluoropropene), HFO-1243zf (3,3,3-trifluoropropene), HFC-161 (fluoroethane), HFC-152 (1,2-difluoroethane), HFC-143 (1,1,2-trifluoroethane), HFC-143a (1,1,1-trifluoroethane), HCFO-1122 (2-chloro-1,1-difluoroethene), HCFO-1122aE (E-1-chloro-1,2-difluoroethylene), HCFO-1122aZ (Z-1-chloro-1,2-difluoroethylene), HCC-150 (1,2-dichloroethane), HCFC-151 (1-chloro-2-fluoroethane), CFO-1112E (E-1,2-dichloro-1,2-difluoroethylene), CFO-1112Z (Z-1,2-dichloro-1,2-difluoroethylene), HCFC-142a (1-chloro-1,2-difluoroethane), HCFC-132 (1,2-dichloro-1,2-difluoroethane), HCFC-133 (1-chloro-1,1,2-trifluoroethane), HCFC-133b (2-chloro-1,1,1-trifluoroethane), HCFC-123 (1,1-dichloro-2,2,2-trifluoroethane), HFC-236fa (1,1,1,3,3,3-hexafluoropropane), HFC-245fa (1,1,1,3,3-pentafluoropropane), HFC-245eb (1,1,1,2,3-pentafluoropropane), HFO-1123 (trifluoroethylene), HFO-1132a (1,1-difluoroethylene), HCFO-1131E (E-1-chloro-2-fluoroethylene), HCFO-1131Z (Z-1-chloro-2-fluoroethylene), ethylene, and acetylene.

[0081] Any one or more of the above-disclosed compositions may further comprise at least one additional compound selected from HCFC-22, HCC-40, HFO-1234yf, HFO-1243zf, HFO-1132a, and HFO-1252ye. Any one or more of the above-disclosed compositions may further comprise at least one additional compound selected from HCFC-22, HCC-40, HFO-1234yf, HFO-1243zf, HFO-1132a, and HFO-1252ye. Any one or more of the above-disclosed compositions may further comprise at least one additional compound comprising HFO-1234yf. Any one or more of the above-disclosed compositions may further comprise at least one additional compound comprising HFO-1234yf. Any one or more of the above-disclosed compositions may further comprise at least one additional compound comprising HFO-1243zf. Any one or more of the above-disclosed compositions may further comprise at least one additional compound comprising HCFC-142a. Any one or more of the above-disclosed compositions may further comprise at least one additional compound comprising HCFC-22 or HCC-40.

[0082] Any one or more of the above-disclosed compositions, the amount of additional compounds present in any of the foregoing refrigerant compositions can be greater than 0 ppm and less than 5,000 ppm and, in particular, can range from greater than zero to about 1,000 ppm, about 5 to about 500 ppm and about 1 to about 100 ppm.

[0083] Any one or more of the above-disclosed compositions, the amount of additional compounds present in any of the foregoing refrigerant compositions can be greater than 0 and less than 1 weight percent of the refrigerant composition, preferably less than 0.5 weight percent, or more preferably less than 0.1 weight percent.

[0084] Any one or more of the above-disclosed compositions will perform more consistently and be more stable with only minor amounts of water present. Thus, the compositions may further comprise less than 100 ppm (by weight) water, preferably less than 20 ppm (by weight) water, and even more preferably less than 10 ppm (by weight) water.

[0085] Additionally, the above-disclosed compositions will perform more consistently and be more stable with only minor amounts of oxygen or air present. Therefore, any one or more of the above-disclosed compositions may further comprise less than about 5 volume percent non-adsorbable gases (NAG), preferably less than 3 volume percent NAG, and more preferably less than 1.5 volume percent NAG. Further, any one or more of the above-disclosed compositions, due to the presence of air or NAG, may 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.

[0086] Any one or more of the above-disclosed compositions may contain a stabilizer. Such stabilizer compounds are intended to be present in a small amount and prevent decomposition due to the presence of water, air, NAG, or oxygen in a system while in use or while the composition is stored. HFO type refrigerants, due to the presence of a double bond, may be subject to thermal instability and decompose under extreme use, handling or storage situations also. Therefore, there may be advantages to adding stabilizers to HFO type refrigerants. Stabilizers may notably include nitromethane, ascorbic acid, terephthalic acid, azoles such as tolutriazole or

benzotriazole, phenolic compounds such as tocopherol, hydroquinone, t-butyl hydroquinone, 2,6-di-tertbutyl-4-methylphenol, epoxides (possibly fluorinated or perfluorinated alkyl epoxides or alkenyl or aromatic epoxides) such as n-butyl glycidyl ether, hexanediol diglycidyl ether, allyl glycidyl ether, butylphenylglycidyl ether, cyclic monoterpenes, terpenes, such as d-limonene, α -terpinene, β -terpinene, γ -terpinene, α -pinene, or β -pinene, phosphites, phosphates, phosphonates, thiols and lactones. Examples of suitable stabilizers are disclosed in WO2019213004, WO2020222864, and WO2020222865; the disclosures of which are hereby incorporated by reference.

[0087] If one of the above-described compositions does include a stabilizer, it may include any amount from 0.001 weight percent up to 1 weight percent, 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.

[0088] Any one or more of the above-disclosed compositions may contain a tracer compound or tracers. The tracer may comprise two or more tracer compounds. In some embodiments, the tracer is present in the compositions at a total concentration of about 50 parts per million by weight (ppm) to about 1000 ppm, based on the weight of the total composition. In other embodiments, the tracer is present at a total concentration of about 50 ppm to about 500 ppm. Alternatively, the tracer is present at a total concentration of about 100 ppm to about 300 ppm.

[0089] 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.

[0090] 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.

[0091] Any one or more of the above-disclosed compositions may further comprise at least one lubricant. Lubricants may be selected from polyol ester (POE), polyvinyl ether (PVE), poly- α -olefin (PAO), and polyalkylene glycol (PAG). Any one or more of the above-disclosed compositions may further comprise at least one lubricant selected from polyol ester (POE) or polyvinyl ether (PVE).

[0092] Lubricants may also comprise those commonly known as “mineral oils” in the field of compression refrigeration lubrication. Mineral oils comprise paraffins (i.e. straight-chain and branched-carbon-chain, saturated hydrocarbons), naphthenes (i.e. cyclic or ring structure saturated hydrocarbons, which may be paraffins) and aromatics (i.e. unsaturated, cyclic hydrocarbons containing one or more rings characterized by alternating double bonds). Lubricants of the present invention further comprise those commonly known as “synthetic oils” in the field of compression refrigeration lubrication. Synthetic oils comprise alkylaryls (i.e. linear and branched alkyl alkylbenzenes), synthetic paraffins and naphthenes, silicones, and polyalphaolefins. Representative conventional lubricants of the present invention are the commercially available BVM 100 N (paraffinic mineral oil sold by BVA Oils), naphthenic mineral oil commercially available under the trademark from Suniso® 3GS and Suniso® 5GS by Crompton Co., naphthenic mineral oil commercially available from Pennzoil under the trademark Sontex® 372LT, naphthenic mineral oil commercially available from Calumet Lubricants under the trademark Calumet® RO-30, linear alkylbenzenes commercially available from Shrieve Chemicals under the trademarks Zerol® 75, Zerol® 150 and Zerol® 500 and branched alkylbenzene, sold by Nippon Oil as HAB 22.

[0093] 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.

[0094] In one particular embodiment, any one or more of the above-disclosed compositions may further comprises a poly- α -olefin combined with a PAG lubricant or a PVE lubricant or a POE lubricant for usage in an air-conditioning system or heat pump system.

[0095] If one of the above-disclosed compositions that includes a lubricant, the lubricant may be present in an amount of less than 80 weight percent of the total composition. The lubricant may further be present in an amount of less than 60

weight percent of the total composition. In other embodiments, the amount of lubricant may be between about 0.1 and 50 weight percent of the total composition. The lubricant may also be between about 0.1 and 20 weight percent of the total composition. The lubricant may also be between about 0.1 and 5 weight percent of the total composition.

[0096] In another aspect of the invention, any one or more of the above-disclosed compositions 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.

[0097] Examples of the acid scavengers that may be included in any one or more of the above-disclosed compositions include, but are not limited to, 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.

[0098] 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.

[0099] 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.

[0100] 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.

[0101] 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).

[0102] Acid number is measured according to ASTM D664-01 in units of mg KOH/g. The total halides concentration, the fluoride 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.

[0103] Mouli et al. (WO 2008/027595 and WO 2009/042847) teach the use of alkyl silanes as a stabilizer in refrigerant compositions containing fluoroolefins. Phosphates, phosphites, epoxides, and phenolic additives also have been employed in certain refrigerant compositions. These are described for example by Kaneko (U.S. patent application Ser. No. 11/575,256, published as U.S. Publication 2007/0290164) and Singh et al. (U.S. patent application Ser. No. 11/250,219, published as U.S. Publication 2006/0116310). All of these aforementioned applications are expressly incorporated herein by reference.

[0104] Preferred flame suppressants include the flame retardants described in patent application "Refrigerant compositions containing fluorine substituted olefins CA 2557873 A1" and incorporated by reference, as well as fluorinated products such as HFC-125, HFC-227ea, HFC-236fa, CF₃I, and/or Krytox[®] lubricants, also incorporated by reference and described in patent application "Refrigerant compositions comprising fluoroolefins and uses thereof WO2009018117A1."

[0105] In one embodiment, as used herein, "Group A Fluorinated Substances" includes any substance that (i) contains at least one fully fluorinated methyl ($-\text{CF}_3$) or methylene ($-\text{CF}_2-$) carbon atom (without any H/Cl/Br/I attached to it); and (ii) meets the criterion for persistence in soil/sediment and water established in Annex XIII (Section 1.1.1) of the European Union's REACH Regulation (<https://reachonline.eu/reach/en/annex-xiii-1-1.1-1.1.1.html> as accessed on May 2, 2023) and referenced in the Annex XV Restriction Report dated March 22, 2023, the disclosure of which is hereby incorporated by reference (<https://echa.europa.eu/documents/10162/f605d4b5-7c17-7414-8823-b49b9fd43aea> as accessed on May 2, 2023). In one embodiment, Group A Fluorinated Substances include, but are not limited to, trifluoroacetic acid (TFA).

[0106] In another embodiment, as used herein, "Group A Fluorinated Substances" includes any substance that has a Henry's Law constant $\leq 250 \text{ Pa}\cdot\text{m}^3/\text{mol}$ and contains at least one fully fluorinated methyl ($-\text{CF}_3$) or methylene ($-\text{CF}_2-$) carbon atom (without any H/Cl/Br/I attached to it). In one embodiment, Group A Fluorinated Substances include, but are not limited to, TFA.

[0107] Thus, according to some embodiments, any one or more of the above-disclosed compositions are free of or substantially free of Group A Fluorinated Substances, such as TFA. In one embodiment, the phrase "free of" as used herein with respect to the presence of Group A Fluorinated Substances in the present compositions means that the amount of such substances in the compositions is sufficiently low so as to not be detectable, including but not limited to 0%, when measured by gas chromatography with a flame ionization detector, gas chromatography with a mass detector by analysis of a gas sample or liquid sample, and/or ion chromatography by analysis of a water sample after bubbling the thermal fluid through water. Such methodologies are well known to those skilled in the art. In one embodiment, the phrase "substantially free of" as used herein with respect to the presence of Group A Fluorinated Substances in the present compositions means that the amount of such substances in the compositions is $> 0 \text{ wt.}\%$ and $\leq 5 \text{ wt.}\%$, or $> 0 \text{ wt.}\%$ and $\leq 4 \text{ wt.}\%$, or $> 0 \text{ wt.}\%$ and $\leq 3 \text{ wt.}\%$, or $> 0 \text{ wt.}\%$ and $\leq 2 \text{ wt.}\%$, or $> 0 \text{ wt.}\%$ and $\leq 1 \text{ wt.}\%$, and all values and ranges therebetween, when measured by gas chromatographic (GC) techniques, for example gas chromatography (GC) with a flame ionization or electron-capture detector, or GC coupled with a mass detector

(gas chromatography/mass spectral (GC/MS) method), by ion chromatograph(IC) or ion chromatography mass spectrometry (IC-MS) techniques, or by high-performance liquid chromatography (HPLC) or high-performance liquid chromatography mass spectrometry (HPLC-MS) techniques. The TFA analytical standard may be used in either gas chromatography or ion chromatography and is available from, for example, Sigma Aldrich.

[0108] Further, in some embodiments, for any one or more of the above-disclosed compositions, degradation products from the HFO-1132E, HFO-1132Z, HFC-32, HFC-134, and/or HFO-1234zeE 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

[0109] The compositions comprising, consisting of, or consisting essentially of HFO-1132 and at least one compound selected from the group consisting of HFC-32, HFC-134, and HFO-1234zeE are useful in numerous methods and systems that provide air-conditioning and heating.

[0110] In one embodiment, provided is a method of cooling comprising evaporating one of the above-disclosed compositions in the vicinity of a body to be cooled and thereafter condensing said composition, wherein said cooling is provided by an air-conditioner or heat pump.

[0111] 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.

[0112] 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-1132 and at least one compound selected from the group consisting of HFC-32, HFC-134, and HFO-1234zeE.

[0113] In another embodiment, the method for producing cooling is particularly useful in regions where the ambient temperature can exceed at least 35°C.

[0114] 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 HFC-321 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 HFC-321. 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.

[0115] In another embodiment, a method for producing air conditioning in high ambient temperatures is provided. The method comprises evaporating one of the above-disclosed compositions and thereafter condensing said composition. The method is particularly useful in regions where ambient temperatures can exceed 35°C or more.

[0116] In another embodiment, a method is provided for replacing HCFC-22 in high ambient air conditioning apparatus comprising providing one of the above-disclosed compositions to said apparatus. The method of replacing HCFC-22 is particularly useful in regions where ambient temperatures can exceed 35°C or more.

[0117] 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-1132 and at least one compound selected from the group consisting of HFC-32, HFC-134, and HFO-1234zeE to said apparatus. The method of replacing HCFC-124 is particularly useful in regions where ambient temperatures can exceed 35°C or more.

