

TITLE OF THE INVENTION

RECLAMATION PROCESSES INCLUDING AZEOTROPIC
AND OTHER CLOSE-BOILING THERMAL FLUIDS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of priority of U.S. Provisional Application 63/627,429 filed January 31, 2024 and U.S. Provisional Application 63/564,049 filed March 12, 2024, the disclosure of each of which is incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

[0002] The present disclosure relates to systems and processes of thermal fluid reclamation. More specifically, the present disclosure relates to systems and processes of converting spent thermal fluids into reclaimed azeotropic, near-azeotrope, and other close-boiling thermal fluids.

BACKGROUND OF THE INVENTION

[0003] Thermal fluid or refrigerant reclamation has long attracted significant attention due to regulatory requirements and increasing emphasis on circularity, emissions reduction, and resource efficiency. An efficient and effective reclamation process benefits both the environment and the global economy. Indeed, in the absence of such a reclamation process, the thermal fluids would have to be destroyed or otherwise disposed of, such as by thermal oxidation, which is very energy intensive and results in a loss of product to the circular economy.

[0004] Historically, most reclamation processes have simply been achieved by removing contaminants from the thermal fluids and rebalancing the purified blends by addition of components. Historically, where separation has been used, refrigerant reclamation has been limited essentially to single-compound fluids.

[0005] Conventional reclamation requires sending the used refrigerants to a reclamation site for further processing, including purification, which may include drying, acids removal, and/or separation of various components by distillation. During the process, the used refrigerants are often combined in a mixed tank at the

reclamation site. Although this simplifies the storage process, it brings challenges and complexity in separation, especially for close-boiling, near-azeotrope, and azeotropic components in the recovered mixture. For example, to obtain pure close-boiling, near-azeotrope, and azeotropic components, a large separation column may be required, in addition to technical processes such as extraction distillation, all of which may be energy-intensive, labor-intensive, and time-consuming, and lead to a large environmental footprint.

[0006] Efficient and effective reclamation of azeotropic, near-azeotrope, and other close-boiling thermal fluids which minimize environmental footprint would further benefit both the environment and the global economy.

SUMMARY OF THE INVENTION

[0007] Embodiment 1. A process of thermal fluid reclamation comprising: recovering a thermal fluid comprising at least a first refrigerant compound, a second refrigerant compound and a third refrigerant compound; testing the recovered thermal fluid and validating that the recovered thermal fluid has greater than about 95 wt%, preferably greater than about 99 wt%, most preferably greater than about 99.5 wt% organic purity; and distilling the recovered thermal fluid to form at least one distillate comprising the first refrigerant compound and the second refrigerant compound as a reclaimed thermal fluid, wherein the reclaimed thermal fluid is azeotropic, near-azeotrope, or close-boiling.

[0008] Embodiment 2. The process of Embodiment 1, wherein the reclaimed thermal fluid is a thermal fluid product, the process further comprising supplying the reclaimed thermal fluid to a heat transfer system for use therein.

[0009] Embodiment 3. The process of Embodiment 1, further comprising packaging the reclaimed thermal fluid for commercial sale as a thermal fluid product for use in a heat transfer system.

[0010] Embodiment 4. The process of Embodiment 1, further comprising supplying the reclaimed thermal fluid for formation of a thermal fluid product.

[0011] Embodiment 5. The process of any of Embodiments 1-4, the process further comprising adjusting a ratio of the first refrigerant compound to the second

refrigerant compound of the reclaimed thermal fluid by adding an additional amount of at least one of the first refrigerant compound and the second refrigerant compound to the reclaimed thermal fluid.

[0012] Embodiment 6. The process of any of Embodiments 1-5, wherein the validating comprises removing one or more impurities from the recovered thermal fluid before distilling such that the recovered thermal fluid has greater than about 95 wt%, preferably greater than about 99 wt%, most preferably greater than about 99.5 wt% organic purity.

[0013] Embodiment 7. The process of Embodiment 6, wherein the one or more impurities comprises an oil.

[0014] Embodiment 8. The process of any of Embodiments 1-7, further comprising adding a stabilizer package to the reclaimed thermal fluid.

[0015] Embodiment 9. The process of any of Embodiments 1-8, wherein the reclaimed thermal fluid is azeotropic.

[0016] Embodiment 10. The process of any of Embodiments 1-9, further comprising testing the reclaimed thermal fluid and validating that the reclaimed thermal fluid has greater than about 95 wt%, preferably greater than about 99 wt%, most preferably greater than about 99.5 wt% organic purity

[0017] Embodiment 11. The process of Embodiment 10, wherein validating of the reclaimed thermal fluid comprises removing one or more impurities from the reclaimed thermal fluid such that the reclaimed thermal fluid has greater than about 95 wt%, preferably greater than about 99 wt%, most preferably greater than about 99.5 wt% organic purity.

[0018] Embodiment 12. The process of any of Embodiments 1-11, further comprising purifying the reclaimed thermal fluid to a state that meets AHRI Standard 700 purity specifications.

[0019] Embodiment 13. The process of any of Embodiments 1-12, wherein the distilling of the recovered thermal fluid forms a further distillate comprising the third refrigerant compound as a second reclaimed thermal fluid, wherein the second reclaimed thermal fluid is a neat reclaimed thermal fluid.

[0020] Embodiment 14. The process of any of Embodiments 1-12, wherein the recovered thermal fluid further comprises a fourth refrigerant compound, and wherein the distilling of the recovered thermal fluid forms a further distillate comprising the third refrigerant compound and the fourth refrigerant compound as a second reclaimed thermal fluid, wherein the first reclaimed thermal fluid and the second reclaimed thermal fluid are azeotropic, near-azeotrope, or close-boiling.

[0021] Embodiment 15. The process of any of Embodiments 1-12, wherein the recovered thermal fluid further comprises a fourth refrigerant compound and a fifth refrigerant compound, and wherein the distilling of the recovered thermal fluid forms a second distillate comprising the third refrigerant compound and the fourth refrigerant compound as a second reclaimed thermal fluid and a third distillate comprising the fifth refrigerant compound as a third reclaimed thermal fluid, wherein the first reclaimed thermal fluid and the second reclaimed thermal fluid are azeotropic, near-azeotrope, or close-boiling and wherein the third reclaimed thermal fluid is a neat reclaimed thermal fluid.

[0022] Embodiment 16. The process of any of Embodiments 1-15, wherein the first refrigerant compound and the second refrigerant compound are HFC-125 and HFC-32.

[0023] Embodiment 17. The process of Embodiment 16, wherein the recovered thermal fluid is selected from the group consisting of R-407A, R-407B, R-407C, R-407D, R-407E, R-407F, R-407G, R407H and R407I, preferably R-407C.

[0024] Embodiment 18. The process of Embodiment 17, wherein the third refrigerant compound is HFC-134a.

[0025] Embodiment 19. The process of any of Embodiments 16-18, wherein near-azeotrope or close-boiling reclaimed thermal fluid is R-410A (50% HFC-125 / 50% HFC-32).

[0026] Embodiment 20. The process of any of Embodiments 16-19, wherein the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-125; HFC-32; one or more additional compounds selected from HFC-23, HFC-32, HFC-143a, HFC-134a, HFC-134, CFC-115, CFCO-1113 and HCC-40; and one or

more additional compounds selected from HFC-143a, HFC-41, HFC-134a, HCFC-22, CFC-12 and HCC-40.

[0027] Embodiment 21. The process of Embodiment 14, wherein the first refrigerant compound and the second refrigerant compound are HFC-125 and HFC-32, and wherein the third refrigerant compound and the fourth refrigerant compound are HFC-134a and HFO-1234yf.

[0028] Embodiment 22. The process of Embodiment 21, wherein the recovered thermal fluid is R-449A.

[0029] Embodiment 23. The process of any of Embodiments 21-22, wherein the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is R-410A (50% HFC-125 / 50% HFC-32), and wherein the second azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is selected from the group consisting of R-513A (44% HFC-134a / 56% HFO-1234yf) and R-513B (41.5% HFC-134a / 58.5% HFO-1234yf).

[0030] Embodiment 24. The process of any of Embodiments 21-23, wherein the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-125; HFC-32; one or more additional compounds selected from HFC-23, HFC-32, HFC-143a, HFC-134a, HFC-134, CFC-115, CFCO-1113 and HCC-40; and one or more additional compounds selected from HFC-143a, HFC-41, HFC-134a, HCFC-22, CFC-12 and HCC-40; and wherein the second azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-134a; HFO-1234yf; one or more additional compounds selected from HFC-143a, HFO-1225zc, HFC-245cb, HFC-134, HFC-152a, HFO-1225ye, HFC-161, E-HFO-1234ze, HCFC-22, HFO-1243zf, CHFC-124, HCC-40, CHFO-1122, HCFC-31, CFC-114, CFC-114a and HCO-1140; and one or more additional compounds selected from HFO-1225ye, HFO-1243zf, E-HFO-1234ze, HFC-236ea, HCFC-244bb, HFC-245fa, HFC-245eb, HFC-245cb, 3,3,3-trifluoropropyne, HFC-152a, FO-1114, HFO-1123, HCFO-1131a, trans-HCFO-1131, HCO-1140, HCFO-1214ya, FO-1216, HCFO-1224yd, HFO-1252 isomers, HFC-143a, HCFC-225, HFC-254eb, HFC-263fb, HFC-236fa, HCFC-142b, HCFC-244cc, HCFO-1223, HFO-1132a and HCC-40.