[0118] In another embodiment, the method for producing cooling and method for replacing HCFC-22 or HCFC-124 are useful for systems operating in ambient temperatures of 40°C or higher. In another embodiment, the method for producing cooling is useful for systems operating in ambient temperatures of 45°C or higher. In another embodiment, the method for producing cooling is useful for systems operating in ambient temperatures of 50°C or higher. In another embodiment, the method for producing cooling is useful for systems operating in ambient temperatures of 55°C or higher. In another embodiment, the method for producing cooling is useful for systems operating in ambient temperatures of 60°C or higher. In

another embodiment, the method for producing cooling is useful for systems operating in ambient temperatures from 35-50°C. In another embodiment, the method for producing cooling is useful for systems operating in ambient temperatures from 35-60°C. In another embodiment, the method for producing cooling is useful for systems operating in ambient temperatures from 40- 60°C. In another embodiment, the method for producing cooling is useful for systems operating in ambient temperatures from 45-60°C. In another embodiment, the method for producing cooling is useful for systems operating in ambient temperatures from 50-60°C.

[0119] In another embodiment, provided is a method of heating comprising evaporating one of the above-disclosed compositions and thereafter condensing said composition in the vicinity of a body to be heated, wherein said heating is provided by a heat pump. In another embodiment, provided is a method of heating comprising evaporating one of the above-disclosed compositions and thereafter condensing said composition in the vicinity of a body to be heated, wherein said heating is provided by a heat pump.

[0120] 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-1132 and at least one compound selected from the group consisting of HFC-32, HFC-134, and HFO-1234zeE, it is possible to heat water to higher temperatures than propane or R-454C.

[0121] In another embodiment, is provided a system for cooling or heating comprising one of the above-disclosed compositions and an evaporator, compressor, condenser, and expansion device, each operably connected to perform a vapor compression cycle.

[0122] In another embodiment, one of the above-disclosed compositions contained within the system, may further comprise a lubricant. The lubricant for inclusion in the system may be a PAG, POE, or PVE lubricant.

[0123] 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.

[0124] In one embodiment, the air conditioner may be a residential, commercial, or industrial air-conditioning system. These may include, but are not limited to, window, ducted, ductless, packaged terminal, and those exterior to, but connected to the building, such as rooftop systems. These may also include, residential heat pumps that provide comfort air-conditioning and heating.

[0125] In one embodiment, the system is a heat pump, which may be 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 (with condensing temperature of 50 °C or higher).

[0126] In another embodiment, the system containing the above-disclosed composition may be an automobile heat pump for cooling and heating the passenger compartment of an electric or hybrid vehicle. Electric or hybrid vehicles include automobiles with no internal combustion engine (ICE) or those that maintain an ICE but also use electric power and are therefore hybrid electric vehicles (HEV) or plug-in hybrid electric vehicles (PHEV) or mild hybrid electric vehicles (MHEV). Additionally, electric or hybrid vehicles include full electric vehicles (EV), such as battery electric vehicles (BEV). All of these electric or hybrid vehicles use at least one electric motor, wherein the electric motor provides some form of propulsion for the vehicles normally provided by the ICE found in gasoline/diesel powered vehicles.

[0127] In one embodiment, the automobile heat pump is a secondary loop system. The secondary loop allows the separation of a flammable refrigerant from the passenger compartment, using a heat transfer fluid to provide cooling or heating to the passenger compartment.

[0128] For secondary loop systems, high efficiency in heat transfer can be achieved by the use of non-azeotropic refrigerant and the use of countercurrent flow heat exchanger, if the temperature profile of the refrigerant can be matched to that of

the heat transfer fluid. If the difference in temperature throughout the heat exchanger can be held constant, then the efficiency of heat exchange can be optimized. Therefore, in another embodiment, disclosed herein is a method of improving heat transfer comprising matching the temperature profile of the refrigerant comprising, consisting of, or consisting essentially of HFO-1132 and at least one compound selected from the group consisting of HFC-32, HFC-134, and HFO-1234zeE to the temperature profile of the heat transfer fluid in a secondary loop system.

[0129] In another embodiment, the automobile heat pump does not include a positive temperature coefficient (PTC) heater. The PTC heater often used in electric vehicles is needed in the absence of an ICE to provide adequate heating to the passenger compartment.

[0130] The following Example are provided to illustrate certain aspects of the invention and shall not limit the scope of the appended claims.

EXAMPLES

[0131] In the examples to follow, the conditions for Residential heat pumps in cooling and heating mode are 7°C and 47 °C as the average evaporator and condenser temperatures, 3 K of superheat and 12 K of subcooling and -5 °C and 35 °C as the average evaporator and condenser temperatures, 10 K of superheat and 0 K of subcooling respectively.

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

[0132] Broadly, a composition range of 0.5 to 98.5 wt-% of HFO-1132E, 0.5 to 98.5 wt-% HFO-1234zeE, and 0.5 to 44 wt-% HFC-321 will have a GWP less than 300, a maximum average glide of about 10.3 K, a cooling capacity range that is 48% less and 65% greater than the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range is 4% less and 4% greater than the cooling COP of R-454C evaluated with the same conditions set. Similarly, a composition range of 0.5 to 98.5 wt-% of HFO-1132E, 0.5 to 98.5 wt-% HFO-1234zeE, and 0.5 to 22 wt-% HFC-321 will have a GWP less than 150, a maximum average glide of about 10.3 K, a cooling capacity range that is 48% less and 60%

greater than the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range is 4% less and 4% greater than the cooling COP of R-454C evaluated with the same conditions set. Table X1 lists example compositions within the GWP<300 range that have ASHRAE flammability classifications of 2L or 2.

[0133] Broadly, for heating mode a composition range of 0.5 to 98.5 wt-% of HFO-1132E, 0.5 to 98.5 wt-% HFO-1234zeE, and 0.5 to 44 wt-% HFC-321 will have a GWP less than 300, a maximum average glide of about 10.9 K, a heating capacity range that is 51% less and 68% greater than the heating capacity of R-454C evaluated with the same conditions set, and the cooling COP range is 3% less and 2% greater than the heating COP of R-454C evaluated with the same conditions set. Similarly, a composition range of 0.5 to 98.5 wt-% of HFO-1132E, 0.5 to 98.5 wt-% HFO-1234zeE, and 0.5 to 22 wt-% HFC-321 will have a GWP less than 150, a maximum average glide of about 10.9 K, a heating capacity range that is 51% less and 63% greater than the heating capacity of R-454C evaluated with the same conditions set, and the heating COP range is 3% less and 2% greater than the heating COP of R-454C evaluated with the same conditions set. Table X1b lists example compositions within the GWP<300 range that have ASHRAE flammability classifications of 2L or 2.

[0134] Preferred blend composition ranges for cooling within a composition range of 6 to 98.5 wt-% of HFO-1132E, 0.5 to 72 wt-% of HFO-1234zeE, and 0.5 to 22 wt-% of HFC-321 will have a GWP < 150, a maximum average heat exchanger glide of 10.3 K, an ASHRAE flammability classification of 2L or 2, and a minimum cooling capacity of 10% less than that of R-454C evaluated at the same conditions set.

[0135] Preferred blend composition ranges for heating within a composition range of 8 to 98.5 wt-% of HFO-1132E, 0.5 to 70 of HFO-1234zeE, and 0.5 to 22 wt-% HFC-321 will have a GWP < 150, a maximum average heat exchanger glide of 11 K, an ASHRAE flammability classification of 2L or 2, and a minimum heating capacity of 10% less than that of R-454C at the same conditions.

[0136] Even more preferred composition ranges for cooling mode that result in ASHRAE flammability classifications of 2L are 6 to 42 wt-% HFO-1132E, 47 to 72 wt-% HFO-1234zeE, and 3 to 22 wt-% HFC-321, where the minimum and maximum cooling capacities are 10% less and 10% greater than those of R-454C respectively.

The composition for this maximum cooling capacity for a 2L blend is 27 wt-% HFO-1132E, 51 wt-% HFO-1234zeE and 22 wt-% HFC-321, where the COP for cooling is about the same as that for R-454C under the same cycle conditions.

[0137] Even more preferred composition ranges for heating mode that result in ASHRAE flammability classifications of 2L are 8 to 42 wt-% HFO-1132E, 46 to 70 wt-% HFO-1234zeE, and 4 to 22 wt-% HFC-321, where the minimum and maximum heating capacities are 10% less and 10% greater than those of R-454C respectively. The composition for this maximum heating capacity for a 2L blend is 40 wt-% HFO-1132E, 46 wt-% HFO-1234zeE and 14 wt-% HFC-321, where the COP for heating is about the same as that for R-454C under the same cycle conditions.

[0138] The optimal composition for cooling efficiency, which is 3% greater than the COP of incumbent fluid R-454C evaluated at the same conditions, is 7 wt-% HFO-1132E, 72 wt-% HFO-1234zeE and 21 wt-% HFC-321, where the CAP for cooling is 10% less than that for the CAP of R-454C, the average glide is about 10.3 K, the GWP is 143, and the flammability class is 2L. The optimal composition for cooling capacity, which is 10% greater than for R-454C under the same conditions, is 27 wt-% HFO-1132E, 51 wt-% HFO-1234zeE, and 22 wt-% HFC-321, where the COP for cooling is the same as the COP of R-454C for cooling, the average glide is about 9.1 K, the GWP is 149, and the flammability class is 2L.

[0139] The optimal composition for heating efficiency, which is 1% greater than the COP of incumbent fluid R-454C in the same conditions, is 8 wt-% HFO-1132E, 70 wt-% HFO-1234zeE and 22 wt-% HFC-321, where the heating capacity is 10% less than that for R-454C, the average glide is about 11 K, the GWP is <150, and the flammability class is 2L. The optimal composition for heating capacity, which is 10% greater than the heating capacity of incumbent fluid R-454C in the same conditions, is 40 wt-% HFO-1132E, 46 wt-% HFO-1234zeE, and 14 wt-% HFC-321, where the COP for heating is the same as that for the COP of R-454C for heating, the average glide is 9 K, the GWP is 95, and the flammability class is 2L.

Table X1a: Residential Heat Pump conditions in cooling mode, cycle metric performance and fluid property ranges for HFO-1132E/HFO-1234zeE/HFC-321 in Example 1.

wt-frac R1132(E)	wt-frac R1234ze (E)	wt-frac HFC-321	GWP AR5	ASHRAE flammability class	Glide (K)	COP _c (% dev from R- 454C)	CAP _c (% dev from R- 454C)
0.01	0.55	0.44	298	2L	8.3	0	12
0.985	0.005	0.01	7	2	0.2	-3	50
0.005	0.716	0.279	189	2L	10.2	3	-7
0.01	0.985	0.005	4	2L	1.1	4	-48
0.766	0.005	0.229	155	2	0.2	-4	60
0.18	0.38	0.44	298	2L	6.4	-1	28
0.587	0.408	0.005	4	2	7.3	0	9
0.557	0.005	0.438	296	2L	0.1	-4	65
0.005	0.866	0.129	88	2L	8.6	4	-27
0.005	0.886	0.109	75	2L	7.9	4	-30
0.005	0.876	0.119	82	2L	8.3	4	-29
0.577	0.005	0.418	283	2L	0.1	-4	64
0.587	0.005	0.408	276	2L	0.1	-4	64
0.59	0.01	0.4	271	2L	0.2	-4	64
0.6	0.01	0.39	264	2L	0.2	-4	63
0.597	0.005	0.398	269	2L	0.1	-4	64
0.607	0.005	0.388	263	2	0.1	-4	64
0.61	0.01	0.38	257	2	0.2	-4	63
0.62	0.01	0.37	251	2	0.3	-4	63
0.617	0.005	0.378	256	2	0.1	-4	64
0.627	0.005	0.368	249	2	0.1	-4	64
0.63	0.01	0.36	244	2	0.3	-4	63
0.637	0.005	0.358	243	2	0.1	-4	63
0.64	0.01	0.35	237	2	0.3	-4	63
0.647	0.005	0.348	236	2	0.1	-4	63
0.65	0.01	0.34	230	2	0.3	-4	62
0.657	0.005	0.338	229	2	0.2	-4	63

wt-frac R1132(E)	wt-frac R1234ze (E)	wt-frac HFC-321	GWP AR5	ASHRAE flammab ility class	Glide (K)	COP_c (% dev from R- 454C)	CAP_c (% dev from R- 454C)
0.66	0.01	0.33	223	2	0.3	-4	62
0.667	0.005	0.328	222	2	0.2	-4	63
0.67	0.01	0.32	217	2	0.3	-4	62
0.677	0.005	0.318	216	2	0.2	-4	62
0.03	0.73	0.24	163	2L	10.3	3	-9
0.01	0.77	0.22	150	2L	10.2	3	-14
0.005	0.945	0.05	35	2L	4.7	4	-40
0.005	0.985	0.01	8	2L	1.3	4	-47
0.866	0.005	0.129	88	2	0.3	-3	56
0.1	0.68	0.22	150	2L	10.2	2	-6
0.219	0.776	0.005	4	2L	7	3	-26
0.776	0.005	0.219	148	2	0.2	-4	60
0.76	0.02	0.22	149	2	0.7	-4	58
0.77	0.01	0.22	149	2	0.4	-4	59
0.05	0.73	0.22	150	2L	10.3	3	-10
0.06	0.72	0.22	150	2L	10.3	3	-9
0.945	0.005	0.05	34	2	0.3	-3	52
0.33	0.45	0.22	149	2L	8.5	0	15
0.896	0.1	0.005	3	2	2.6	-3	39
0.08	0.72	0.2	136	2L	10.3	3	-10
0.07	0.72	0.21	143	2L	10.3	3	-10
0.42	0.47	0.11	75	2L	8.6	0	9
0.22	0.56	0.22	150	2L	9.5	1	5
0.35	0.62	0.03	21	2L	8.5	2	-10
0.27	0.51	0.22	149	2L	9.1	0	10
0.4	0.47	0.13	88	2L	8.7	0	10
0.005	0.557	0.438	297	2L	8.4	0	11
0.005	0.866	0.129	88	2L	8.6	4	-27
0.005	0.985	0.01	8	2L	1.3	4	-47
0.01	0.55	0.44	298	2L	8.3	0	12

wt-frac R1132(E)	wt-frac R1234ze (E)	wt-frac HFC-321	GWP AR5	ASHRAE flammab ility class	Glide (K)	COP _c (% dev from R- 454C)	CAP _c (% dev from R- 454C)
0.01	0.77	0.22	150	2L	10.2	3	-14
0.01	0.985	0.005	4	2L	1.1	4	-48
0.07	0.72	0.21	143	2L	10.3	3	-10
0.08	0.72	0.2	136	2L	10.3	3	-10
0.27	0.51	0.22	149	2L	9.1	0	10
0.36	0.61	0.03	21	2L	8.5	2	-9
0.4	0.47	0.13	88	2L	8.7	0	10
0.42	0.47	0.11	75	2L	8.6	0	9
0.557	0.005	0.438	296	2L	0.1	-4	65
0.56	0.41	0.03	21	2	7.6	0	10
0.67	0.01	0.32	217	2	0.3	-4	62
0.76	0.02	0.22	149	2	0.7	-4	58
0.776	0.005	0.219	148	2	0.2	-4	60
0.985	0.005	0.01	7	2	0.2	-3	50
0.985	0.01	0.005	3	2	0.3	-3	49
0.005	0.557	0.438	297	2L	8.4	0	11
0.005	0.866	0.129	88	2L	8.6	4	-27

Table X1b: Residential Heat Pump conditions in heating mode, cycle metric performance and fluid property ranges for HFO-1132E/HFO-1234zeE/HFC-321 in Example 1.

wt-frac R1132(E)	wt-frac R1234ze (E)	wt-frac HFC-321	GWP AR5	ASHRAE flammab ility class	Glide (K)	COP _h (% dev from R- 454C)	CAP _h (% dev from R- 454C)
0.01	0.55	0.44	298	2L	8.8	-1	10
0.985	0.005	0.01	7	2	0.2	-2	53
0.005	0.756	0.239	162	2L	10.9	2	-15
0.005	0.985	0.01	8	2L	1.4	2	-50
0.796	0.005	0.199	135	2	0.3	-3	62
0.31	0.25	0.44	298	2L	5	-2	40
0.458	0.537	0.005	4	2	8.6	1	-5

wt-frac R1132(E)	wt-frac R1234ze (E)	wt-frac HFC-321	GWP AR5	ASHRAE flammab ility class	Glide (K)	COP_h (% dev from R- 454C)	CAP_h (% dev from R- 454C)
0.557	0.005	0.438	296	2L	0.1	-3	68
0.01	0.985	0.005	4	2L	1.1	2	-51
0.005	0.876	0.119	82	2L	8.8	2	-32
0.01	0.87	0.12	82	2L	8.9	2	-31
0.005	0.866	0.129	88	2L	9.2	2	-30
0.01	0.86	0.13	89	2L	9.3	2	-30
0.005	0.856	0.139	95	2L	9.5	2	-29
0.01	0.85	0.14	96	2L	9.6	2	-28
0.005	0.846	0.149	102	2L	9.8	2	-27
0.54	0.03	0.43	291	2L	0.7	-3	64
0.53	0.03	0.44	298	2L	0.7	-3	65
0.56	0.02	0.42	284	2L	0.5	-3	66
0.55	0.02	0.43	291	2L	0.5	-3	66
0.54	0.02	0.44	298	2L	0.5	-3	66
0.57	0.01	0.42	284	2L	0.3	-3	67
0.56	0.01	0.43	291	2L	0.2	-3	67
0.55	0.01	0.44	298	2L	0.2	-3	67
0.577	0.005	0.418	283	2L	0.1	-3	67
0.567	0.005	0.428	290	2L	0.1	-3	68
0.05	0.72	0.23	156	2L	10.9	1	-11
0.01	0.77	0.22	150	2L	10.8	2	-17
0.005	0.826	0.169	115	2L	10.2	2	-24
0.856	0.005	0.139	94	2	0.3	-3	60
0.24	0.54	0.22	149	2L	10	0	5
0.766	0.229	0.005	4	2	5.6	-2	26
0.776	0.005	0.219	148	2	0.3	-3	63
0.72	0.06	0.22	149	2	1.9	-3	56
0.73	0.05	0.22	149	2	1.6	-3	57
0.74	0.04	0.22	149	2	1.3	-3	58
0.75	0.03	0.22	149	2	1	-3	60

wt-frac R1132(E)	wt-frac R1234ze (E)	wt-frac HFC-321	GWP AR5	ASHRAE flammab ility class	Glide (K)	COP _h (% dev from R- 454C)	CAP _h (% dev from R- 454C)
0.06	0.72	0.22	150	2L	10.9	1	-12
0.08	0.7	0.22	150	2L	10.9	1	-10
0.955	0.005	0.04	27	2	0.3	-2	55
0.6	0.18	0.22	149	2	4.7	-3	42
0.547	0.448	0.005	4	2	8.2	0	3
0.24	0.65	0.11	75	2L	10.3	1	-10
0.42	0.46	0.12	82	2L	9.2	0	9
0.4	0.46	0.14	95	2L	9.2	0	10
0.37	0.59	0.04	28	2L	9.3	1	-8
0.3	0.49	0.21	143	2L	9.5	0	10
0.005	0.846	0.149	102	2L	9.8	2	-27
0.005	0.985	0.01	8	2L	1.4	2	-50
0.01	0.985	0.005	4	2L	1.1	2	-51
0.01	0.55	0.44	298	2L	8.8	-1	10
0.01	0.77	0.22	150	2L	10.8	2	-17
0.08	0.7	0.22	150	2L	10.9	1	-10
0.24	0.65	0.11	75	2L	10.3	1	-10
0.37	0.59	0.04	28	2L	9.3	1	-8
0.4	0.46	0.14	95	2L	9.2	0	10
0.42	0.46	0.12	82	2L	9.2	0	9
0.54	0.03	0.43	291	2L	0.7	-3	64
0.557	0.005	0.438	296	2L	0.1	-3	68
0.72	0.06	0.22	149	2	1.9	-3	56
0.776	0.005	0.219	148	2	0.3	-3	63
0.985	0.005	0.01	7	2	0.2	-2	53
0.985	0.01	0.005	3	2	0.4	-2	52

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

[0140] Broadly, a composition range of 1 to 98 wt-% of HFO-1132Z, 1 to 98 wt-% HFO-1234zeE, and 1 to 44 wt-% HFC-321 will have a GWP less than 300, a

maximum average glide of 10 K, a cooling capacity range that is 49% less and 11% greater than the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP ranges from the same as to 6% greater than the cooling capacity of R-454C evaluated with the same conditions set. Similarly, a composition range of 1 to 98 wt-% of HFO-1132Z, 1 to 98 wt-% HFO-1234zeE, and 1 to 22 wt-% HFC-321 will have a GWP less than 150, a maximum average glide of about 10 K, a cooling capacity range that is 49% less and 15% less than the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range is 3% greater and 6% greater than the cooling COP of R-454C evaluated with the same conditions set. Table X2 lists example compositions within the GWP<300 range that have ASHRAE flammability classifications of 2L or 2.

[0141] Preferred blend composition ranges for cooling within a composition range of 1 to 79 wt-% of HFO-1132Z, 1 to 81 wt-% of HFO-1234zeE, and 19 to 22 of HFC-321 will have a GWP < 150, a maximum heat exchanger glide of 10.5 K (in the condenser), an ASHRAE flammability classification of 2L or 2, and a minimum cooling capacity of 20% less than that of R-454C evaluated at the same conditions set.

[0142] Preferred blend composition ranges for heating within a composition range of 1 to 51 wt-% of HFO-1132Z, 27 to 78 of HFO-1234zeE, and 21 to 22 wt-% HFC-321 will have a GWP < 150, a maximum heat exchanger glide of 11 K (in the condenser), an ASHRAE flammability classification of 2L or 2, and a minimum heating capacity of 20% less than that of R-454C at the same conditions.

[0143] Even more preferred composition ranges for cooling mode that result in ASHRAE flammability classifications of 2L are 1 to 49 wt-% HFO-1132Z, 29 to 81 wt-% HFO-1234zeE, and 19 to 22 wt-% HFC-321, where the minimum and maximum cooling capacities are 20% to 15% less than those of R-454C respectively at the same cooling cycle condition set. The composition for this maximum cooling capacity for a 2L blend is 1 wt-% HFO-1132Z, 77 wt-% HFO-1234zeE and 22 wt-% HFC-321, where the COP for cooling is 3% greater than that for R-454C under the same cycle conditions.

[0144] Even more preferred composition ranges for heating mode that result in ASHRAE flammability classifications of 2L are 1 to 51 wt-% HFO-1132Z, 27 to 78 wt-

% HFO-1234zeE, and 21 to 22 wt-% HFC-321, where the minimum and maximum heating capacities are 20% to 18% less than those of R-454C respectively under the same heat pump cycle conditions set. The composition for this maximum cooling capacity for a 2L blend is 1 wt-% HFO-1132Z, 77 wt-% HFO-1234zeE and 22 wt-% HFC-321, where the COP for heating is 2% greater than that for R-454C under the same cycle conditions.

Table X2: Residential Heat Pump conditions in cooling mode, cycle metric performance and fluid property ranges for HFO-1132Z/HFO-1234zeE/HFC-321 in Example 2.

wt-frac R1132(Z)	wt-frac R1234ze(E)	wt-frac HFC- 321	GWP AR5	ASHRAE flammabil ity class	Glide (K)	CAP_c (relative to R-454C)	COP_c (relative to R-454C)
0.01	0.99	0.01	4.4	2L	0.55	1.04	0.51
0.02	0.56	0.42	284.9	2L	8.63	1.01	1.09
0.05	0.64	0.31	210.6	2L	9.71	1.02	0.96
0.07	0.54	0.39	264.7	2L	8.85	1.01	1.05
0.12	0.75	0.13	88.9	2L	7.54	1.04	0.73
0.14	0.75	0.11	75.4	2L	6.72	1.04	0.70
0.14	0.60	0.26	176.8	2L	9.20	1.03	0.89
0.15	0.70	0.15	102.5	2L	7.84	1.04	0.76
0.19	0.72	0.09	61.9	2L	5.60	1.04	0.67
0.21	0.43	0.36	244.5	2L	8.54	1.02	1.00
0.22	0.61	0.17	116.0	2L	7.73	1.04	0.78
0.28	0.65	0.07	48.5	2L	4.24	1.05	0.65
0.33	0.48	0.19	129.6	2L	7.32	1.04	0.80
0.41	0.54	0.05	35.0	2	2.83	1.05	0.64
0.43	0.29	0.28	190.5	2L	7.60	1.04	0.90
0.44	0.23	0.33	224.3	2L	7.69	1.03	0.94
0.48	0.31	0.21	143.2	2L	6.77	1.04	0.82
0.58	0.39	0.03	21.6	2	1.54	1.05	0.63
0.67	0.10	0.23	156.8	2	6.19	1.04	0.83
0.79	0.20	0.01	8.2	2	0.46	1.06	0.62

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

[0145] Broadly, a composition range of 1 to 97 wt-% of HFO-1132Z, 1 to 97 wt-% of HFO-1132E, 1 to 97 wt-% HFO-1234zeE, and 1 to 44 wt-% HFC-321 will have a GWP less than 300, a maximum average glide of about 10 K, a cooling capacity range that is 51% less to 65% greater than the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range is 4% less and 6% greater than the cooling capacity of R-454C evaluated with the same conditions set. Similarly, a composition range of 1 to 97 wt-% of HFO-1132Z, 1 to 97 wt-% of HFO-1132E, 1 to 97 wt-% HFO-1234zeE, and 1 to 22 wt-% HFC-321 will have a GWP less than 150, a maximum average glide of about 10 K, a cooling capacity range that is 49% less and 59% greater than the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range is 4% less and 6% greater than the cooling capacity of R-454C evaluated with the same conditions set. Table X3 lists example compositions within the GWP<300 range that have ASHRAE flammability classifications of 2L or 2.

[0146] Preferred blend composition ranges for cooling within a composition range of 1 to 66 wt-% of HFO-1132Z, 6 to 64 wt-% of HFO-1132E, 1 to 72 wt-% of HFO-1234zeE, and 1 to 22 of HFC-321 will have a GWP < 150, a maximum heat exchanger glide of 10.5 K (in the condenser), an ASHRAE flammability classification of 2L or 2, and a cooling capacity range of 10% less to 10% greater than that of R-454C evaluated at the same conditions set.

[0147] Preferred blend composition ranges for heating within a composition range of 1 to 63 wt-% of HFO-1132Z, 8 to 65 wt-% of HFO-1132E, 1 to 69 of HFO-1234zeE, and 1 to 22 wt-% HFC-321 will have a GWP < 150, a maximum heat exchanger glide of 11 K (in the condenser), an ASHRAE flammability classification of 2L or 2, and a heating capacity range of 10% less to 10% greater than that of R-454C at the same conditions.

[0148] Even more preferred composition ranges for cooling mode that result in ASHRAE flammability classifications of 2L are 1 to 40 wt-% HFO-1132Z, 6 to 41 wt-% HFO-1132E, 29 to 72 wt-% HFO-1234zeE, and 3 to 22 wt-% HFC-321, where the minimum and maximum cooling capacities are 10% less and 10% greater than those of R-454C respectively at the same cycle conditions. The composition for this

maximum cooling capacity for a 2L blend is 13 wt-% HFO-1132Z, 30 wt-% HFO-1132E, 36 wt-% HFO-1234zeE and 21 wt-% HFC-321, where the COP for cooling is 1% greater than that for R-454C under the same cycle conditions. The composition for this maximum cooling efficiency, which is 4% greater than that for R-454C at the same cycle conditions, for a 2L blend is 40 wt-% HFO-1132Z, 9 wt-% HFO-1132E, 29 wt-% HFO-1234zeE and 22 wt-% HFC-321, where the cooling capacity is 10% less than that for R-454C under the same cycle conditions.