[0031] Embodiment 25. The process of Embodiment 15, wherein the first refrigerant compound and the second refrigerant compound are HFC-125 and HFC-

32, wherein the third refrigerant compound and the fourth refrigerant compound are HFC-134a and HFO-1234yf, wherein the fifth refrigerant compound is E-HFO-1234ze.

[0032] Embodiment 26. The process of Embodiment 25, wherein the recovered thermal fluid is R-448A.

[0033] Embodiment 27. The process of any of Embodiments 25-26, wherein the near-azeotrope or close-boiling reclaimed thermal fluid is R-410A (50% HFC-125 / 50% HFC-32), wherein the second azeotropic reclaimed thermal fluid is selected from the group consisting of R-513A (44% HFC-134a / 56% HFO-1234yf) and R-513B (41.5% HFC-134a/58.5% HFO-1234yf), and wherein the third reclaimed fluid comprises E HFO-1234ze.

[0034] Embodiment 28. The process of any of Embodiments 25-27, wherein the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-125; HFC-32; one or more additional compounds selected from HFC-23, HFC-32, HFC-143a, HFC-134a, CFC-115, CFCO-1113 and HCC-40; and one or more additional compounds selected from HFC-143a, HFC-41, HFC-134a, HCFC-22, CFC-12 and HCC-40; and wherein the second azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-134a; HFO-1234yf; one or more additional compounds selected from HFC-143a, HFO-1225zc, HFC-245cb, HFC-134, HFC-152a, HFO-1225ye, HFC-161, E-HFO-1234ze, HCFC-22, HFO-1243zf, CHFC-124, HCC-40, CHFO-1122, HCFC-31, CFC-114, CFC-114a and HCO-1140; and one or more additional compounds selected from HFO-1225ye, HFO-1243zf, E-HFO-1234ze, HFC-236ea, HCFC-244bb, HFC-245fa, HFC-245eb, HFC-245cb, 3,3,3-trifluoropropyne, HFC-152a, FO-1114, HFO-1123, HCFO-1131a, trans-HCFO-1131, HCO-1140, HCFO-1214ya, FO-1216, HCFO-1224yd, HFO-1252 isomers, HFC-143a, HCFC-225, HFC-254eb, HFC-263fb, HFC-236fa, HCFC-142b, HCFC-244cc, HCFO-1223, HFO-1132a and HCC-40.

[0035] Embodiment 29. The process of any of Embodiments 1-15, wherein the first refrigerant compound and the second refrigerant compound are HFC-227ea and E-HFO-1234ze.

[0036] Embodiment 30. The process of Embodiment 29, wherein the recovered thermal fluid is R-471A.

[0037] Embodiment 31. The process of any of Embodiments 29-30, wherein the third refrigerant compound is E-HFO-1336mzz.

[0038] Embodiment 32. The process of any of Embodiments 29-31, wherein the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is R-515B (8.9% HFC-227ea / 91.1% E-HFO-1234ze).

[0039] Embodiment 33. The process of any of Embodiments 29-32, wherein the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-227ea; E-HFO-1234ze; one or more additional compounds selected from HFC-23, FC-1216, HFC-143a, HFC-134a, HCFC-22, HCFC-124, FC-218, HFC-236fa and HFO-1225zc; and one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225yf(E), HFO-1225yf(Z), HFO-1225zc, HFC-236fa, HFC-152a, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, R-2223, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb and HFC-134.

[0040] Embodiment 34. The process of any of Embodiments 1-15, wherein the first refrigerant compound and the second refrigerant compound are HFC-32 and E-HFO-1132.

[0041] Embodiment 35. The process of Embodiment 34, wherein the recovered thermal fluid is R-479A.

[0042] Embodiment 36. The process of any of Embodiments 34-35, wherein the third refrigerant compound is HFO-1234yf.

[0043] Embodiment 37. The process of any of Embodiments 34-36, wherein the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-32; E-HFO-1132; one or more additional compounds selected from HFC-143a, HFC-41, HFC-134a, HCFC-22, CFC-12 and HCC-40; and one or more additional compounds selected from HFC-32, HFC-125, HCFO-E-1122a, HCFO-Z-1122a, HFO-1123, HFO-1141, HCFC-133, HCFC-133b, HCFC-123, HFC-152, HFC-143, HFC-41, HCFC-22, ethylene, HCFC-142a, HFO-1132a, HCFO-1131a, HCFO-E-1131, HCFO-Z-1131, HCFO-1122, acetylene and HCO-1140.

[0044] Embodiment 38. The process of any of Embodiments 1-15, wherein the first refrigerant compound and the second refrigerant compound are HFC-152a and E-HFO-1234ze.

[0045] Embodiment 39. The process of Embodiment 38, wherein the recovered thermal fluid is R-444A or R 444B.

[0046] Embodiment 40. The process of any of Embodiments 38-39, wherein the third refrigerant compound is HFC-32.

[0047] Embodiment 41. The process of any of Embodiments 38-40, wherein the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-152a; E-HFO-1234ze; one or more additional compounds selected from HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a; and one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225yf(E), HFO-1225yf(Z), HFO-1225zc, HFC-236fa, HFC-152a, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, R-2223, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb and HFC-134.

[0048] Embodiment 42: The process of any of Embodiments 1-41, wherein the recovered thermal fluid and/or the at least one distillate comprises at least one acid scavenger and/or at least one inhibitor selected from the group consisting of hydrocarbons including at least cyclic monoterpene; lipophilic organic compounds; and phenols, aromatic organic compounds having at least one chemical moiety - C₆H₄(OH), preferably at least one member selected from the group consisting of D-limonene, pinene, α -pinene, β -pinene, α -terpinene, α -tocopherol, butylated hydroxytoluene, 4-methoxyphenol, benzene-1,4-diol, and mixtures thereof.

[0049] Embodiment 43. A reclaimed thermal fluid formed by the process of any of Embodiments 1-42.

[0050] Other features and advantages of the present invention will be apparent from the following more detailed description, taken in conjunction with the accompanying drawings which illustrate, by way of example, the principles of this disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0051] FIG. 1 schematically shows a system for reclaiming thermal fluid compositions as azeotropes or near-azeotropes or close-boiling compositions or fractions and as neat compositions, according to an embodiment of the present invention.

[0052] FIG. 2 schematically shows a system for reclaiming thermal fluid compositions as multiple azeotropes or near-azeotropes or close-boiling compositions or fractions, according to an embodiment of the present invention,

[0053] FIG. 3 schematically shows a system for reclaiming thermal fluid compositions as multiple azeotropes or near-azeotropes or close-boiling compositions or fractions and as a neat composition, according to an embodiment of the present invention.

[0054] FIG. 4 schematically shows a system for reclaiming thermal fluid compositions as azeotropes or near-azeotropes or close-boiling compositions or fractions and as neat compositions, according to an embodiment of the present invention.

[0055] FIG. 5 schematically shows distillation systems for Example 1 and Comparative Example 1.

[0056] FIG. 6 schematically shows distillation systems for Example 2 and Comparative Example 2.

[0057] FIG. 7 schematically shows distillation systems for Example 3 and Comparative Example 3.

[0058] FIG. 8 schematically shows distillation systems for Example 4 and Comparative Example 4.

[0059] FIG. 9 schematically shows distillation systems for Example 6 and Comparative Example 6.

[0060] FIG. 10 schematically shows distillation systems for Example 7 and Comparative Example 7.

[0061] Wherever possible, the same reference numbers will be used throughout the drawings to represent the same parts.

DETAILED DESCRIPTION OF THE INVENTION

[0062] In exemplary embodiments, an integrated business and engineering process effectively and efficiently recovers a multicomponent thermal fluid blend, purifies the recovered fluid, and provides product streams of reclaimed azeotropic, near-azeotrope, and/or close-boiling thermal fluids for use in a heat transfer system. The systems and methods of the present invention reduces both manufacture of virgin thermal fluids and the need for energy intensive destruction of out-of-specification (conventionally unreclaimable) spent thermal fluids.

[0063] In exemplary embodiments, systems and processes of thermal fluid reclamation collect a recovered thermal fluid including at least three refrigerant compounds. The systems and processes validate that the collected thermal fluid has greater than about 95 wt%, about 96 wt%, about 97 wt%, about 98 wt%, about 99 wt%, or about 99.5 wt% organic purity. The systems and processes distill the collected thermal fluid to form at least one reclaimed thermal fluid. The systems and processes further include analyzing and purifying the at least one reclaimed thermal fluid. The at least one reclaimed thermal fluid is azeotropic, near-azeotrope, or close-boiling.