[0149] Even more preferred composition ranges for heating mode that result in ASHRAE flammability classifications of 2L are 1 to 37 wt-% HFO-1132Z, 8 to 42 wt-% HFO-1132E, 29 to 69 wt-% HFO-1234zeE, and 3 to 22 wt-% HFC-321, where the minimum and maximum heating capacities are 10% less and 10% greater than those of R-454C respectively at the same cycle conditions. The composition for this maximum heating capacity for a 2L blend is 10 wt-% HFO-1132Z, 34 wt-% HFO-1132E, 37 wt-% HFO-1234zeE and 19 wt-% HFC-321, where the COP for heating is about the same as that for R-454C under the same cycle conditions. The composition for this maximum heating efficiency, which is 1% greater than that for R-454C at the same cycle conditions, for a 2L blend is 34 wt-% HFO-1132Z, 14 wt-% HFO-1132E, 32 wt-% HFO-1234zeE and 20 wt-% HFC-321, where the heating capacity is 10% less than that for R-454C under the same cycle conditions.

Table X3: Residential Heat Pump conditions in cooling mode, cycle metric performance and fluid property ranges for HFO-1132Z/HFO-1132E/HFO-1234zeE/HFC-321 in Example 3.

wt-frac R1132(Z)	wt-frac R1132(E)	wt-frac R1234ze (E)	wt-frac HFC- 321	GWP AR5	ASHRAE flammability class	Glide (K)	CAP_c (relative to R- 454C)	COP_c (relative to R- 454C)
0.02	0.77	0.05	0.16	108.4	2.00	1.90	0.97	1.50
0.04	0.59	0.23	0.14	95.1	2.00	5.95	0.98	1.29
0.06	0.47	0.46	0.01	7.3	2.00	8.15	1.01	0.99
0.08	0.43	0.25	0.24	162.9	2.00	6.80	0.99	1.26
0.10	0.37	0.11	0.42	284.6	1.00	4.48	0.98	1.40
0.13	0.25	0.44	0.18	122.5	1.00	9.13	1.02	1.02
0.15	0.30	0.19	0.36	244.1	1.00	6.61	0.99	1.26
0.18	0.09	0.53	0.20	136.2	1.00	9.00	1.03	0.90

wt-frac R1132(Z)	wt-frac R1132(E)	wt-frac R1234ze (E)	wt-frac HFC- 321	GWP AR5	ASHRAE flammability class	Glide (K)	CAP_c (relative to R- 454C)	COP_c (relative to R- 454C)
0.21	0.38	0.19	0.22	149.4	2.00	7.63	1.00	1.17
0.24	0.01	0.66	0.10	68.4	1.00	5.77	1.04	0.70
0.27	0.02	0.71	0.01	4.5	1.00	1.32	1.05	0.58
0.30	0.55	0.14	0.01	7.4	2.00	6.92	1.02	1.05
0.33	0.04	0.62	0.01	7.9	2.00	2.18	1.05	0.61
0.37	0.32	0.22	0.09	61.7	2.00	7.75	1.03	0.95
0.41	0.21	0.24	0.14	95.6	2.00	7.77	1.04	0.92
0.45	0.07	0.14	0.34	231.0	1.00	7.79	1.03	1.00
0.51	0.26	0.04	0.19	129.4	2.00	7.75	1.03	1.00
0.57	0.07	0.22	0.14	95.9	2.00	6.07	1.05	0.80
0.66	0.15	0.18	0.01	7.9	2.00	3.88	1.05	0.73

Example 4: HFO-1132E, HFO-1234zeE and HFC-134

[0150] Broadly, for cooling mode, a composition range of 0.5 to 98.5 wt-% of HFO-1132E, 0.5 to 98.5 wt-% HFO-1234zeE, and 0.5 to 26 wt-% HFC-134 will have a GWP less than 300, a maximum average glide of about 8 K, a cooling capacity range that is 49% less and 49% greater than the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range is 3% less and 4% greater than the cooling COP of R-454C evaluated with the same conditions set. Similarly, a composition range of 0.5 to 98.5 wt-% of HFO-1132E, 0.5 to 98.5 wt-% HFO-1234zeE, and 0.5 to 13 wt-% HFC-134 will have a GWP less than 150, a maximum average glide of about 8 K, a cooling capacity range that is 49% less and 49% greater than the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range is 3% less and 4% greater than the cooling COP of R-454C evaluated with the same conditions set. Table X4 lists example compositions within the GWP<300 range that have ASHRAE flammability classifications of 1, 2L or 2.

[0151] Broadly, for heating mode, a composition range of 0.5 to 98.5 wt-% of HFO-1132E, 0.5 to 98.5 wt-% HFO-1234zeE, and 0.5 to 26 wt-% HFC-134 will have a GWP less than 300, a maximum average glide of about 8.5 K, a heating capacity range that is 52% less and 52% greater than the heating capacity of R-454C

evaluated with the same conditions set, and the heating COP range is 2% less and 2% greater than the heating COP of R-454C evaluated with the same conditions set. Similarly, a composition range of 0.5 to 98.5 wt-% of HFO-1132E, 0.5 to 98.5 wt-% HFO-1234zeE, and 0.5 to 13 wt-% HFC-134 will have a GWP less than 150, a maximum average glide of about 8.5 K, a heating capacity range that is 52% less and 52% greater than the heating capacity of R-454C evaluated with the same conditions set, and the heating COP range is 2% less and 2% greater than the heating COP of R-454C evaluated with the same conditions set. Table X4b lists example compositions within the GWP<300 range that have ASHRAE flammability classifications of 1, 2L or 2.

[0152] Preferred blend composition ranges for cooling within a composition range of 39 to 98.5 wt-% of HFO-1132E, 0.5 to 60 wt-% of HFO-1234zeE, and 0.5 to 13 of HFC-134 will have a GWP < 150, a maximum average heat exchanger glide of 8 K, an ASHRAE flammability classification of 2L or 2, and a minimum cooling capacity of 10% less than that of R-454C evaluated at the same conditions set.

[0153] Preferred blend composition ranges for heating within a composition range of 41 to 98.5 wt-% of HFO-1132E, 0.5 to 57 of HFO-1234zeE, and 0.5 to 13 wt-% HFC-134 will have a GWP < 150, a maximum heat exchanger glide of 8.5 K (in the condenser), an ASHRAE flammability classification of 2L or 2, and a minimum heating capacity of 10% less than that of R-454C at the same conditions.

[0154] Even more preferred composition ranges for cooling mode that result in ASHRAE flammability classifications of 2L are 39 to 47 wt-% HFO-1132E, 40 to 54 wt-% HFO-1234zeE, and 6 to 13 wt-% HFC-134, where the minimum and maximum cooling capacities are 10% less and 2% less than those of R-454C respectively. The composition for this maximum cooling capacity (2% less than that of R-454C) for a 2L blend is 47 wt-% HFO-1132E, 40 wt-% HFO-1234zeE and 13 wt-% HFC-134, where the COP for cooling is about 2% greater than that for R-454C under the same cycle conditions.

[0155] Even more preferred composition ranges for heating mode that result in ASHRAE flammability classifications of 2L are 41 to 47 wt-% HFO-1132E, 40 to 50 wt-% HFO-1234zeE, and 8 to 13 wt-% HFC-134, where the minimum and maximum heating capacities are 10% less and 4% less than those of R-454C respectively. The

composition for this maximum heating capacity (4% less than that of R-454C) for a 2L blend is 47 wt-% HFO-1132E, 40 wt-% HFO-1234zeE and 13 wt-% HFC-134, where the COP for heating is about 1% greater than that for R-454C under the same cycle conditions.

[0156] The optimal composition for cooling efficiency, which is 2% greater than the COP of incumbent fluid R-454C evaluated at the same conditions, is 39 wt-% HFO-1132E, 49 wt-% HFO-1234zeE and 12 wt-% HFC-134, where the CAP for cooling is 10% less than that for the CAP of R-454C, the average glide is 7.6 K, the GWP is 135, and the flammability class is 2L. The optimal composition for cooling capacity, which is 2% less than for R-454C under the same conditions, is 47 wt-% HFO-1132E, 40 wt-% HFO-1234zeE and 13 wt-% HFC-134, where the COP for cooling is 2% greater than the COP of R-454C for cooling, the average glide is 7.6 K, the GWP is 146, and the flammability class is 2L.

[0157] The optimal composition for heating efficiency, which is 1% greater than the COP of incumbent fluid R-454C in the same conditions, is 41 wt-% HFO-1132E, 50 wt-% HFO-1234zeE and 9 wt-% HFC-134, where the heating capacity is 10% less than that for R-454C, the average glide is 8.3 K, the GWP is 101, and the flammability class is 2L. The optimal composition for heating capacity, which is 4% less than the heating capacity of incumbent fluid R-454C in the same conditions, is 47 wt-% HFO-1132E, 40 wt-% HFO-1234zeE and 13 wt-% HFC-134, where the COP for heating is about 1% greater than that for R-454C under the same cycle conditions, the average glide is 8.1 K, the GWP is 146, and the flammability class is 2L.

Table X4a: Residential Heat Pump conditions in cooling mode, cycle metric performance and fluid property ranges for HFO-1132E/HFO-1234zeE/HFC-134 in Example 4.

wt-frac R1132(E)	wt-frac R1234ze (E)	wt-frac HFC-134	GWP AR5	ASHRAE flammability class	Glide (K)	COP _h (% dev from R- 454C)	CAP _h (% dev from R- 454C)
0.01	0.73	0.26	292	2L	0.6	3.93	-45.63
0.985	0.005	0.01	11	2	0.3	-2.88	48.59
0.005	0.905	0.09	101	2L	0.3	3.74	-48
0.01	0.985	0.005	7	2L	0.6	3.64	-48.51
0.975	0.005	0.02	22	2	0.5	-2.83	47.63
0.28	0.46	0.26	292	2L	6.8	3.17	-18.55
0.229	0.766	0.005	6	2L	6.9	3.29	-26.06
0.005	0.985	0.01	12	2L	0.3	3.64	-48.99
0.005	0.736	0.259	290	2L	0.3	3.93	-46.17
0.975	0.02	0.005	6	2	0.7	-2.9	47.24
0.985	0.01	0.005	6	2	0.4	-2.9	48.45
0.418	0.577	0.005	6	2	8	1.95	-8.03
0.01	0.86	0.13	146	2L	0.6	3.76	-46.99
0.005	0.965	0.03	34	2L	0.3	3.67	-48.73
0.866	0.005	0.129	145	2	2.6	-2.27	37.26
0.67	0.2	0.13	146	2	6.1	-0.45	17.41
0.239	0.756	0.005	6	2L	7	3.24	-25.1
0.005	0.876	0.119	135	2L	0.4	3.76	-47.65
0.005	0.866	0.129	146	2L	0.4	3.76	-47.53
0.01	0.87	0.12	135	2L	0.6	3.76	-47.1
0.02	0.85	0.13	146	2L	1.1	3.76	-45.91
0.03	0.84	0.13	146	2L	1.5	3.76	-44.85
0.04	0.83	0.13	146	2L	1.9	3.76	-43.79
0.05	0.82	0.13	146	2L	2.3	3.76	-42.73
0.06	0.81	0.13	146	2L	2.7	3.76	-41.68
0.07	0.8	0.13	146	2L	3.1	3.76	-40.64
0.39	0.48	0.13	146	2L	7.6	2.26	-9.26

wt-frac R1132(E)	wt-frac R1234ze (E)	wt-frac HFC-134	GWP AR5	ASHRAE flammab ility class	Glide (K)	COP_h (% dev from R- 454C)	CAP_h (% dev from R- 454C)
0.39	0.54	0.07	79	2L	7.7	2.21	-9.92
0.398	0.597	0.005	6	2	8	2.11	-9.91
0.945	0.005	0.05	56	2	1.1	-2.71	44.78
0.83	0.04	0.13	146	2	3.4	-2.01	33.43
0.766	0.229	0.005	6	2	5.2	-1.46	25.04
0.39	0.49	0.12	135	2L	7.6	2.26	-9.37
0.47	0.4	0.13	146	2L	7.6	1.55	-1.66
0.39	0.51	0.1	113	2L	7.7	2.23	-9.58
0.4	0.54	0.06	68	2L	7.8	2.11	-9.08
0.42	0.45	0.13	146	2L	7.6	2	-6.41
0.91	0.09	0.01	5.7	2	2.48	-3	39
0.72	0.27	0.01	11.5	2	5.85	-1	21
0.52	0.46	0.02	22.9	2	7.67	1	2
0.31	0.66	0.03	34.3	2L	7.55	3	-18
0.09	0.87	0.04	45.7	2L	3.84	4	-40
0.81	0.13	0.06	67.3	2	4.17	-2	30
0.56	0.37	0.07	78.8	2	7.29	1	6
0.3	0.62	0.08	90.2	2L	7.34	3	-18
0.03	0.88	0.09	101.7	2L	1.54	4	-45
0.65	0.24	0.11	123.4	2	6.39	0	15
0.35	0.53	0.12	134.9	2L	7.51	3	-13
0.04	0.83	0.13	146.4	2L	1.94	4	-44
0.58	0.27	0.15	168.3	2	6.96	0	9
0.24	0.6	0.16	179.8	2L	6.58	3	-23
0.72	0.1	0.18	201.7	2	5.3	-1	23
0.35	0.46	0.19	213.3	2L	7.38	3	-12
0.77	0.02	0.21	235.2	2	4.38	-2	28
0.37	0.41	0.22	246.8	2L	7.41	2	-10
0.73	0.03	0.24	268.8	2	5.04	-1	25
0.04	0.7	0.26	291.9	1	1.83	4	-42

[0158] Table X4b: Residential Heat Pump conditions in heating mode, cycle metric performance and fluid property ranges for HFO-1132E/HFO-1234zeE/HFC-134 in Example 4.

wt-frac R1132(E)	wt-frac R1234ze (E)	wt-frac HFC-134	GWP AR5	ASHRAE flammability class	Glide (K)	COP _h (% dev from R- 454C)	CAP _h (% dev from R- 454C)
0.01	0.73	0.26	292	2L	0.6	2.34	-48.75
0.05	0.69	0.26	292	1	2.3377	2.26	-44.55
0.985	0.005	0.01	11	2	0.4	-2.31	51.54
0.005	0.886	0.109	123	2L	0.4	2.26	-50.74
0.01	0.985	0.005	7	2L	0.6	2.2	-51.4
0.816	0.005	0.179	201	2	4	-1.86	33.2
0.62	0.12	0.26	291	2	7.1	-0.48	12.73
0.587	0.408	0.005	6	2	7.8	-0.19	6.67
0.005	0.985	0.01	12	2L	0.3	2.22	-51.88
0.005	0.736	0.259	290	2L	0.4	2.35	-49.29
0.945	0.05	0.005	6	2	1.7	-2.35	46.04
0.96	0.03	0.01	11	2	1.2	-2.35	48.1
0.955	0.04	0.005	6	2	1.4	-2.35	47.34
0.975	0.02	0.005	6	2	0.8	-2.35	50.01
0.965	0.03	0.005	6	2	1.1	-2.35	48.66
0.428	0.567	0.005	6	2	8.5	0.88	-9.15
0.01	0.86	0.13	146	2L	0.6	2.26	-49.98
0.005	0.915	0.08	90	2L	0.4	2.24	-51.07
0.935	0.005	0.06	67	2	1.5	-2.25	46.03
0.2	0.67	0.13	146	2L	6.5	2	-30.38
0.856	0.139	0.005	6	2	3.9	-2.02	35.16
0.005	0.876	0.119	135	2L	0.4	2.28	-50.63
0.005	0.866	0.129	146	2L	0.4	2.28	-50.53
0.41	0.46	0.13	146	2L	8.2	1.01	-9.59
0.41	0.5	0.09	101	2L	8.3	1.01	-9.99
0.42	0.57	0.01	12	2	8.5	0.94	-9.87
0.6	0.27	0.13	146	2	7.4	-0.27	9.46

wt-frac R1132(E)	wt-frac R1234ze (E)	wt-frac HFC-134	GWP AR5	ASHRAE flammab ility class	Glide (K)	COP _h (% dev from R- 454C)	CAP _h (% dev from R- 454C)
0.796	0.199	0.005	6	2	5.1	-1.67	28.46
0.41	0.48	0.11	124	2L	8.2	1.01	-9.79
0.41	0.47	0.12	135	2L	8.2	1.01	-9.69
0.41	0.49	0.1	112	2L	8.2	1.01	-9.89
0.47	0.4	0.13	146	2L	8.1	0.64	-3.63
0.42	0.5	0.08	90	2L	8.3	0.94	-9.11

Example 5: HFO-1132E, HFO-1234zeE, HFC-134 and HFC-32

[0159] Broadly, for cooling mode, a composition range of 0.25 to 98.5 wt-% of HFO-1132E, 0.25 to 98.5 wt-% of HFO-1234zeE, 0.25 to 26 wt-% HFC-134, and 0.25 to 44 wt-% HFC-321 will have a GWP less than 300, a maximum average glide of about 10.3 K, a cooling capacity range that is 49% less to 65% greater than the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range is 4% less and 4% greater than the cooling capacity of R-454C evaluated with the same conditions set. Similarly, a composition range of 0.25 to 98.5 wt-% of HFO-1132E, 0.25 to 98.5 wt-% of HFO-1234zeE, 0.25 to 13 wt-% HFC-134, and 0.25 to 21 wt-% HFC-321 will have a GWP less than 150, a maximum average glide of about 10.2 K, a cooling capacity range that is 49% less and 59% greater than the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range is 4% less and 4% greater than the cooling capacity of R-454C evaluated with the same conditions set. Table X5 lists example compositions within the GWP<300 range that have ASHRAE flammability classifications of 1, 2L or 2 for cooling mode.

[0160] Broadly, for heating mode, a composition range of 0.25 to 98.5 wt-% of HFO-1132E, 0.25 to 98.5 wt-% of HFO-1234zeE, 0.25 to 26 wt-% HFC-134, and 0.25 to 44 wt-% HFC-321 will have a GWP less than 300, a maximum average glide of about 10.9 K, a heating capacity range that is 52% less to 68% greater than the cooling capacity of R-454C evaluated with the same conditions set, and the heating COP range is 3% less and 2% greater than the heating capacity of R-454C evaluated with the same conditions set. Similarly, a composition range of 0.25 to

98.5 wt-% of HFO-1132E, 0.25 to 98.5 wt-% of HFO-1234zeE, 0.25 to 13 wt-% HFC-134, and 0.25 to 21 wt-% HFC-321 will have a GWP less than 150, a maximum average glide of about 10.9 K, a heating capacity range that is 52% less and 63% greater than the heating capacity of R-454C evaluated with the same conditions set, and the heating COP range is 3% less and 2% greater than the heating capacity of R-454C evaluated with the same conditions set. Table X5b lists example compositions within the GWP<300 range that have ASHRAE flammability classifications of 1, 2L or 2 for heating mode.

[0161] Preferred blend composition ranges for cooling within a composition range of 7 to 98.5 wt-% of HFO-1132E, 0.25 to 72 wt-% of HFO-1234zeE, 0.25 to 13 wt-% of HFC-134, and 0.25 to 21 of HFC-321 will have a GWP < 150, a maximum average heat exchanger glide of 10.2 K, an ASHRAE flammability classification of 2L or 2, and a cooling capacity range greater than 10% less than that of R-454C evaluated at the same conditions set.

[0162] Preferred blend composition ranges for heating within a composition range of 10 to 98.5 wt-% of HFO-1132E, 0.25 to 69 wt-% of HFO-1234zeE, 0.25 to 13 of HFC-134, and 0.25 to 21 wt-% HFC-321 will have a GWP < 150, a maximum average heat exchanger glide of 10.8 K, an ASHRAE flammability classification of 2L or 2, and a heating capacity range greater than 10% less than that of R-454C at the same conditions.

[0163] Even more preferred composition ranges for cooling mode that result in ASHRAE flammability classifications of 2L are 7 to 48 wt-% HFO-1132E, 36 to 72 wt-% HFO-1234zeE, 0.5 to 13 wt-% HFC-134, and 0.5 to 21 wt-% HFC-321, where the minimum and maximum cooling capacities are 10% less and 10% greater than those of R-454C respectively at the same cycle conditions. The composition of this maximum cooling capacity for a 2L blend is 41.8 wt-% HFO-1132E, 45.8 wt-% HFO-1234zeE, 0.5 wt-% HFC-134 and 11.9 wt-% HFC-321, where the COP for cooling is about the same as that for R-454C under the same cycle conditions. The composition for the maximum cooling efficiency, which is 3% greater than that for R-454C at the same cycle conditions, for a 2L blend is 7.0 wt-% HFO-1132E, 71.6 wt-% HFO-1234zeE, 0.5 wt-% HFC-134 and 20.9 wt-% HFC-321, where the cooling capacity is 10% less than that for R-454C under the same cycle conditions.

[0164] Even more preferred composition ranges for heating mode that result in ASHRAE flammability classifications of 2L are 10 to 48 wt-% HFO-1132E, 36 to 69 wt-% HFO-1234zeE, 0.5 to 13 wt-% HFC-134, and 0.5 to 21 wt-% HFC-321, where the minimum and maximum heating capacities are 10% less and 10% greater than those of R-454C respectively at the same cycle conditions. The composition for this maximum heating capacity for a 2L blend is 40 wt-% HFO-1132E, 42 wt-% HFO-1234zeE, 4 wt-% HFC-134 and 14 wt-% HFC-321, where the COP for heating is about the same as that for R-454C under the same cycle conditions. The composition for this maximum heating efficiency, which is 1% greater than that for R-454C at the same cycle conditions, for a 2L blend is 10.9 wt-% HFO-1132E, 68.7 wt-% HFO-1234zeE, 0.5 wt-% HFC-134 and 19.9 wt-% HFC-321, where the heating capacity is 10% less than that for R-454C under the same cycle conditions.

Table X5a: Residential Heat Pump conditions in cooling mode, cycle metric performance and fluid property ranges for HFO-1132E/HFO-1234zeE/HFC-134/HFC-321 in Example 5.

wt-frac R1132(E)	wt-frac R1234ze(E)	wt-frac R134	wt-frac HFC-321	GWP AR5	ASHRAE flammability class	Glide (K)	COP _c (% dev from R-454C)	CAP _c (% dev from R-454C)
0.55	0.02	0.02	0.41	300	2L	1	-4	60
0.985	0.002	0.002	0.01	10	2	0.2	-3	50
0.002	0.607	0.002	0.388	266	2L	9.2	1	6
0.002	0.985	0.002	0.01	11	2L	1.2	4	-48
0.657	0.002	0.002	0.338	232	2	0.2	-4	63
0.57	0.16	0.26	0.01	298	2L	7	0	11
0.239	0.756	0.002	0.002	5	2L	7.1	3	-25
0.557	0.002	0.002	0.438	299	2L	0.1	-4	65
0.1	0.896	0.002	0.002	5	2L	4.4	4	-39
0.002	0.985	0.01	0.002	14	2L	0.4	4	-49
0.005	0.706	0.179	0.109	275	2L	6.5	4	-30
0.005	0.706	0.189	0.1	280	2L	6.1	4	-31
0.005	0.696	0.179	0.119	282	2L	6.8	4	-29
0.005	0.696	0.189	0.109	287	2L	6.4	4	-30
0.005	0.696	0.199	0.1	291	2L	6	4	-31

wt-frac R1132(E)	wt-frac R1234ze(E)	wt-frac R134	wt-frac HFC-321	GWP AR5	ASHRAE flammability class	Glide (K)	COP _c (% dev from R-454C)	CAP _c (% dev from R-454C)
0.005	0.687	0.189	0.119	293	2L	6.7	4	-28
0.005	0.696	0.209	0.09	295	2L	5.6	4	-33
0.005	0.687	0.199	0.109	298	2L	6.4	4	-30
0.01	0.68	0.2	0.11	299	2L	6.5	4	-29
0.667	0.002	0.002	0.328	225	2	0.2	-4	63
0.647	0.002	0.002	0.348	239	2	0.2	-4	63
0.637	0.002	0.002	0.358	245	2	0.2	-4	63
0.627	0.002	0.002	0.368	252	2	0.1	-4	64
0.617	0.002	0.002	0.378	259	2	0.1	-4	64
0.607	0.002	0.002	0.388	266	2	0.1	-4	64
0.597	0.002	0.002	0.398	272	2L	0.1	-4	64
0.587	0.002	0.002	0.408	279	2L	0.1	-4	64
0.577	0.002	0.002	0.418	286	2L	0.1	-4	64
0.567	0.002	0.002	0.428	292	2L	0.1	-4	65
0.04	0.716	0.005	0.239	168	2L	10.3	3	-9
0.826	0.005	0.08	0.09	150	2	2	-3	46
0.985	0.002	0.01	0.002	13	2	0.3	-3	49
0.002	0.896	0.002	0.1	71	2L	7.4	4	-32
0.01	0.985	0.002	0.002	5	2L	0.8	4	-48
0.05	0.816	0.129	0.005	149	2L	2.7	4	-42
0.846	0.149	0.002	0.002	5	2	3.7	-2	33
0.318	0.468	0.005	0.209	148	2L	8.7	0	13
0.259	0.736	0.002	0.002	5	2L	7.3	3	-23
0.786	0.002	0.002	0.209	144	2	0.2	-4	59
0.005	0.846	0.03	0.119	115	2L	8	4	-29
0.005	0.836	0.04	0.119	126	2L	7.9	4	-29
0.005	0.836	0.05	0.109	131	2L	7.4	4	-30
0.005	0.826	0.05	0.119	137	2L	7.8	4	-29
0.005	0.826	0.06	0.109	142	2L	7.3	4	-30
0.005	0.816	0.05	0.129	144	2L	8.1	4	-27

wt-frac R1132(E)	wt-frac R1234ze(E)	wt-frac R134	wt-frac HFC- 321	GWP AR5	ASHRAE flammability class	Glide (K)	COP_c (% dev from R- 454C)	CAP_c (% dev from R- 454C)
0.005	0.816	0.06	0.119	149	2L	7.7	4	-29
0.796	0.002	0.002	0.199	138	2	0.3	-4	59
0.786	0.01	0.005	0.199	140	2	0.5	-4	58
0.776	0.01	0.005	0.209	147	2	0.5	-4	58
0.766	0.02	0.005	0.209	147	2	0.8	-4	57
0.756	0.03	0.005	0.209	147	2	1	-4	56
0.07	0.716	0.005	0.209	148	2L	10.2	3	-10
0.925	0.002	0.002	0.07	50	2	0.3	-3	53
0.766	0.1	0.129	0.005	148	2	4.6	-2	28
0.726	0.269	0.002	0.002	5	2	5.8	-1	22
0.418	0.577	0.002	0.002	5	2	8	2	-8
0.29	0.58	0.07	0.06	120	2L	8.7	2	-10
0.13	0.67	0.03	0.17	149	2L	9.9	3	-9
0.48	0.36	0.09	0.07	149	2L	7.9	1	9
0.438	0.428	0.129	0.005	149	2L	7.7	2	-4
0.139	0.647	0.005	0.209	148	2L	10.1	2	-3
0.199	0.587	0.005	0.209	148	2L	9.8	1	2
0.378	0.517	0.1	0.005	115	2L	7.7	2	-10
0.418	0.458	0.005	0.119	87	2L	8.6	0	10
0.01	0.71	0.22	0.06	287.7	1	4.4	4	-37
0.1	0.65	0.24	0.01	276.2	2L	4.3	4	-35
0.13	0.62	0.22	0.03	267.3	2L	6	4	-29
0.41	0.32	0.22	0.05	280.6	2L	8	2	1
0.32	0.39	0.22	0.07	294.2	2L	8.3	2	-5
0.38	0.49	0.03	0.1	101.8	2L	8.8	1	4
0.31	0.49	0.08	0.12	171.3	2L	9	2	1
0.48	0.23	0.15	0.14	263	2L	7.3	0	19
0.41	0.37	0.05	0.17	171.5	2L	8	0	16
0.28	0.52	0.01	0.2	140.8	2L	9.2	1	8
0.02	0.63	0.13	0.22	295.2	2L	9	3	-13

wt-frac R1132(E)	wt-frac R1234ze(E)	wt-frac R134	wt-frac HFC-321	GWP AR5	ASHRAE flammability class	Glide (K)	COP _c (% dev from R-454C)	CAP _c (% dev from R-454C)
0.06	0.64	0.04	0.26	221.5	2L	9.9	2	-4
0.24	0.43	0.03	0.3	237.1	2L	8.2	0	17
0.36	0.25	0.04	0.35	282	2L	5.8	-2	34
0.49	0.38	0.13	0.01	148.6	2	7.6	1	1
0.91	0.05	0.01	0.03	31.6	2	1.7	-3	45
0.76	0.02	0.17	0.05	224.3	2	4	-2	34
0.73	0.17	0.01	0.09	72.3	2	4.5	-2	35
0.56	0.29	0.02	0.13	110.7	2	6.7	-1	25