[0064] As used herein, "refrigerant compound" refers to any fluorocarbon (FC), hydrofluorocarbon (HFC), hydrochlorofluorocarbon (HCFC), chlorofluorocarbon (CFC), hydrochloroolefin (HCO), hydrofluoroolefin (HFO), chlorofluoroolefin (CFO), hydrochlorofluoroolefin (HCFO), hydrocarbon (HC), or carbon dioxide (R-744) that may be used alone or in a blend with other refrigerant compounds as a thermal fluid.

[0065] As used herein, "thermal fluid" refers to any fluid used for heat transfer in a closed-loop system.

[0066] As used herein, "near-azeotrope" refers to a composition of two or more refrigerant compounds that behaves like an azeotropic composition (i.e., has constant boiling characteristics or a tendency not to fractionate upon boiling or evaporation). Hence, during boiling or evaporation, the vapor and liquid compositions, if they change at all, change only to a minimal or negligible extent. In

contrast, the vapor and liquid compositions of non-near-azeotrope compositions change to a substantial degree during boiling or evaporation. As used herein, "near-azeotrope" refers to a composition exhibiting near-azeotrope behavior.

[0067] As used herein, "near-azeotrope behavior" refers to a behavior exhibiting dew point pressure and bubble point pressure with virtually no pressure differential. In some embodiments, the difference in the dew point pressure and bubble point pressure at a given temperature is 10% or less, alternatively 9% or less, alternatively 8% or less, alternatively 7% or less, alternatively 6% or less, alternatively 5% or less, alternatively 4% or less, alternatively 3% or less, alternatively 2% or less, alternatively 1% or less, or any value, range, or sub-range therebetween.

[0068] As used herein, "close-boiling composition" refers to compositions including at least two refrigerant compounds having a boiling point difference within about 20°C, or within about 18°C, or within about 15°C, or within about 10°C, or within about 8°C, or within about 5°C, or within about 3°C. In some embodiments, the boiling point difference is less than about 20°C, alternatively less than about 19°C, alternatively less than about 18°C, alternatively less than about 17°C, alternatively less than about 16°C, alternatively less than about 15°C, alternatively less than about 14°C, alternatively less than about 13°C, alternatively less than about 12°C, alternatively less than about 11°C, alternatively less than about 10°C, alternatively less than about 9°C, alternatively less than about 8°C, alternatively less than about 7°C, alternatively less than about 6°C, alternatively less than about 5°C, alternatively less than about 4°C, alternatively less than about 3°C, alternatively less than about 2°C, or any value, range, or sub-range therebetween.

[0069] As used herein, "virgin thermal fluid" refers to a thermal fluid composition having at least about 95 wt% organic purity, preferably at least about 99 wt% organic purity, most preferably at least about 99.5 wt% organic purity, and that has not yet been used in a thermal fluid application.

[0070] As used herein, "used thermal fluid" refers to a thermal fluid composition having at least about 95 wt% organic purity, preferably at least about 99 wt% organic purity, most preferably at least about 99.5 wt% organic purity, and that has been used as a thermal fluid.

[0071] As used herein, “spent thermal fluid” refers to a thermal fluid composition having less than about 95 wt% organic purity, preferably less than about 99 wt% organic purity, most preferably less than about 99.5 wt% organic purity, and that has been used as a thermal fluid.

[0072] As used herein, “recovered thermal fluid” refers to a spent thermal fluid or a used thermal fluid drained or otherwise removed from a thermal management device, such as, for example, a refrigeration, an air-conditioning system or a heat pump.

[0073] As used herein, “reclaimed thermal fluid” refers to a distillation product of a consolidated thermal fluid having at least about 95 wt% organic purity, preferably at least about 99 wt% organic purity, most preferably at least about 99.5 wt% organic purity and meeting conventional specifications for commercial use or sale as a thermal fluid.

[0074] As used herein, “organic purity” refers to the degree to which a fluid or fluid composition is free of contaminants such as oil and inorganic materials, such as water, acid, non-absorbable gases (NAGs), particulates/solids, and the like.

[0075] In some embodiments, “virgin thermal fluid”, “used thermal fluid”, “spent thermal fluid”, “recovered thermal fluid” and/or “reclaimed thermal fluid”, as used herein, refer to a thermal fluid composition as each is defined above, and optionally further comprising at least one stabilizer, particularly when the thermal fluid composition includes an HFO refrigerant compound, such as R-1234yf. In some embodiments, the stabilizer comprises at least one inhibitor compound that inhibits, if not eliminates, a fluoroethylene from interacting with another compound and forming dimers, oligomers, homopolymers, or polymeric products. In some embodiments, the at least one inhibitor is selected from hydrocarbons such as cyclic monoterpenes (e.g., limonene, pinene, α -pinene, β -pinene, and terpinene); lipophilic organic compounds such as tocopherols (e.g., α -tocopherol) or butylated hydroxytoluene (BHT); phenols or aromatic organic compounds having at least one chemical moiety -C₆H₄(OH) (e.g., benzene-1,4-diol, 4-methoxyphenol); and mixtures thereof. Specific examples of inhibitor compounds may include at least one member selected from limonene (particularly D-limonene), α -terpinene, pinene, α -pinene, β -pinene, α -tocopherol, butylated hydroxytoluene (BHT), 4-methoxyphenol, benzene-1,4-diol,

and mixtures thereof. In one embodiment, the thermal fluid composition of any of a “virgin thermal fluid”, “used thermal fluid”, “spent thermal fluid”, “recovered thermal fluid” and/or “reclaimed thermal fluid”, each as defined above, comprises R-1234yf and at least one stabilizer comprising at least one inhibitor selected from hydrocarbons including at least cyclic monoterpene; lipophilic organic compounds; or phenols, aromatic organic compounds having at least one chemical moiety - $C_6H_4(OH)$, and more particularly selected from limonene (particularly D-limonene), α -terpinene, pinene, α -pinene, β -pinene, α -tocopherol, butylated hydroxytoluene (BHT), 4-methoxyphenol, benzene-1,4-diol, and mixtures thereof.

[0076] In another embodiment, the stabilizer comprises an acid scavenger, such as, but not limited to, hindered amines and epoxy compounds such as epoxy butene. In one embodiment, the thermal fluid composition of any of a “virgin thermal fluid”, “used thermal fluid”, “spent thermal fluid”, “recovered thermal fluid” “consolidated thermal fluid composition” and/or “reclaimed thermal fluid”, each as defined above, comprises at least one refrigerant compound, such as an HFO refrigerant compound, and at least one stabilizer comprising at least one acid scavenger, such as, but not limited to, hindered amines and epoxy compounds such as epoxy butene.

[0077] Further details of the optional stabilizer are provided herein.

[0078] FIGS. 1-4 show a system for reclaiming one or more thermal fluid compositions 20, 22, 24 from a recovered thermal fluid 10. The recovered thermal fluid 10 is a blend of two or more refrigerant compounds, preferably a blend of three or more refrigerant compounds. The recovered thermal fluid 10 is collected in a storage tank 16. In the methods and systems of the present invention, the identities of the refrigerant compounds in each recovered thermal fluid 10 are known or determined prior to adding the recovered thermal fluid 10 to the storage tank 16.

[0079] The recovered thermal fluid 10 is preferably tested and/or validated for organic purity. In one embodiment, the recovered thermal fluid is tested to determine the composition, water content, NAG content, acidity content, and/or the organic purity.

[0080] In one embodiment, the recovered thermal fluid 10 is validated or treated, such as by purifying as needed for at least one of water content, NAG content, acidity content, and/or removing one or more impurities to achieve an organic purity

of at least about 95 wt%, or about 96 wt%, or about 97 wt%, or about 98 wt%, or about 99 wt%, or about 99.5 wt%.

[0081] The tested and validated (also referred to herein as treated) recovered thermal fluid 12 is then fed as needed to at least one distillation column or other appropriate distillation system 18, from which one or more distillate streams are collected and stored in respective reclaimed storage tanks until needed for a further application. In one embodiment, as shown in FIGS. 1-2 and 4, at least two distillate streams 20, 22, 24 are collected from the distillation system 18 and stored as reclaimed thermal fluids in respective reclaimed storage tanks 30, 32, 34, one for each reclaimed thermal fluid composition, until needed for a further application. In one embodiment, as shown in FIG. 3, at least three distillate streams 20, 22, 24 are collected from the distillation system 18 and stored as reclaimed thermal fluids in first and second reclaimed storage tanks 30, 32, 34, respectively, one for each reclaimed thermal fluid composition, until needed for a further application.

[0082] It will be understood by those skilled in the art that that while the description herein primarily refers to one, two or three reclaimed thermal fluid compositions 20, 22, 24 of the exemplary embodiments of FIGS. 1-4, the invention applies to any number of collected distillate streams and any number of reclaimed thermal fluid compositions and is not limited to one, two or three such streams and compositions as shown in FIGS. 1-4.

[0083] At least one of the reclaimed thermal fluids 20, 22, 24 is an azeotropic, near-azeotrope, or a close-boiling composition of two or more refrigerant compounds. Alternatively, in some embodiments, two, three, or all of the reclaimed thermal fluids 20, 22, 24 are azeotropic, near-azeotrope, or close-boiling compositions of two or more refrigerant compounds (for example, see FIG. 2).