Table X5b: Residential Heat Pump conditions in heating mode, cycle metric performance and fluid property ranges for HFO-1132E/HFO-1234zeE/HFC-134/HFC-321 in Example 5.

wt-frac R1132(E)	wt-frac R1234ze(E)	wt-frac R134	wt-frac HFC-321	GWP AR5	ASHRAE flammability class	Glide (K)	COP _c (% dev from R-454C)	CAP _c (% dev from R-454C)
0.55	0.02	0.02	0.41	300	2L	1.1	-3	63
0.985	0.002	0.01	0.002	13	2	0.3	-2	52
0.002	0.657	0.002	0.338	232	2L	10.3	1	-3
0.01	0.985	0.002	0.002	5	2L	0.9	2	-51
0.925	0.002	0.07	0.002	80	2	1.6	-2	45
0.34	0.39	0.26	0.01	298	2L	8	1	-14
0.04	0.69	0.26	0.01	299	1	2.6	2	-44
0.002	0.647	0.002	0.348	239	2L	10.2	1	-1
0.002	0.557	0.002	0.438	300	2L	8.9	0	9
0.06	0.935	0.002	0.002	5	2L	3.2	2	-46
0.557	0.002	0.002	0.438	299	2L	0.1	-3	68
0.002	0.985	0.01	0.002	14	2L	0.4	2	-52
0.002	0.746	0.249	0.002	281	2L	0.4	2	-49
0.002	0.736	0.259	0.002	292	2L	0.4	2	-49
0.577	0.005	0.02	0.398	292	2L	0.8	-3	64
0.57	0.01	0.02	0.4	293	2L	0.9	-3	64

wt-frac R1132(E)	wt-frac R1234ze(E)	wt-frac R134	wt-frac HFC-321	GWP AR5	ASHRAE flammability class	Glide (K)	COP _c (% dev from R-454C)	CAP _c (% dev from R-454C)
0.577	0.005	0.03	0.388	296	2L	1.1	-3	63
0.567	0.005	0.02	0.408	298	2L	0.8	-3	64
0.56	0.01	0.02	0.41	300	2L	0.9	-3	64
0.05	0.716	0.005	0.229	161	2L	10.9	1	-12
0.826	0.005	0.08	0.09	150	2	2.2	-3	48
0.002	0.935	0.002	0.06	44	2L	5.6	2	-42
0.955	0.002	0.002	0.04	30	2	0.2	-2	55
0.129	0.736	0.129	0.005	149	2L	5.4	2	-37
0.109	0.886	0.002	0.002	5	2L	5	2	-40
0.298	0.488	0.005	0.209	148	2L	9.5	0	10
0.002	0.886	0.109	0.002	125	2L	0.5	2	-51
0.786	0.002	0.002	0.209	144	2	0.3	-3	63
0.002	0.866	0.002	0.129	91	2L	9.1	2	-30
0.002	0.856	0.002	0.139	98	2L	9.4	2	-29
0.756	0.03	0.005	0.209	147	2	1.2	-3	59
0.746	0.04	0.005	0.209	147	2	1.4	-3	57
0.736	0.05	0.005	0.209	147	2	1.7	-3	56
0.07	0.716	0.005	0.209	148	2L	10.9	2	-12
0.985	0.01	0.002	0.002	5	2	0.4	-2	52
0.1	0.687	0.005	0.209	148	2L	10.8	1	-9
0.965	0.002	0.002	0.03	23	2	0.2	-2	55
0.647	0.219	0.129	0.005	148	2	6.9	-1	15
0.796	0.199	0.002	0.002	5	2	5.1	-2	29
0.955	0.002	0.04	0.002	46	2	1	-2	49
0.408	0.557	0.03	0.005	37	2	8.5	1	-10
0.109	0.687	0.005	0.199	141	2L	10.8	1	-10
0.15	0.65	0.03	0.17	149	2L	10.5	1	-10
0.48	0.36	0.09	0.07	149	2L	8.5	0	8
0.468	0.398	0.129	0.005	149	2L	8.2	1	-3
0.318	0.498	0.005	0.179	127	2L	9.7	0	7

wt-frac R1132(E)	wt-frac R1234ze(E)	wt-frac R134	wt-frac HFC-321	GWP AR5	ASHRAE flammability class	Glide (K)	COP _c (% dev from R-454C)	CAP _c (% dev from R-454C)
0.289	0.498	0.005	0.209	148	2L	9.6	0	9
0.418	0.507	0.07	0.005	82	2L	8.4	1	-9
0.4	0.42	0.04	0.14	140	2L	9.1	0	10
0.398	0.468	0.129	0.005	149	2L	8.2	1	-10
0.358	0.468	0.005	0.169	121	2L	9.4	0	10

Example 6: HFO-1132E, HFC-134 and HFC-32

[0165] Broadly, a composition range of 57 to 98.5 wt-% of HFO-1132E, 0.5 to 26 wt-% HFC-134, and 0.5 to 43 wt-% HFC-321 will have a GWP less than 300, a maximum average glide of about 4.9 K in cooling mode, a cooling capacity range that is 26% to 65% greater than the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range is 4% to 1% less than the cooling COP of R-454C evaluated with the same conditions set. This same composition range will also result in a maximum average glide of about 5.5 K in heating mode, a heating capacity range that is 26% to 67% greater than the heating capacity of R-454C evaluated with the same conditions set, and the heating COP range is 3% to 1% less than the heating COP of R-454C evaluated with the same conditions set. Table X6 lists example compositions within the GWP<300 range that have ASHRAE flammability classifications of 2L or 2.

[0166] Similarly, and also broadly, a composition range of 79 to 98.5 wt-% of HFO-1132E, 0.5 to 13 wt-% HFC-134, and 0.5 to 21 wt-% HFC-321 will have a GWP less than 150, a maximum average glide of about 2.5 K, a cooling capacity range that is 38% to 59% greater than the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range is 4% to 2% less than the cooling COP of R-454C evaluated with the same conditions set. This same composition range will also result in a maximum average glide of about 2.9 K in heating mode, a heating capacity range that is 39% to 63% greater than the heating capacity of R-454C evaluated with the same conditions set, and the heating COP range is 3% to 2% less than the heating COP of R-454C evaluated with the same conditions set.

[0167] The optimal 2L composition for both cooling and heating efficiency that has a GWP less than 300, which is 3% less than the COP (both cooling and heating) of incumbent fluid R-454C evaluated at the same conditions, is 62 wt-% HFO-1132E, 9 wt-% HFC-134 and 29 wt-% HFC-321, where the CAP for cooling and heating is 52% and 53% greater respectively than that for the CAP of R-454C evaluated at the same conditions and the average glide is 2.3 K for cooling and 2.3 K for heating. Similarly, the optimal composition for both cooling and heating efficiency that has a GWP less than 150, which is 2% less than the COP (both cooling and heating) of incumbent fluid R-454C evaluated at the same conditions, is 86.6 wt-% HFO-1132E, 12.9 wt-% HFC-134 and 0.5 wt-% HFC-321, where the CAP for cooling and heating is 39% and 21% greater respectively than that for the CAP of R-454C evaluated at the same conditions and the average glide is 2.4 K for cooling and 2.7 K for heating.

[0168] The optimal composition for both cooling and heating capacity, which is 65% and 66% greater respectively than the capacities of incumbent fluid R-454C evaluated at the same conditions, that has a GWP less than 300, an ASHRAE flammability classification of 2L, a maximum average glide of 0.1 K respectively and COP efficiencies that are 4% and 3% less respectively than the COP of incumbent fluid R-454C evaluated at the same conditions, is 56.7 wt-% HFO-1132E, 0.5 wt-% HFC-134 and 42.8 wt-% HFC-321. Similarly, the optimal composition for both cooling and heating capacity, which is 58% and 62% greater respectively than the capacities of incumbent fluid R-454C evaluated at the same conditions, that has a GWP less than 150, a maximum average glide of 0.4 K and 0.3K respectively, and COP efficiencies that are 3% less than the COP (both cooling and heating) of incumbent fluid R-454C evaluated at the same conditions, is 78.6 wt-% HFO-1132E, 0.5 wt-% HFC-134 and 20.9 wt-% HFC-321.

Table X6: Residential Heat Pump conditions in both cooling and heating mode, cycle metric performance and fluid property ranges for HFO-1132E/HFC-134/HFC-321 in Example 6. Note that * indicates heating mode.

wt-frac R1132(E)	wt-frac R134	wt-frac R32	GWP AR5	ASHRAE flammability class	Glide (K)	COP (% dev from R-454C)	CAP (% dev from R-454C)
0.57	0.02	0.41	300	2L	0.6	-4	62
0.985	0.01	0.005	15	2	0.2	-3	50

wt-frac R1132(E)	wt-frac R134	wt-frac R32	GWP AR5	ASHRAE flammab ility class	Glide (K)	COP (% dev from R-454C)	CAP (% dev from R-454C)
0.567	0.005	0.428	295	2L	0.1	-4	65
0.73	0.26	0.01	298	2	4.9	-1	26
0.935	0.005	0.06	46	2	0.2	-3	53
0.836	0.159	0.005	182	2	3.1	-2	35
0.736	0.259	0.005	293	2	4.9	-1	26
0.57	0.01	0.42	296	2L	0.3	-4	64
0.577	0.005	0.418	289	2L	0.1	-4	64
0.58	0.01	0.41	289	2L	0.3	-4	64
0.587	0.005	0.408	282	2L	0.1	-4	64
0.59	0.01	0.4	282	2L	0.3	-4	63
0.597	0.005	0.398	275	2L	0.2	-4	64
0.6	0.01	0.39	275	2L	0.3	-4	63
0.607	0.005	0.388	268	2	0.2	-4	64
0.61	0.01	0.38	268	2	0.3	-4	63
0.617	0.005	0.378	262	2	0.2	-4	64
0.62	0.01	0.37	262	2	0.3	-4	63
0.627	0.005	0.368	255	2	0.2	-4	64
0.63	0.01	0.36	255	2	0.3	-4	63
0.637	0.005	0.358	248	2	0.2	-4	63
0.647	0.005	0.348	241	2	0.2	-4	63
0.657	0.005	0.338	235	2	0.2	-4	63
0.8	0.03	0.17	149	2	0.8	-3	55
0.985	0.005	0.01	12	2	0.1	-3	50
0.786	0.005	0.209	147	2	0.2	-4	59
0.866	0.129	0.005	148	2	2.5	-2	38
0.846	0.005	0.149	107	2	0.3	-3	57
0.965	0.03	0.005	37	2	0.6	-3	48
0.955	0.04	0.005	48	2	0.8	-3	47
0.57	0.01	0.42	296	2L	0.3	-4	64
0.59	0.03	0.38	291	2L	0.8	-4	61

wt-frac R1132(E)	wt-frac R134	wt-frac R32	GWP AR5	ASHRAE flammab ility class	Glide (K)	COP (% dev from R-454C)	CAP (% dev from R-454C)
0.62	0.09	0.29	297	2L	2.3	-3	52
0.62	0.02	0.36	266	2	0.6	-4	62
0.65	0.01	0.34	241	2	0.3	-4	62
0.67	0.02	0.31	232	2	0.6	-4	60
0.68	0.16	0.16	288	2	3.8	-3	41
0.7	0.08	0.22	239	2	2	-3	52
0.71	0.18	0.11	276	2	4.1	-2	38
0.73	0.01	0.26	187	2	0.3	-4	60
0.74	0.05	0.21	198	2	1.3	-3	54
0.75	0.1	0.15	214	2	2.4	-3	47
0.76	0.16	0.08	233	2	3.6	-2	39
0.79	0.08	0.13	178	2	1.9	-3	49
0.8	0.18	0.02	215	2	3.6	-2	34
0.82	0.09	0.09	162	2	2.1	-3	46
0.84	0.04	0.12	126	2	1	-3	52
0.86	0.03	0.11	108	2	0.8	-3	53
0.88	0.06	0.06	108	2	1.4	-3	47
0.91	0.02	0.07	70	2	0.6	-3	52
0.57	0.02	0.41	300	2L	0.7*	-3*	65*
0.985	0.005	0.01	12	2	0.1*	-2*	53*
0.567	0.005	0.428	295	2L	0.2*	-3*	67*
0.73	0.26	0.01	298	2	5.5*	-2*	26*
0.696	0.005	0.298	208	2	0.2*	-3*	65*
0.826	0.169	0.005	193	2	3.7*	-2*	35*
0.736	0.259	0.005	293	2	5.4*	-1*	26*
0.57	0.01	0.42	296	2L	0.3*	-3*	67*
0.58	0.02	0.4	293	2L	0.7*	-3*	65*
0.58	0.03	0.39	298	2L	1*	-3*	63*
0.8	0.03	0.17	149	2	0.9*	-3*	58*
0.985	0.01	0.005	15	2	0.2*	-2*	53*

wt-frac R1132(E)	wt-frac R134	wt-frac R32	GWP AR5	ASHRAE flammab ility class	Glide (K)	COP (% dev from R-454C)	CAP (% dev from R-454C)
0.786	0.005	0.209	147	2	0.3*	-3*	63*
0.866	0.129	0.005	148	2	2.9*	-2*	39*
0.955	0.04	0.005	48	2	0.9*	-2*	49*
0.79	0.01	0.2	147	2	0.4*	-3*	62*
0.826	0.005	0.169	120	2	0.3*	-3*	61*
0.915	0.08	0.005	93	2	1.8*	-2*	45*

Example 7: HFO-1132E and HFO-1234zeE

[0169] Broadly, a composition range of 1 to 99 wt-% of HFO-1132E and 1 to 99 wt-% HFO-1234zeE will have a GWP less than 6, a maximum average glide of about 8 K in cooling mode, a cooling capacity range that is 49% less to 49% greater than the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range is 3% less to 4% more than the cooling COP of R-454C evaluated with the same conditions set. This same composition range will also result in a maximum average glide of about 8.5 K in heating mode, a heating capacity range that is 51% less to 52% greater than the heating capacity of R-454C evaluated with the same conditions set, and the heating COP range is 4% less to 2% more than the heating COP of R-454C evaluated with the same conditions set. Table X7 lists example compositions within the GWP<6 range that have ASHRAE flammability classifications of 2L or 2.