[0084] Alternatively, in some embodiments, as shown in FIGS. 1 and 3-4, at least one or at least two of the reclaimed thermal fluids 20, 24 are azeotropic, near-azeotrope, or close-boiling compositions of two or more refrigerant compounds, while at least one other of the reclaimed thermal fluids 22 is a single refrigerant composition. As shown in FIG. 4, the reclaimed thermal fluid 20 may be an azeotropic, near-azeotrope, or close-boiling composition of three or more refrigerant compounds. It will be understood by those skilled in the art that the azeotropic, near-

azeotrope, or close-boiling compositions may comprise any plurality of refrigerant compounds. It will also be understood by those skilled in the art that while the reclaimed thermal fluid 22 is referred to herein as comprising a single refrigerant compound, the fluid 22 may further comprise very small amounts of one or more additional refrigerant compounds. Such fluids are referred to herein as a neat reclaimed thermal fluid.

[0085] Each distillate stream 20, 22, 24 is comprised of a single or a plurality of fractions. Each distillate fraction is comprised of the same refrigerant compound or compounds which make up the respective stream 20, 22, 24. In some embodiments, where the stream 20, 24 comprises two or more refrigerant compounds, each fraction is comprised of the two or more refrigerant compounds. The proportions of the compounds may be the same or may be different among the various distillate fractions.

[0086] The system may operate on a continuous, batch, or semi-batch basis.

[0087] The reclaimed thermal fluids 20, 22, 24, whether blended or single component reclaimed thermal fluids, may each individually be subjected to a final purification and analysis to confirm their composition and that they are commercial grade. The final purification and analysis may include analyzing and purifying as needed for water content, NAG content, acidity content of other impurities, and/or organic purity.

[0088] In some embodiments, all or a portion of an azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid 20, 24 may be used directly in a heat transfer system or packaged for use in a heat transfer system. That is, an azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid 20, 24 obtained from the distillation system 18 and optionally after purification constitutes a commercial-grade thermal fluid blend and is thus directly suitable for use in a heat transfer system, without the need for adjustment of the composition ratios of the compounds contained in the thermal fluid 20, 24. In some cases, the present invention relates to operating the distillation system 18 such that one or more of the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluids 20, 24 obtained therefrom are commercial-grade.

[0089] In some embodiments, all or a portion of an azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid 20, 24 may be combined with one or more of the same refrigerant compounds contained in the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid 20, 24 to adjust their composition ratios, for example to form an azeotropic, near-azeotrope, or close-boiling composition or commercial thermal fluid blend.

[0090] In some embodiments, all or a portion of an azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid 20, 24 may be combined with a virgin, used, or other reclaimed thermal fluid(s) sharing the same refrigerant compounds as the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid 20, 24 to adjust the composition ratios of these compounds, for example to form an azeotropic, near-azeotrope, or close-boiling composition or commercial thermal fluid blend.

[0091] In another embodiment, all or a portion of an azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluids 20, 24 may be packaged and sold as a blending building block, such as for forming commercial thermal fluid blends. For example, in some embodiments, all or a portion of an azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid 20, 24 may be combined with all or a portion of a virgin, a used, or other reclaimed thermal fluid(s) having at least one additional refrigerant compound to make an azeotropic, near-azeotrope or zeotropic composition or azeotropic, near-azeotrope or zeotropic commercial thermal fluid blend.

[0092] In some embodiments, the neat reclaimed thermal fluid 22 may be disposed of as a waste stream.

[0093] In other embodiments, all or a portion of a neat reclaimed thermal fluid 22 may be used directly in a heat transfer system or packaged for use in a heat transfer system. That is, a neat reclaimed thermal fluid 22 obtained from the distillation system 18 and optionally after purification constitutes a commercial-grade thermal fluid and is thus directly suitable for use in a heat transfer system.

[0094] In some embodiments, all or a portion of a neat reclaimed thermal fluid 22 may be packaged and sold as a blending building block, such as for forming commercial thermal fluid blends. For example, in some embodiments, all or a portion of a neat reclaimed thermal fluid 22 may be combined with another

refrigerant compound or with a virgin, a used, or other reclaimed thermal fluid(s) having at least one additional refrigerant compound to make an azeotropic, near-azeotrope or zeotropic composition or commercial thermal fluid blend.

[0095] In some embodiments, the system of the present invention, which provides reclaimed material via distillation, may be located at a site separate and distinct from the site of a blending facility or a refrigerant manufacturing facility which produces virgin material, or may be co-located with a blending facility or refrigerant manufacturing facility.

[0096] It will be understood by those skilled in the art that the systems and methods of the present invention are not limited to the formation of one or two azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluids 20, 24 and one neat reclaimed thermal fluid 22, as shown in FIGS. 1-4. Instead, any number of azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluids and neat thermal fluids may be formed, and the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluids may comprise any number of refrigerant compounds, dependent upon the composition of the recovered thermal fluid.

[0097] In some embodiments, the types of recovered thermal fluids 10 directed to the storage tank 16 may be selected based on the refrigerant compounds that they include and the refrigerant compounds in the reclaimed thermal fluid 20, 22, 24 to be formed from the recovered thermal fluid 10.

[0098] In exemplary embodiments, when the reclaimed thermal fluid 20, 22, 24 includes at least one HFO refrigerant compound, the reclamation process includes adding a stabilizer package to the thermal fluid. In exemplary embodiments, the stabilizer package includes an effective amount of at least one inhibitor such that the thermal fluid 20, 22, 24 remains substantially free of oligomeric, homopolymeric, or other polymeric products derived from the thermal fluid. In some embodiments, at least one inhibitor is selected from hydrocarbons such as cyclic monoterpenes (e.g., limonene, pinene, α -pinene, β -pinene, and terpinene); lipophilic organic compounds such as tocopherols (e.g., α -tocopherol) or butylated hydroxytoluene (BHT); phenols or aromatic organic compounds having at least one chemical moiety $-C_6H_4(OH)$ (e.g., benzene-1,4-diol, 4-methoxyphenol); and mixtures thereof. Specific examples of inhibitor compounds may include at least one member selected from limonene

(particularly D-limonene), α -terpinene, pinene, α -pinene, β -pinene, α -tocopherol, butylated hydroxytoluene (BHT), 4-methoxyphenol, benzene-1,4-diol, and mixtures thereof. In one embodiment, the inhibitor composition includes a liquid at a temperature from about -80°C to about 180°C, about -70°C to about 170°C, and in some cases about -60°C to about 160°C. By “stabilized” it is meant to refer to a composition including an effective amount of at least one inhibitor compound that inhibits, if not eliminates, a fluoroethylene from interacting with another compound and forming dimers, oligomers, homopolymers, or polymeric products.

[0099] In some embodiments, the stabilizer package further comprises at least one acid scavenger. Examples of the acid scavengers that may be included in the present compositions include, but are not limited, the stabilizers and/or the epoxide component of the stabilizers disclosed in U.S. Patent No. 8,535,555 and the acid scavengers disclosed in International Application Publication No. WO 2020/222864, the disclosure of each of which is incorporated herein by reference in its entirety.

[0100] In some embodiments, the 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.

[0101] In some embodiments, an analyzer determines the composition and organic purity of one or more of the thermal fluids 10, 20, 22, 24 of the system and process. In some embodiments, the analyzer determines the type of recovered thermal fluid 10 and organic purity as it is being recovered from a thermal management device. The analyzer may alternatively determine the type and organic purity of the recovered thermal fluid 10 and/or the reclaimed thermal fluid 20, 22, 24. If the analyzed thermal fluid is determined to be organically pure (≥ 95 wt%, or ≥ 96 wt%, or ≥ 97 wt%, or ≥ 98 wt%, or ≥ 99 wt%, or > 99.5 wt%) and of a single type by the analyzer, the thermal fluid may be transferred to an appropriate recovery tank. If, however, there are impurities (or the organic purity is less than 95 wt%, or 96 wt%, or 97 wt%, or 98 wt%, or 99 wt%, or 99.5 wt%), such as, oil, water, dirt, and/or acid, found in the analyzed thermal fluid by the analyzer, the analyzed thermal fluid may be sent to a regenerator for reprocessing.

[0102] In some embodiments, a regenerator purifies the recovered thermal fluid 10 and/or the reclaimed thermal fluid 20, 22, 24 to a state that meets AHRI Standard

700 purity specifications. The regenerator can include at least a compressor, a separator, and/or a filter dryer, and may further include at least one of a distiller, a diluter, and a reformulator. In some embodiments, the compressor is driven to circulate the thermal fluid in a refrigerant circuit such that a voltage is applied to reduce or remove oil, such as the refrigerating machine oil, in the thermal fluid. In some embodiments, the separator is a type of oil separator. In some embodiments, the filter dryer reduces or removes water and acid included in the thermal fluid. The regenerator can also determine information on the appropriateness of the oil, water, and acid included in the thermal fluid after the regeneration processing and compile the thermal fluid composition, the weight, and the like.

[0103] In some embodiments, the reclaimed thermal fluid 20, 22, 24 is selected from, and meets the standards of *Standard for Specifications for Refrigerants*, Air-Conditioning, Heating & Refrigeration Institute (AHRI 700), which is incorporated by reference in its entirety herein. AHRI 700 specifies acceptable levels of contaminants (purity requirements) for fluorocarbon, hydrocarbon, and carbon dioxide refrigerants regardless of source and lists acceptable test methods. These refrigerants are as referenced in the ANSI/American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 34 with Addenda, which is also incorporated by reference in its entirety herein. The compositions of certain blends can be found in “Factsheet 1: Update on New Refrigerants Designations and Safety Classifications”, ASHRAE, April 2023; or at <https://www.ashrae.org/technical-resources/standards-and-guidelines/ashrae-refrigerant-designations>; or in ISO 817 (International Organization for Standardization), each of which is incorporated by reference in its entirety herein.

[0104] Appropriate refrigerant compounds for systems and methods of the present disclosure may include, but are not limited to, R-11; R-12; R-13; R-22; R-23; R-32; R-50; R-113; R-114; R-115; R-116; R-123; R-124; R-125; R-134a; R-141b; R-142b; R-143a; R-152a; R-170; R-218; R-227ea; R-236fa; R-245fa; R-290; R-600; R-600a; R-601; R-601a; R-610; R-744; R-1123; R-1132(E); R-1132(Z); R-1132a; R-1150; R-1233yd; R-1233zd(E); R-1233zd(Z); R-1234yf; R-1234ze(Z); R-1234ze(E); R-1224yd(E); R-1224yd(Z); R-1243yc; R-1252zc; R-153-10mczz; R-43-10mee; R-1270; R-1336mzz(E) and R-1336mzz(Z).

[0105] Appropriate zeotropic, near-azeotrope or close-boiling blend thermal fluids for systems and methods of the present disclosure, either as the recovered thermal fluid 10 and/or the reclaimed thermal fluid 20, 24, may include, but are not limited to, R-401A; R-401B; R-402A; R-402B; R-403A; R-403B; R-404A; R-405A; R-406A; R-407A; R-407B; R-407C; R-407D; R-407E; R-407F; R-407G; R-407H; R-407I; R-408A; R-409A; R-409B; R-410A; R-410B; R-411A; R-411B; R-412A; R-413A; R-414A; R-414B; R-415A; R-415B; R-416A; R-417A; R-417B; R-417C; R-418A; R-419A; R-419B; R-420A; R-421A; R-421B; R-422A; R-422B; R-422C; R-422D; R-422E; R-423A; R-424A; R-425A; R-426A; R-427A; R-428A; R-429A; R-430A; R-431A; R-432A; R-433A; R-433B; R-433C; R-434A; R-435A; R-436A; R-436B; R-437A; R-438A; R-439A; R-440A; R-441A; R-442A; R-443A; R-444A; R-444B; R-445A; R-446A; R-447A; R-447B; R-448A; R-449A; R-449B; R-449C; R-450A; R-451A; R-451B; R-452A; R-452B; R-452C; R-453A; R-454A; R-454B; R-454C; R-454D; R-455A; R-455B; R-455C; R-456A; R-457A; R-457B; R-457C; R-457D; R-458A; R-459A; R-459B; R-460A; R-460B; R-461A; R-462A; R-463A; R-464A; R-465A; R-466A; R-467A; R-468A; R-468B; R-468A; R-469A; R-470A; R-471A; R-471B; R-472A; R-472B; R-473A; R-474A; R-475A; R-476A; R-479A; R-482A; R-491A; R-1234ze(E)/R-1132(Z) containing blends; R-1234ze(E)/R-152a containing blends; R-32/R-1132(E)/R-1234ze(E) containing blends; R-32/R-1123 containing blends; R-1234ze(E)/R-1234ze(Z)/R-134a containing blends; R-1234ze(E)/R-1234ze(Z)/R-1336mzz(E) containing blends; R-1234yf/R-1152zc containing blends; R-1234zeE/R-1252zc containing blends; R-152a/R-1252zc containing blends; R-1234zeZ/R-1336mzzE containing blends; and R-1234zeZ/R-1233zdE containing blends.

[0106] Appropriate azeotropic blend thermal fluids for systems and methods of the present disclosure, either as the recovered thermal fluid 10 and/or the reclaimed thermal fluid 20, 24, may include, but are not limited to, R-500; R-502; R-503; R-507A; R-508A; R-508B; R-509A; R-510A; R-511A; R-512A; R-513A; R-513B; R-514A; R-515A; 515B; 516A; and R-516B.

EXAMPLES

[0107] The invention will be described in greater detail by way of specific examples. The following examples are offered for illustrative purposes and are not intended to limit the invention in any manner. Those of skill in the art will readily

recognize a variety of non-critical parameters which can be changed or modified to yield essentially the same results.

Example 1

[0108] A used or spent thermal fluid is recovered, tested and validated to form a consolidated thermal fluid composition.

[0109] In some embodiments, the recovered thermal fluid composition includes at least pentafluoroethane ($\text{CF}_3\text{-CHF}_2$, HFC-125) and difluoromethane (CH_2F_2 , HFC-32).

[0110] It will be understood by those skilled in the art that the recovered thermal fluid composition may be any commercial thermal fluid comprising HFC-32 and HFC-125 and at least one other refrigerant compound, such as, but not limited to, R-407A, R-407B, R-407C, R-407D, R-407E, R-407F, R-407G, R-407H, R-407I, R-427A, R-427B, R-427C, R-438A, R-447A, R-447B, R-448A, R-448B, R-449A, R-449B, R-449C, R-452A, R-452B, R-452C, R-453A, R-458A, R-460A, R-460B, R-460C, R-462A, R-463A, R-464A, R-466A, R-467A, R-469A, R-470A, R-470B, R-478A and R-481A.

[0111] In some embodiments, the recovered thermal fluid composition comprises at least HFC-125, HFC-32 and 1,1,1,2-tetrafluoroethane ($\text{CF}_3\text{CH}_2\text{F}$, HFC-134a). In some embodiments, the recovered thermal fluid composition is selected from R-407A, R-407B, R-407C, R-407D, R-407E, R-407F, R-407G, R-407H and R-407I.

[0112] If the impurities are greater than 5%, the composition may be purified to reduce the level of impurities to less than 5%; or if the impurities are greater than 0.5%, the composition may be purified to reduce the level of impurities to less than 0.5%.

[0113] The recovered thermal fluid composition is distilled and at least one distillate fraction containing HFC-125 and HFC-32 is collected to provide an azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid containing HFC-125 and HFC-32. In some embodiments, the 125/HFC-32 reclaimed thermal fluid is collected and may be used as-is without any adjustment of the ratio of the compounds contained therein. In some embodiments, the HFC-125/HFC-32

reclaimed thermal fluid is collected and may optionally be combined with additional HFC-125 and/or HFC-32 to adjust the ratio of HFC-32 to HFC-125 to form R-410A (50% HFC-125 / 50% HFC-32). In some embodiments, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid containing HFC-125 and HFC-32 has a ratio of HFC-32 to HFC-125 of about 5:95 to about 95:5, or about 1.75:1 to about 2:1, or about 9:1 to about 11.5:1.

[0114] In one embodiment, the recovered thermal fluid composition (e.g., R-407A, R-407B, R-407C, R-407D, R-407E, R-407F, R-407G, R-407H or R-407I) is distilled and at least one distillate fraction containing R-410A (50% HFC-125 / 50% HFC-32) is collected.

[0115] In one embodiment, the recovered thermal fluid composition (e.g., R-407A, R-407B, R-407C, R-407D, R-407E, R-407F, R-407G, R-407H or R-407I) is distilled and at least one distillate fraction containing R-410A (50% HFC-125 / 50% HFC-32) is collected, and at least one other distillate fraction containing HFC-134a is collected as a neat reclaimed thermal fluid.

[0116] In one embodiment, the recovered thermal fluid composition comprises R-407C (25% HFC-125 / 23% HFC-32 / 52% HFC-134a) and is distilled, such that one distillate fraction containing R-410A (50% HFC-125 / 50% HFC-32) is collected, and another distillate fraction containing HFC-134a is collected as a neat reclaimed thermal fluid.

[0117] In one embodiment, the recovered thermal fluid composition comprises HFC-125, HFC-32 and HFC-134a (e.g., the recovered thermal fluid composition may comprise R-407C (25% HFC-125 / 23% HFC-32 / 52% HFC-134a)) and is distilled. One distillate fraction containing HFC-125 and HFC-32 (e.g., the distillate fraction may contain R-410A (50% HFC-125 / 50% HFC-32)) is collected, and another distillate fraction containing HFC-134a is collected as a neat reclaimed thermal fluid. Table 1 shows distillation requirements for obtaining an HFC-32/HFC-125 (e.g., R-410A) composition as compared with the distillation requirements for obtaining individual fractions of HFC-32, HFC-125 and HFC-134a. The latter requires two distillation columns as compared with one distillation column for obtaining an HFC-32/HFC-125 blend (see, e.g., Fig. 5). Also, the molar reflux ratio for distilling the latter is more than five times that required for obtaining an HFC-32/HFC-125 blend.

Thus, the data show that obtaining separate fractions of HFC-32, HFC-125 and HFC-134a would require larger distillation columns and a larger number of distillation columns as well as higher energy input, and thus exhibit a much larger environmental footprint, as compared with the present invention.