[0170] Preferred blend composition ranges for cooling within a composition range of 40 to 61 wt-% of HFO-1132E and 39 to 60 wt-% of HFO-1234zeE will have GWP < 6, a maximum heat exchanger glide of 8 K (in the condenser), an ASHRAE flammability classification 2, and minimum and maximum cooling capacities of 10% less and 10% more than that of R-454C evaluated at the same conditions set. Preferred blend composition ranges for heating within a composition range of 42 to 62 wt-% of HFO-1132E and 38 to 58 of HFO-1234zeE will have a GWP < 6, a maximum heat exchanger glide of 8.7 K (in the condenser), an ASHRAE flammability classification of 2, and minimum and maximum heating capacities of 10% less and 10% more than that of R-454C evaluated at the same conditions set.

[0171] **Table X7:** Residential Heat Pump conditions in both cooling and heating mode, cycle metric performance and fluid property ranges for HFO-1132E/HFO-1234zeE in Example 7. Note that “*” indicates heating mode.

wt-frac R1132(E)	wt-frac R1234ze (E)	GWP AR5	ASHRAE flammab ility class	Glide (K)	COP (% dev from R-454C)	CAP (% dev from R-454C)
0.01	0.99	~1	2L	0.5	3.64	-48.57
0.99	0.01	~1	2	0.3	-3	49
0.05	0.95	~1	2L	2.4	4	-44
0.06	0.94	~1	2L	2.8	4	-43
0.07	0.93	~1	2L	3.2	4	-42
0.08	0.92	~1	2L	3.6	4	-41
0.09	0.91	~1	2L	3.9	4	-40
0.1	0.9	~1	2L	4.2	4	-39
0.11	0.89	~1	2L	4.5	4	-38
0.12	0.88	~1	2L	4.8	4	-37
0.98	0.02	~1	2	0.6	-3	48
0.42	0.58	~1	2	8	2	-8
0.4	0.6	~1	2	8	2	-10
0.03	0.97	~1	2L	1.5	4	-46
0.08	0.92	~1	2L	3.6	4	-41
0.13	0.87	~1	2L	5	4	-36
0.18	0.82	~1	2L	6.1	4	-31
0.23	0.77	~1	2L	6.9	3	-26
0.28	0.72	~1	2L	7.4	3	-21
0.33	0.67	~1	2L	7.8	3	-16
0.38	0.62	~1	2	7.9	2	-12
0.43	0.57	~1	2	8	2	-7
0.48	0.52	~1	2	7.9	1	-2
0.53	0.47	~1	2	7.7	1	2
0.58	0.42	~1	2	7.4	0	7
0.63	0.37	~1	2	6.9	0	12
0.68	0.32	~1	2	6.4	-1	17

wt-frac R1132(E)	wt-frac R1234ze (E)	GWP AR5	ASHRAE flammab ility class	Glide (K)	COP (% dev from R-454C)	CAP (% dev from R-454C)
0.73	0.27	~1	2	5.7	-1	21
0.78	0.22	~1	2	5	-2	26
0.83	0.17	~1	2	4.1	-2	31
0.88	0.12	~1	2	3.1	-2	36
0.93	0.07	~1	2	1.9	-3	42
0.98	0.02	~1	2	0.6	-3	48
0.01	0.99	~1	2L	0.6*	2*	-51*
0.99	0.01	~1	2	0.3*	-2*	52*
0.96	0.04	~1	2	1.3*	-2*	48*
0.97	0.03	~1	2	1*	-2*	49*
0.42	0.58	~1	2	8.5*	1*	-10*

Example 8: HFO-1132E and HFC-134

[0172] Broadly, a composition range of 74 to 99 wt-% of HFO-1132E and 1 to 26 wt-% HFC-134 will have a GWP less than 300, a maximum average glide of about 4.8 K in cooling mode, a cooling capacity range that is 26% to 49% greater than the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range is 3% to 1% less than the cooling COP of R-454C evaluated with the same conditions set. This same composition range will also result in a maximum average glide of about 5.4 K in heating mode, a heating capacity range that is 25% to 52% greater than the heating capacity of R-454C evaluated with the same conditions set, and the heating COP range is 2% to 1% less than the heating COP of R-454C evaluated with the same conditions set. Table X8 lists example compositions within the GWP<300 range that have ASHRAE flammability classifications of 2.

[0173] Preferred blend composition ranges for cooling within a composition range of 87 to 99 wt-% of HFO-1132E and 1 to 13 wt-% of HFC-134 will have GWP < 150, a maximum heat exchanger glide of 2.9 K (in the evaporator), an ASHRAE flammability classification 2, and minimum and maximum cooling capacities of 38% to 49% more than that of R-454C evaluated at the same conditions set. Preferred

blend composition ranges for heating within a composition range of 87 to 99 wt-% of HFO-1132E and 1 to 13 wt-% of HFC-134 will have a GWP < 150, a maximum heat exchanger glide of 3.1 K (in the evaporator), an ASHRAE flammability classification of 2, and minimum and maximum heating capacities of 39% less and 52% more than that of R-454C evaluated at the same conditions set.

[0174] The optimal composition for efficiency in both cooling and heating modes, which is 1% less than that for R-454C at the same conditions, is 74 wt-% HFO-1132E and 26 wt-% HFC-321, which has a GWP less than 300, an average glide of 4.8 and 5.4 K respectively for cooling and heating modes, 26% and 25% greater CAP than that for R-454C at the same conditions respectively, and has an ASHRAE flammability classification of 2.

Table X8: Residential Heat Pump conditions in both cooling and heating mode, cycle metric performance and fluid property ranges for HFO-1132E/HFC-134 in Example 8. Note that “*” indicates heating mode.

wt-frac R1132(E)	wt-frac R134	GWP AR5	ASHRAE flammab ility class	Glide (K)	COP (% dev from R-454C)	CAP (% dev from R-454C)
0.74	0.26	291	2	4.8	-1	26
0.99	0.01	11	2	0.2	-3	49
0.87	0.13	146	2	2.5	-2	38
0.98	0.02	22	2	0.4	-3	50
0.97	0.03	34	2	0.7	-3	49
0.96	0.04	45	2	0.9	-3	48
0.94	0.06	67	2	1.3	-3	46
0.93	0.07	78	2	1.6	-3	45
0.92	0.08	90	2	1.8	-3	44
0.91	0.09	101	2	2	-3	43
0.9	0.1	112	2	2.2	-3	42
0.89	0.11	123	2	2.4	-3	40
0.88	0.12	134	2	2.6	-3	39
0.87	0.13	146	2	2.8	-3	38
0.85	0.15	168	2	3.2	-3	36

wt-frac R1132(E)	wt-frac R134	GWP AR5	ASHRAE flammab ility class	Glide (K)	COP (% dev from R-454C)	CAP (% dev from R-454C)
0.83	0.17	190	2	3.7	-2	34
0.82	0.18	202	2	3.9	-2	33
0.8	0.2	224	2	4.2	-2	31
0.79	0.21	235	2	4.4	-2	30
0.78	0.22	246	2	4.6	-2	29
0.76	0.24	269	2	5	-2	27
0.75	0.25	280	2	5.2	-2	26
0.74	0.26	291	2	5.4	-2	25
0.74	0.26	291	2	5.4*	-1*	25*
0.99	0.01	11	2	0.2*	-2*	52*
0.98	0.02	22	2	0.4*	-2*	51*
0.97	0.03	34	2	0.7*	-2*	50*
0.87	0.13	146	2	2.8*	-2*	39*

Example 9: HFO-1132E and HFC-32

[0175] Broadly, a composition range of 56 to 99 wt-% of HFO-1132E and 1 to 44 wt-% HFC-321 will have a GWP less than 300, a maximum average glide of about 0.2 K in cooling mode, a cooling capacity range that is 51% to 65% greater than the cooling capacity of R-454C evaluated with the same conditions set, and the cooling COP range is 4% to 3% less than the cooling COP of R-454C evaluated with the same conditions set. This same composition range will also result in a maximum average glide of about 0.2 K in heating mode, a heating capacity range that is 54% to 68% greater than the heating capacity of R-454C evaluated with the same conditions set, and the heating COP range is 3% to 2% less than the heating COP of R-454C evaluated with the same conditions set. Table X9 lists example compositions within the GWP<300 range that have ASHRAE flammability classifications of 2L and 2.

[0176] Preferred blend composition ranges for cooling within a composition range of 78 to 99 wt-% of HFO-1132E and 1 to 22 wt-% of HFC-321 will have GWP < 150, a maximum heat exchanger glide of 0.2 K (in the condenser), an ASHRAE

flammability classification 2, and minimum and maximum cooling capacities of 51% to 60% more than that of R-454C evaluated at the same conditions set. Preferred blend composition ranges for heating within a composition range of 78 to 99 wt-% of HFO-1132E and 1 to 22 wt-% of HFC-321 will have a GWP < 150, a maximum heat exchanger glide of 0.2 K (in the condenser), an ASHRAE flammability classification of 2, and minimum and maximum heating capacities of 54% less and 64% more than that of R-454C evaluated at the same conditions set.

[0177] Other preferred blend composition ranges for cooling within a composition range of 56 to 60 wt-% of HFO-1132E and 40 to 44 wt-% of HFC-321 will have GWP < 300, a maximum heat exchanger glide less than 0.1 K (in the condenser), an ASHRAE flammability classification 2L, and minimum and maximum cooling capacities of 65% more than that of R-454C evaluated at the same conditions set. Other preferred blend composition ranges for heating within a composition range of 56 to 60 wt-% of HFO-1132E and 40 to 44 wt-% of HFC-321 will have a GWP < 300, a maximum heat exchanger glide of less than 0.1 K (in the condenser), an ASHRAE flammability classification of 2L, and minimum and maximum heating capacities of about 68% more than that of R-454C evaluated at the same conditions set.

[0178] The optimal composition for capacity for cooling and heating, which is 65% and 68% greater than that for R-454C at the same conditions respectively, is 56 wt-% HFO-1132E and 44 wt-% HFC-321, which has a GWP less than 300, an average glide of <0.1 K, 4% and 3% less COP than that for R-454C at the same conditions respectively, and has an ASHRAE flammability classification of 2L.

Table X9: Residential Heat Pump conditions in both cooling and heating mode, cycle metric performance and fluid property ranges for HFO-1132E/HFC-321 in Example 9. Note that “*” indicates heating mode.

wt-frac R1132(E)	wt-frac R32	GWP AR5	ASHRAE flammab ility class	Glide (K)	COP _c (% dev from R- 454C)	CAP _c (% dev from R- 454C)
0.56	0.44	298	2L	0	-4	65
0.99	0.01	7	2	0	-3	51
0.57	0.43	291	2L	0	-4	65
0.58	0.42	284	2L	0	-4	65

wt-frac R1132(E)	wt-frac R32	GWP AR5	ASHRAE flammab ility class	Glide (K)	COP_c (% dev from R- 454C)	CAP_c (% dev from R- 454C)
0.59	0.41	278	2L	0	-4	65
0.6	0.4	271	2L	0	-4	65
0.61	0.39	264	2	0	-4	65
0.62	0.38	257	2	0	-4	64
0.63	0.37	250	2	0	-4	64
0.64	0.36	244	2	0	-4	64
0.65	0.35	237	2	0	-4	64
0.66	0.34	230	2	0	-4	64
0.67	0.33	223	2	0	-4	63
0.68	0.32	217	2	0	-4	63
0.88	0.12	81	2	0.2	-3	56
0.78	0.22	149	2	0.1	-4	60
0.79	0.21	142	2	0.1	-4	60
0.57	0.43	291	2L	0	-4	65
0.59	0.41	278	2L	0.01	-4	65
0.61	0.39	264	2	0.01	-4	65
0.63	0.37	250	2	0.02	-4	64
0.65	0.35	237	2	0.03	-4	64
0.67	0.33	223	2	0.04	-4	63
0.69	0.31	210	2	0.05	-4	63
0.71	0.29	196	2	0.06	-4	62
0.75	0.25	169	2	0.09	-4	61
0.77	0.23	156	2	0.1	-4	61
0.79	0.21	142	2	0.12	-4	60
0.81	0.19	129	2	0.13	-4	59
0.83	0.17	115	2	0.14	-3	58
0.85	0.15	102	2	0.15	-3	58
0.87	0.13	88	2	0.15	-3	57
0.91	0.09	61	2	0.15	-3	55
0.93	0.07	47	2	0.13	-3	54

wt-fraction R1132(E)	wt-fraction R32	GWP AR5	ASHRAE flammability class	Glide (K)	COP _c (% dev from R- 454C)	CAP _c (% dev from R- 454C)
0.95	0.05	34	2	0.11	-3	53
0.97	0.03	20	2	0.08	-3	52
0.99	0.01	7	2	0.03	-3	51
0.56	0.44	298	2L	0*	-3*	68*
0.99	0.01	7	2	0*	-2*	54*
0.57	0.43	291	2L	0*	-3*	68*
0.88	0.12	81	2	0.2*	-3*	60*
0.78	0.22	149	2	0.1*	-3*	64*

[0179] While the invention has been described with reference to a preferred embodiment, it will be understood by those skilled in the art that various changes may be made, and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

CLAIMS

What is claimed is:

1. A composition comprising HFO-1132 and at least one compound selected from the group consisting of HFC-32, HFC-134, and HFO-1234zeE.
2. The composition of claim 1, wherein said composition comprises:
 - about 56 to about 99 weight percent HFO-1132E and about 1 to about 44 weight percent HFC-32; or
 - about 78 to about 99 weight percent HFO-1132E and about 1 to about 22 weight percent HFC-32; or
 - about 56 to about 60 weight percent of HFO-1132E and about 40 to about 44 weight percent of HFC-32; or
 - about 56 weight percent HFO-1132E and about 44 weight percent HFC-32.
3. The composition of claim 1, wherein said composition comprises:
 - about 74 to about 99 weight percent of HFO-1132E and 1 to about 26 weight percent HFC-134; or
 - about 87 to about 99 weight percent of HFO-1132E and 1 to about 13 weight percent of HFC-134; or
 - about 87 to about 99 weight percent of HFO-1132E and 1 to about 13 weight percent of HFC-134; or
 - about 74 weight percent HFO-1132E and about 26 weight percent HFC-134.
4. The composition of claim 1, wherein said composition comprises:
 - about 1 to about 99 weight percent of HFO-1132E and 1 to about 99 weight percent HFO-1234zeE; or
 - about 40 to about 61 weight percent of HFO-1132E and 39 to about 60 weight percent of HFO-1234zeE; or
 - about 42 to about 62 weight percent of HFO-1132E and about 38 to 58 of HFO-1234zeE.