TABLE 1

	Example 1		
	Column (B1)		
Column Stages	30		
Molar reflux ratio	2.1		
Stream	Feed	Overhead	Bottom
Temp (deg C)	25.0	-0.262937513	30.77379011
Pressure (psia)	169.18	114.6959488	114.6959488
32 wt fraction	0.23000	0.478980	0.000358523
125 wt fraction	0.25000	0.516020	0.00464159
134a wt fraction	0.52000	0.005000	0.995

	Comparative Example 1					
	Column 1 (B2)			Column 2 (B3)		
Column Stages	30			70		
Molar reflux ratio	3.3			11		
Stream	Feed	Overhead	Bottom	Feed	Overhead	Bottom
Temp (°C)	25	-0.3454451	30.7794894	-0.3454451	-0.9315186	5.23294849
Pressure (psia)	169.17974	114.69595	114.6959488	114.69595	114.69595	114.6959488
32 wt fraction	0.23000	0.4814467	0.000268958	0.48145	0.7749627	0.002999916
125 wt fraction	0.25000	0.5184533	0.004731054	0.51845	0.2250373	0.9967
134a wt fraction	0.52000	0.0001	0.995	0.00009	1.86E-18	0.000263036

[0118] In one embodiment, the neat reclaimed thermal fluid comprising HFC-134a may be used directly in a heat transfer system as a single thermal fluid or may be packaged and sold as-is as a suitable refrigerant. In another embodiment, the neat reclaimed thermal fluid comprising HFC-134a may be disposed of as waste or converted back to HF. Alternatively, the neat reclaimed thermal fluid comprising HFC-134a may be sold as-is as a reclaimed blending building block, or may be combined with virgin, used, or other reclaimed thermal fluids containing at least one other refrigerant compound in order to form a commercial thermal fluid.

[0119] In one embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-125, HFC-32; one or more additional

compounds selected from HFC-23, HFC-143a, HFC-134a, CFC-115, CFCO-1113 and HCC-40; and one or more additional compounds selected from HFC-143a, HFC-41, HFC-134a, HCFC-22, CFC-12 and HCC-40.

[0120] In one embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-125, HFC-32; HFC-134a; and one or more additional compounds selected from HCFC-22, CFC-12, HFC-23, HFC-143a, CFC-115, CFCO-1113, HFC-41 and HCC-40.

[0121] In one embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-125, HFC-32; HFC-134a; HFC-134; and one or more additional compounds selected from HCFC-22, CFC-12, HFC-23, HFC-143a, CFC-115, CFCO-1113, HFC-41 and HCC-40.

[0122] In one embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-125, HFC-32; HFC-134a; HFC-143a; and one or more additional compounds selected from HCFC-22, CFC-12, HFC-23, CFC-115, CFCO-1113, HFC-41 and HCC-40.

[0123] In one embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-125, HFC-32; HFC-134a; HCC-40 and one or more additional compounds selected from HCFC-22, CFC-12, HFC-23, HFC-143a, CFC-115, CFCO-1113 and HFC-41.

[0124] In one embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-125, HFC-32; HFC-134a; HFC-143a; HCC-40; and one or more additional compounds selected from HCFC-22, CFC-12, HFC-23, CFC-115, CFCO-1113 and HFC-41.

[0125] In one embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is used as-is in a heat transfer system or is packaged and sold as-is as a suitable refrigerant (e.g., R-410A) for a heat transfer system.

[0126] In one embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is combined with virgin, used, or other reclaimed thermal fluids of HFC-32 and/or HFC-125 to adjust the ratio of HFC-32 to HFC-125 to form a commercial thermal fluid. Appropriate commercial thermal fluids of blends of HFC-32 and HFC-125 include, but are not limited to, R-410A and R-410B.

[0127] In another embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is sold as-is as a reclaimed blending building block, for example for making a commercial thermal fluid containing HFC-32 and HFC-125 and at least one other refrigerant compound, such as, but not limited to, R-427A, R-427B, R-427C, R-438A, R-447A, R-447B, R-448A, R-448B, R-449A, R-449B, R-449C, R-452A, R-452B, R-452C, R-453A, R-458A, R-460A, R-460B, R-460C, R-462A, R-463A, R-464A, R-466A, R-467A, R-469A, R-470A, R-470B, R-478A and R-481A.

[0128] In other embodiments, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is combined with virgin, used, or other reclaimed thermal fluids containing HFC-32 and/or HFC-125 and/or at least one other refrigerant compound to form a commercial thermal fluid. Appropriate commercial thermal fluids of blends containing HFC-32 and HFC-125 and at least one other refrigerant compound include, but are not limited to, R-427A, R-427B, R-427C, R-438A, R-447A, R-447B, R-448A, R-448B, R-449A, R-449B, R-449C, R-452A, R-452B, R-452C, R-453A, R-458A, R-460A, R-460B, R-460C, R-462A, R-463A, R-464A, R-466A, R-467A, R-469A, R-470A, R-470B, R-478A and R-481A.

Example 2

[0129] A used or spent thermal fluid is recovered, tested and validated to form a consolidated thermal fluid composition.

[0130] In some embodiments, the recovered thermal fluid composition includes at least HFC-125, HFC-32, HFC-134a and 2,3,3,3-tetrafluoropropene ($\text{CF}_3\text{CF}=\text{CH}_2$, HFO-1234yf). In some embodiments, the recovered thermal fluid composition is R-449A (24.3% HFC-32 / 24.7% HFC-125 / 25.7% HFC-134a / 25.3% HFO-1234yf) or R-449B (25.2% HFC-32 / 24.3% HFC-125 / 27.3% HFC-134a / 23.2% HFO-1234yf).

[0131] It will be understood by those skilled in the art that the recovered thermal fluid composition may be any commercial thermal fluid comprising HFC-32, HFC-125, HFC-134a and HFO-1234yf and at least one other refrigerant compound.

[0132] If the impurities are greater than 5%, the composition may be purified to reduce the level of impurities to less than 5%; or if the impurities are greater than 0.5%, the composition may be purified to reduce the level of impurities to less than 0.5%.

[0133] In some embodiments, the recovered thermal fluid composition is distilled and a first distillate stream containing HFC-125 and HFC-32 is collected to provide a first azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid containing HFC-125 and HFC-32, and a second distillate stream containing HFC-134a and HFO-1234yf is collected to provide a second azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid containing HFC-134a and HFO-1234yf. The first distillate stream comprises at least one HFC-125/HFC-32 fraction, and the second distillate stream comprises at least one HFC-134a/HFO-1234yf fraction.

[0134] In some embodiments, the HFC-125/HFC-32 reclaimed thermal fluid and the HFC-134a/HFO-1234yf reclaimed thermal fluid are collected and may be used as-is without any adjustment of the ratio of the compounds contained therein. In some embodiments, the HFC-125/HFC-32 reclaimed thermal fluid is collected and may optionally be combined with additional HFC-125 and/or HFC-32 to adjust the ratio of HFC-32 to HFC-125 to form R-410A (50% HFC-125 / 50% HFC-32). In some embodiments, the HFC-134a/HFO-1234yf reclaimed thermal fluid is collected and may optionally be combined with additional HFC-134a and/or HFO-1234yf to adjust the ratio of HFC-134a to HFO-1234yf to form R-513A (44% HFC-134a / 56% HFO-1234yf) or R-513B (41.5% HFC-134a / 58.5% HFO-1234yf).

[0135] In one embodiment, the recovered thermal fluid composition is distilled and a first distillate stream containing R-410A (50% HFC-125 / 50% HFC-32) is collected, and a second distillate stream containing either R-513A (44% HFC-134a / 56% HFO-1234yf) or R-513B (41.5% HFC-134a / 58.5% HFO-1234yf) is collected. Each distillate stream may comprise one or a plurality of fractions.

[0136] In one embodiment, the recovered thermal fluid composition comprises R-449A, and is distilled to form a first distillate stream containing R-410A (50% HFC-125 / 50% HFC-32) which is collected, and a second distillate stream containing either R-513A (44% HFC-134a / 56% HFO-1234yf) or R-513B (41.5% HFC-134a / 58.5% HFO-1234yf) which is collected. Each distillate stream may comprise one or a plurality of fractions.

[0137] In one embodiment, the recovered thermal fluid composition comprises HFC-125, HFC-32, HFC-134a and HFO-1234yf (e.g., the recovered thermal fluid composition may comprise R-449A or R-449B) and is distilled. A first distillate

fraction containing HFC-125 and HFC-32 (e.g., the first distillate fraction may contain R-410A) is collected, and a second distillate fraction containing HFC-134a and HFO-1234yf (e.g., the second distillate fraction may contain R-513A or R-513B) is collected. Table 2 shows distillation requirements for obtaining first and second distillate fractions of HFC-32/HFC-125 (e.g., R410A) and HFC-134a/HFO-1234yf (e.g., R-513A or R-513B), respectively, as compared with the distillation requirements for obtaining individual fractions of HFC-32, HFC-125, HFC-134a and HFO-1234yf. The latter requires three distillation columns as compared with one distillation column for obtaining HFC-32/HFC-125 and HFC-134a/HFO-1234yf blends (see, e.g., Fig. 6). Also, the molar reflux ratio for distilling the latter is about eight times that required for obtaining an HFC-32/HFC-125 and HFC-134a/HFO-1234yf blends. Thus, the data show that obtaining separate fractions of HFC-32, HFC-125, HFC-134a and HFO-1234yf would require larger distillation columns and a larger number of distillation columns as well as higher energy input, and thus exhibit a much larger environmental footprint, as compared with the present invention.

TABLE 2

	Example 2		
	Column 1 (B16)		
Column Stages	30		
Molar reflux ratio	4.2		
Stream	Feed	Overhead	Bottom
Temp (°C)	25	-0.364008407	28.77283218
Pressure (psia)	182.12752	114.6959488	114.6959488
32 wt fraction	0.243	0.495991464	2.80E-05
125 wt fraction	0.247	0.499008742	0.004971801
134a wt fraction	0.257	9.35207E-05	0.503731966
1234yf fraction	0.253	0.004906273	0.491268234

	Comparative Example 2		
	Column 1 (B17)		
Column Stages	40		
Molar reflux ratio	5.2		
Stream	Feed	Overhead	Bottom
Temp (°C)	25	-0.3981987	28.89158753
Pressure (psia)	184.39481	114.69595	114.6959488
32 wt fraction	0.243	0.495928	4.49E-07
125 wt fraction	0.247	0.503572	0.000499561
134a wt fraction	0.257	1.96E-06	0.503909792
1234yf fraction	0.253	0.000498	0.495590198

	Comparative Example 2					
	Column 2 (B18)			Column 3 (B19)		
Column Stages	70			80		
Molar reflux ratio	11			35		
Stream	Feed	Overhead	Bottom	Feed	Overhead	Bottom
Temp (°C)	-0.3981987	-0.9339138	5.201641198	28.891588	28.906903	41.125595
Pressure (psia)	114.69595	114.69595	114.6959488	114.69595	114.69595	114.69595
32 wt fraction	0.495928	0.7773932	3.63E-03	4.49E-07	5.03E-07	9.01E-22
125 wt fraction	0.503572	0.2226068	0.994999734	0.0004996	0.0005589	7.03E-15
134a wt fraction	1.96E-06	3.68E-20	5.40E-06	0.5039098	0.4455721	0.995
1234yf fraction	0.000498	6.53E-10	0.001369165	0.4955902	0.5538685	0.005

[0138] In one embodiment, the first azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-125, HFC-32; one or more additional compounds selected from HFC-23, HFC-32, HFC-143a, HFC-134a, CFC-115, CFCO-1113 and HCC-40; and one or more additional compounds selected from HFC-143a, HFC-41, HFC-134a, HCFC-22, CFC-12 and HCC-40.

[0139] In one embodiment, the first azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-125, HFC-32; HFC-134a; HFO-1234yf; and one or more additional compounds selected from HCFC-22, CFC-12, HFC-23, HFC-143a, CFC-115, CFCO-1113, HFC-41 and HCC-40.

[0140] In one embodiment, the first azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-125, HFC-32; HFC-134a; HFO-1234yf; HFC-143a; and one or more additional compounds selected from HCFC-22, CFC-12, HFC-23, CFC-115, CFCO-1113, HFC-41 and HCC-40.

[0141] In one embodiment, the first azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-125, HFC-32; HFC-134a; HFO-1234yf; HCC-40; and one or more additional compounds selected from HCFC-22, CFC-12, HFC-23, HFC-143a, CFC-115, CFCO-1113 and HFC-41.

[0142] In one embodiment, the first azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-125, HFC-32; HFC-134a; HFO-1234yf; HFC-

143a; HCC-40; and one or more additional compounds selected from HCFC-22, CFC-12, HFC-23, CFC-115, CFCO-1113 and HFC-41.

[0143] In one embodiment, the second azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-134a, HFO-1234yf; one or more additional compounds selected from HFC-143a, HFO-1225zc, HFC-245cb, HFC-134, HFC-152a, HFO-1225ye, HFC-161, E-HFO-1234ze, HCFC-22, HFO-1243zf, CHFC-124, HCC-40, CHFO-1122, HCFC-31, CFC-114, CFC-114a and HCO-1140; and one or more additional compounds selected from HFO-1225ye, HFO-1243zf, E-HFO-1234ze, HFC-236ea, HCFC-244bb, HFC-245fa, HFC-245eb, HFC-245cb, 3,3,3-trifluoropropyne, HFC-152a, FO-1114, HFO-1123, HCFO-1131a, trans-HCFO-1131, HCO-1140, HCFO-1214ya, FO-1216, HCFO-1224yd, HFO-1252 isomers, HFC-143a, HCFC-225, HFC-254eb, HFC-263fb, HFC-236fa, HCFC-142b, HCFC-244cc, HCFO-1223, HFO-1132a and HCC-40.

[0144] In one embodiment, the second azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-134a, HFO-1234yf; HFC-32; HFC-125; and one or more additional compounds selected from HCFC-22, CFC-12, HFC-23, HFC-143a, CFC-115, CFCO-1113, HFC-41 and HCC-40.

[0145] In one embodiment, one or both of the first and second azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluids is used as-is in a heat transfer system, or is packaged and sold as-is as a suitable refrigerant (e.g., R-410A, R-513A and/or R-513B) for a heat transfer system.

[0146] In one embodiment, the first azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is combined with virgin, used, or other reclaimed thermal fluids of HFC-32 and/or HFC-125 to adjust the ratio of HFC-32 to HFC-125 to form a commercial thermal fluid. Appropriate commercial thermal fluids of blends of HFC-32 and HFC-125 include, but are not limited to, R-410A and R-410B.

[0147] In one embodiment, the second azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is combined with virgin, used, or other reclaimed thermal fluids of HFC-134a and/or HFO-1234yf to adjust the ratio of HFC-134a to HFO-1234yf to form a commercial thermal fluid. Appropriate commercial thermal fluids of blends of HFC-134a and HFO-1234yf include, but are not limited to, R-451A, R-451B, R-513A and R-513B.

[0148] In another embodiment, the first azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is sold as-is as a reclaimed blending building block, for example for making a commercial thermal fluid containing HFC-32 and HFC-125 and at least one other refrigerant compound, such as, but not limited to, R-427A, R-427B, R-427C, R-438A, R-447A, R-447B, R-448A, R-448B, R-449A, R-449B, R-449C, R-452A, R-452B, R-452C, R-453A, R-458A, R-460A, R-460B, R-460C, R-462A, R-463A, R-464A, R-466A, R-467A, R-469A, R-470A, R-470B, R-478A and R-481A.

[0149] In another embodiment, the second azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is sold as-is as a reclaimed blending building block, for example for making a commercial thermal fluid containing HFC-134a and HFO-1234yf and at least one other refrigerant compound, such as, but not limited to, R-448A, R-448B, R-449A, R-449B, R-449C, R-475A, R-475B and R-516A.

[0150] In other embodiments, the first azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is combined with virgin, used, or other reclaimed thermal fluids containing HFC-32 and/or HFC-125 and/or at least one other refrigerant compound to form a commercial thermal fluid. Appropriate commercial thermal fluids of blends containing HFC-32 and HFC-125 and at least one other refrigerant compound include, but are not limited to, R-427A, R-427B, R-427C, R-438A, R-447A, R-447B, R-448A, R-448B, R-449A, R-449B, R-449C, R-452A, R-452B, R-452C, R-453A, R-458A, R-460A, R-460B, R-460C, R-462A, R-463A, R-464A, R-466A, R-467A, R-469A, R-470A, R-470B, R-478A and R-481A.

[0151] In another embodiment, the second azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is combined with virgin, used, or other reclaimed thermal fluids containing HFC-134a and/or HFO-1234yf and/or at least one other refrigerant compound to form a commercial thermal fluid. Appropriate commercial thermal fluids of blends containing HFC-134a and HFO-1234yf and at least one other refrigerant compound include, but not limited to, R-448A, R-448B, R-449A, R-449B, R-449C, R-475A, R-475B and R-516A.

Example 3

[0152] A used or spent thermal fluid is recovered, tested and validated to form a consolidated thermal fluid composition.

[0153] In some embodiments, the recovered thermal fluid composition includes at least HFC-125, HFC-32, HFC-134a, HFO-1234yf, and E-1,3,3,3-tetrafluoropropene (E-CF₃CH=CHF, E-HFO-1234ze). In some embodiments, the recovered thermal fluid composition is R-448A (26% HFC-32 / 26% HFC-125 / 21% HFC-134a / 20% HFO-1234yf / 7% E-HFO-1234ze) or R-448B (21% HFC-32 / 21% HFC-125 / 31% HFC-134a / 20% HFO-1234yf / 7% E-HFO-1234ze). However, it will be understood by those skilled in the art that the recovered thermal fluid composition may be any commercial thermal fluid comprising HFC-32, HFC-125, HFC-134a, HFO-1234yf, E-HFO-1234ze and at least one other refrigerant compound.