5. The composition of claim 1, wherein said composition comprises:
- about 57 to about 98.5 wt-% of HFO-1132E, about 0.5 to about 26 wt-% HFC-134, and about 0.5 to about 43 wt-% HFC-32; or
 - about 79 to about 98.5 wt-% of HFO-1132E, about 0.5 to about 13 wt-% HFC-134, and about 0.5 to about 21 wt-% HFC-32; or
 - about 62 wt-% HFO-1132E, about 9 wt-% HFC-134 and about 29 wt-% HFC-32; or
 - about 86.6 wt-% HFO-1132E, about 12.9 wt-% HFC-134 and about 0.5 wt-% HFC-32; or
 - about 56.7 wt-% HFO-1132E, about 0.5 wt-% HFC-134 and about 42.8 wt-% HFC-32; or
 - about 78.6 wt-% HFO-1132E, about 0.5 wt-% HFC-134 and about 20.9 wt-% HFC-32.
6. The composition of claim 1, wherein said composition comprises:
- about 0.5 to about 98.5 wt-% of HFO-1132E, about 0.5 to about 98.5 wt-% HFO-1234zeE, and about 0.5 to about 44 wt-% HFC-32; or
 - about 0.5 to about 98.5 wt-% of HFO-1132E, about 0.5 to about 98.5 wt-% HFO-1234zeE, and about 0.5 to about 22 wt-% HFC-32; or
 - about 0.5 to about 98.5 wt-% of HFO-1132E, about 0.5 to about 98.5 wt-% HFO-1234zeE, and about 0.5 to about 44 wt-% HFC-32; or
 - about 0.5 to about 98.5 wt-% of HFO-1132E, about 0.5 to about 98.5 wt-% HFO-1234zeE, and about 0.5 to about 22 wt-% HFC-32 glide; or
 - about 6 to about 98.5 wt-% of HFO-1132E, about 0.5 to about 72 wt-% of HFO-1234zeE, and about 0.5 to about 22 wt-% of HFC-32; or
 - about 8 to about 98.5 wt-% of HFO-1132E, about 0.5 to about 70 of HFO-1234zeE, and about 0.5 to about 22 wt-% HFC-32; or
 - about 6 to about 42 wt-% HFO-1132E, about 47 to about 72 wt-% HFO-1234zeE, and about 3 to about 22 wt-% HFC-32; or
 - about 27 wt-% HFO-1132E, about 51 wt-% HFO-1234zeE and about 22 wt-% HFC-32; or

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

about 40 wt-% HFO-1132E, about 46 wt-% HFO-1234zeE and about 14 wt-% HFC-32; or

about 7 wt-% HFO-1132E, about 72 wt-% HFO-1234zeE and about 21 wt-% HFC-32; or

about 27 wt-% HFO-1132E, about 51 wt-% HFO-1234zeE, and about 22 wt-% HFC-32; or

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

about 40 wt-% HFO-1132E, about 46 wt-% HFO-1234zeE, and about 14 wt-% HFC-32.

7. The composition of claim 1, wherein said composition comprises:

about 30 weight percent HFO-1132E, about 21 weight percent HFC-32, and about 49 weight percent HFO-1234zeE; or

about 6 weight percent HFO-1132E, about 22 weight percent HFC-32, and about 72 weight percent HFO-1234zeE; or

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

about 45 weight percent HFO-1132E, about 10 weight percent HFC-32, and about 45 weight percent HFO-1234zeE; or

about 53 weight percent HFO-1132E, about 4 weight percent HFC-32, and about 43 weight percent HFO-1234zeE

8. The composition of claim 1, wherein said composition comprises:

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

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

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

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

about 39 to about 98.5 wt-% of HFO-1132E, about 0.5 to about 60 wt-% of HFO-1234zeE, and about 0.5 to about 13 of HFC-134; or

about 41 to about 98.5 wt-% of HFO-1132E, about 0.5 to about 57 of HFO-1234zeE, and about 0.5 to about 13 wt-% HFC-134; or

about 39 to about 47 wt-% HFO-1132E, about 40 to about 54 wt-% HFO-1234zeE, and about 6 to about 13 wt-% HFC-134; or

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

about 41 to about 47 wt-% HFO-1132E, about 40 to about 50 wt-% HFO-1234zeE, and about 8 to about 13 wt-% HFC-134; or

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

about 39 wt-% HFO-1132E, about 49 wt-% HFO-1234zeE and about 12 wt-% HFC-134; or

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

about 41 wt-% HFO-1132E, about 50 wt-% HFO-1234zeE and about 9 wt-% HFC-134; or

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

9. The composition of claim 1, wherein said composition comprises:

about 8 to 59 weight percent HFO-1132E, about 1 to about 22 weight percent HFC-32, about 1 to about 13 weight percent HFC-134, and about 30 to about 61 weight percent HFO-1234zeE; or

about 8 to 47 weight percent HFO-1132E, about 1 to about 22 weight percent HFC-32, about 1 to about 13 weight percent HFC-134, and about 37 to about 71 weight percent HFO-1234zeE; or

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

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

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

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

about 7 to about 98.5 wt-% of HFO-1132E, 0.25 to about 72 wt-% of HFO-1234zeE, 0.25 to about 13 wt-% of HFC-134, and 0.25 to about 21 wt-% of HFC-32; or

about 10 to about 98.5 wt-% of HFO-1132E, 0.25 to about 69 wt-% of HFO-1234zeE, 0.25 to about 13 wt-% of HFC-134, and 0.25 to about 21 wt-% HFC-32; or

about 7 to about 48 wt-% HFO-1132E, about 36 to about 72 wt-% HFO-1234zeE, about 0.5 to about 13 wt-% HFC-134, and about 0.5 to about 21 wt-% HFC-32; or

about 41.8 wt-% HFO-1132E, about 45.8 wt-% HFO-1234zeE, about 0.5 wt-% HFC-134 and about 11.9 wt-% HFC-32; or

about 7.0 wt-% HFO-1132E, about 71.6 wt-% HFO-1234zeE, about 0.5 wt-% HFC-134 and about 20.9 wt-% HFC-32; or

about 10 to about 48 wt-% HFO-1132E, about 36 to about 69 wt-% HFO-1234zeE, about 0.5 to about 13 wt-% HFC-134, and about 0.5 to about 21 wt-% HFC-32; or

about 40 wt-% HFO-1132E, about 42 wt-% HFO-1234zeE, about 4 wt-% HFC-134 and about 14 wt-% HFC-32; or

about 10.9 wt-% HFO-1132E, about 68.7 wt-% HFO-1234zeE, about 0.5 wt-% HFC-134 and about 19.9 wt-% HFC-32.

10. The composition of claim 1, wherein said composition comprises:

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

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

about 6 to about 64 weight percent HFO-1132E, about 1 to about 66 weight percent HFO-1132Z, about 1 to about 22 weight percent HFC-32, and about 1 to about 72 weight percent HFO-1234zeE; or

about 8 to about 65 weight percent HFO-1132E, about 1 to about 63 weight percent HFO-1132Z, about 1 to about 22 weight percent HFC-32, and about 1 to about 69 weight percent HFO-1234zeE; or

about 8 to about 42 weight percent HFO-1132E, about 1 to about 37 weight percent HFO-1132Z, about 3 to about 22 weight percent HFC-32, and about 29 to about 69 weight percent HFO-1234zeE

11. The composition of claim 1, wherein said composition comprises:

about 1 to about 79 weight percent HFO-1132Z; about 19 to about 44 weight percent HFC-32, and about 1 to about 81 weight percent HFO-1234zeE; or

about 1 to about 49 weight percent HFO-1132Z, about 19 to about 22 weight percent HFC-32, and about 29 to about 81 weight percent HFO-1234zeE; or

about 1 to about 51 weight percent HFO-1132Z, about 21 to about 22 weight percent HFC-32, and about 27 to about 78 weight percent HFO-1234zeE.

12. The composition of claim 1, wherein said composition comprises:
- about 1 to about 97 weight percent HFO-1132E, about 1 to about 97 weight percent HFO-1132Z, about 1 to about 97 weight percent HFO-1234zeE, and about 1 to about 26 weight percent HFC-134; or
- about 1 to about 97 weight percent HFO-1132E, about 1 to about 97 weight percent HFO-1132Z, about 1 to about 97 weight percent HFO-1234zeE, and about 1 to about 13 weight percent HFC-134.
13. The composition of claim 1, wherein said composition comprises:
- about 30 weight percent HFO-1132Z, about 21 weight percent HFC-32, and about 49 weight percent HFO-1234zeE; or
- about 1 weight percent HFO-1132Z, about 22 weight percent HFC-32, and about 77 weight percent HFO-1234zeE.
14. The composition of claim 1, wherein said composition comprises:
- about 10 weight percent HFO-1132Z, about 34 weight percent HFO-1132E, about 19 weight percent HFC-32, and about 37 weight percent HFO-1234zeE; or
- about 34 weight percent HFO-1132Z, about 14 weight percent HFO-1132E, about 20 weight percent HFC-32, and about 32 weight percent HFO-1234zeE.
15. The composition of any of claims 1 to 14, further comprising at least one additional compound selected from methane, ethane, HCFC-22, HFC-23, HCC-30, HCFC-31, HCC-40, HFC-41, HFCF-22, HFO-1141, HFO-1225yeE, HFO-1225yeZ, HFO-1234yf, HFO-1243zf, HFC-161, HFC-152, HFC-143, HFC-143a, HFC-134a, HCFO-1122, HCFO-1122aE, HCFO-1122aZ, HCC-150, HCFC-151, CFO-1112E, CFO-1112Z, HCFC-142a, HCFC-132, HCFC-133, HCFC-133b, HCFC-123, HFC-236fa, HFC-245fa, HFC-245eb, HFO-1123, HFO-1132a, HCFO-1131E, HCFO-1131Z, ethylene, and acetylene.
16. The composition of any of claims 1 to 15, 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.

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

26. The composition of claim 25, wherein said tracer is present in an amount from about 1.0 ppm by weight to about 1000 ppm by weight.
27. The composition of any of claims 25 or 26, 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.
28. The composition of any of claims 25 to 27, 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.
29. The composition of any of claims 1 to 28, 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.
30. A method for cooling comprising evaporating a composition of any of claims 1 to 29 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.
31. A method for heating comprising evaporating a composition of any of claims 1 to 29 and thereafter condensing said composition in the vicinity of a body to be heated, wherein said heating is provided by a heat pump.

32. A system for cooling or heating comprising a composition of any of claims 1 to 29.
33. The system of claim 32, comprising an evaporator, compressor, condenser, and expansion device, each operably connected to perform a vapor compression cycle.
34. The system of claim 32 or 33, wherein said air-conditioner or heat pump is a residential, light commercial, or industrial air-conditioner or heat pump.
35. The system of any of claims 32 to 34, wherein the system is an automobile heat pump for cooling and heating the passenger compartment of an electric or hybrid vehicle.
36. The system of any of claims 32 to 35, wherein the system is a secondary loop system.
37. The system of any of claims 34, 35, or 36, wherein the system does not include a PTC heater.
38. A method of replacing at least one of R-22, HFC-134a, propane, HFO-1234yf, R-407C, R-404A, R-410A, R-513A, R-454A, R-454B, R-454C, R-448A, R-449A, R-449B, R-449C, R-452A, R-452C, or in refrigeration, air-conditioning, heat pump, or chiller systems comprising providing the composition of any of claims 1 to 29 to the system in place of R-22, HFC-134a, propane, HFO-1234yf, R-407C, R-404A, R-410A, R-513A, R-454A, R-454B, R-454C, R-448A, R-449A, R-449B, R-449C, R-452A, R-452C.
39. Use of the composition of any of claims 1 to 29 as refrigerant in air-conditioning, heat pump systems.
40. The use of claim 39, wherein the air-conditioning or heat pump systems comprise mobile or stationary air conditioning, mobile or stationary heat pumps, residential, light commercial, or industrial air-conditioner, residential, light commercial, or industrial heat pump.
41. The use of claim 39 or 40, wherein the system is an automobile heat pump for cooling and heating the passenger compartment of an electric or hybrid vehicle.

- 42. The use of any of claims 39 to 41, wherein the system is a secondary loop system.
- 42. The use of any of claims 38 to 41, wherein the system does not include a PTC heater.
- 43. The use of any of claims 39 to 42, wherein the composition of claims 1 to 22 is replacing any one of R-22, HFC-134a, propane, HFO-1234yf, R-407C, R-404A, R-410A, R-513A, R-454A, R-454B, R-454C, R-448A, R-449A, R-449B, R-449C, R-452A, or R-452C.