[0154] If the impurities are greater than 5%, the composition may be purified to reduce the level of impurities to less than 5%; or if the impurities are greater than 0.5%, the composition may be purified to reduce the level of impurities to less than 0.5%.

[0155] In some embodiments, the recovered thermal fluid composition is distilled, and a first distillate stream containing HFC-125 and HFC-32 is collected to provide a first azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid containing HFC-125 and HFC-32; a second distillate stream containing HFC-134a and HFO-1234yf is collected to provide a second azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid containing HFC-134a and HFO-1234yf; and a third distillate stream containing E-HFO-1234ze is collected to provide a neat reclaimed thermal fluid. Each distillate stream may comprise one or a plurality of distillate fractions.

[0156] In one embodiment, the recovered thermal fluid composition is distilled, and a first distillate stream containing R-410A (50% HFC-125 / 50% HFC-32) is collected; a second distillate stream containing either R-513A (44% HFC-134a / 56% HFO-1234yf) or R-513B (41.5% HFC-134a / 58.5% HFO-1234yf) is collected; and a third distillate stream containing E-HFO-1234ze is collected as a neat reclaimed thermal fluid.

[0157] In one embodiment, the recovered thermal fluid composition comprises R-448A and is distilled to form: a first distillate stream containing R-410A (50% HFC-125 / 50% HFC-32) which is collected; a second distillate stream containing either R-513A (44% HFC-134a / 56% HFO-1234yf) or R-513B (41.5% HFC-134a / 58.5% HFO-1234yf) which is collected; and a third distillate stream containing E-HFO-1234ze which is collected as a neat reclaimed thermal fluid.

[0158] In one embodiment, the recovered thermal fluid composition comprises HFC-125, HFC-32, HFC-134a, HFO-1234yf, and E-HFO-1234ze (e.g., the recovered thermal fluid composition may comprise R-448A (26% HFC-32 / 26% HFC-125 / 21% HFC-134a / 20% HFO-1234yf / 7% E-HFO-1234ze)) and is distilled. A first distillate fraction containing HFC-125 and HFC-32 (e.g., R-410A) is collected, a second distillate stream containing HFC-134a and HFO-1234yf (e.g., R-513A or R-513B) is collected, and a third distillate fraction containing E-HFO-1234ze is collected as a neat reclaimed thermal fluid. Table 3 shows distillation requirements for obtaining these three distillate fractions as compared with the distillation requirements for obtaining individual fractions of HFC-32, HFC-125, HFC-134a, HFO-1234yf and E-HFO-1234ze. The latter requires four distillation columns as compared with two distillation columns for obtaining the above-described first, second and third distillate fractions (see, e.g., Fig. 7). Also, the molar reflux ratio for distilling the individual compounds is more than four times that required for obtaining the above-described first, second and third distillate fractions. Thus, the data show that obtaining separate fractions of HFC-32, HFC-125, HFC-134a, HFO-1234yf and E-HFO-1234ze would require larger distillation columns and a larger number of distillation columns as well as higher energy input, and thus exhibit a much larger environmental footprint, as compared with the present invention.

TABLE 3

	Example 3					
	Column 1 (B4)			Column 2 (B5)		
Column Stages	30			60		
Molar reflux ratio	4.2			8.1		
Stream	Feed	Overhead	Bottom	Feed	Overhead	Bottom
Temp (°C)	25	-0.371084736	30.20540215	30.205402	28.917475	41.13041037
Pressure (psia)	184.39481	114.6959488	114.6959488	114.69595	114.69595	114.6959488
32 wt fraction	0.26	0.497953263	4.75E-06	4.75E-06	5.55E-06	6.15E-17
125 wt fraction	0.26	0.497046767	0.000995217	0.0009952	0.0011625	7.63E-12
134a wt fraction	0.21	0.000118546	0.439323105	0.4393231	0.5126616	0.0030848
1234yf fraction	0.2	0.004878727	0.413195665	0.4131957	0.4823384	0.001915236
1234ze fraction	0.07	2.70E-06	0.146481264	0.1464813	0.0038319	0.994999963

	Comparative Example 3					
	Column 1 (B6)			Column 2 (B7)		
Column Stages	40			70		
Molar reflux ratio	5.2			11		
Stream	Feed	Overhead	Bottom	Feed	Overhead	Bottom
Temp (°C)	25	-0.4152833	30.21969445	-0.4152833	-0.9339138	5.2016412
Pressure (psia)	184.39481	114.69595	114.6959488	114.69595	114.69595	114.69595
32 wt fraction	0.26	0.4999922	1.65E-07	0.4999922	0.7779087	4.44E-03
125 wt fraction	0.26	0.4998074	0.000200323	0.4998074	0.2220913	0.995
134a wt fraction	0.21	7.62E-07	0.437506459	7.62E-07	1.44E-20	2.12E-06
1234yf fraction	0.2	0.0001997	0.416457304	0.0001997	2.87E-10	0.0005557
1234ze fraction	0.07	1.11E-08	0.145835749	1.11E-08	3.26E-23	3.08E-08

	Comparative Example 3					
	Column 3 (B8)			Column 4 (B9)		
Column Stages	70			80		
Molar reflux ratio	35			35		
Stream	Feed	Overhead	Bottom	Feed	Overhead	Bottom
Temp (°C)	30.219694	28.906903	41.125595	28.906903	28.867042	30.916554
Pressure (psia)	114.69595	114.69595	114.69595	114.69595	114.69595	114.69595
32 wt fraction	1.65E-07	1.93E-07	7.79E-21	1.93E-07	2.19E-07	4.27E-22
125 wt fraction	0.0002003	0.0002347	9.16E-15	0.0002347	0.0002662	3.10E-15
134a wt fraction	0.4375065	0.5117599	0.0048417	0.5117599	0.4468077	0.995
1234yf fraction	0.4164573	0.4879021	0.0001583	0.4879021	0.5529259	0.0041305
1234ze fraction	0.1458357	0.000103	0.995	0.000103	6.13E-09	0.0008695

[0159] In one embodiment, the neat reclaimed thermal fluid comprising E-HFO-1234ze may be used directly in a heat transfer system as a single thermal fluid or may be packaged and sold as-is as a suitable refrigerant. In another embodiment, the neat reclaimed thermal fluid comprising E-HFO-1234ze may be disposed of as waste. Alternatively, the neat reclaimed thermal fluid comprising E-HFO-1234ze may be sold as-is as a reclaimed blending building block, or may be combined with virgin, used, or other reclaimed thermal fluids containing at least one other refrigerant compound in order to form a commercial thermal fluid.

[0160] In one embodiment, the first azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-125, HFC-32; one or more additional compounds selected from HFC-23, HFC-32, HFC-143a, HFC-134a, CFC-115, CFCO-1113 and HCC-40; and one or more additional compounds selected from HFC-143a, HFC-41, HFC-134a, HCFC-22, CFC-12 and HCC-40.

[0161] In one embodiment, the second azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-134a, HFO-1234yf; one or more additional compounds selected from HFC-143a, HFO-1225zc, HFC-245cb, HFC-134, HFC-152a, HFO-1225ye, HFC-161, E-HFO-1234ze, HCFC-22, HFO-1243zf, CHFC-124, HCC-40, CHFO-1122, HCFC-31, CFC-114, CFC-114a and HCO-1140; and one or more additional compounds selected from HFO-1225ye, HFO-1243zf, E-HFO-1234ze, HFC-236ea, HCFC-244bb, HFC-245fa, HFC-245eb, HFC-245cb,

3,3,3-trifluoropropyne, HFC-152a, FO-1114, HFO-1123, HCFO-1131a, trans-HCFO-1131, HCO-1140, HCFO-1214ya, FO-1216, HCFO-1224yd, HFO-1252 isomers, HFC-143a, HCFC-225, HFC-254eb, HFC-263fb, HFC-236fa, HCFC-142b, HCFC-244cc, HCFO-1223, HFO-1132a and HCC-40.

[0162] In one embodiment, the second azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-134a, HFO-1234yf; E-HFO-1234ze; HFC-32; HFC-125; and one or more additional compounds selected from HCFC-22, CFC-12, HFC-23, HFC-32, HFC-143a, HFC-134a, CFC-115, CFCO-1113, HFC-41, HCC-40, HFC-245cb, HFO-1225yf(E), HFO-1225yf(Z), HFO-1225zc, HFC-236fa, HFC-152a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, R-2223, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb and HFC-134.

[0163] In one embodiment, one or both of the first and second azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluids is used as-is in a heat transfer system or is packaged and sold as-is as a suitable refrigerant (e.g., R-410A, R-513A and/or R-513B) for a heat transfer system.

[0164] In one embodiment, the first azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is combined with virgin, used, or other reclaimed thermal fluids of HFC-32 and/or HFC-125 to adjust the ratio of HFC-32 to HFC-125 to form a commercial thermal fluid. Appropriate commercial thermal fluids of blends of HFC-32 and HFC-125 include, but are not limited to, R-410A and R-410B.

[0165] In one embodiment, the second azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is combined with virgin, used, or other reclaimed thermal fluids of HFC-134a and/or HFO-1234yf to adjust the ratio of HFC-134a to HFO-1234yf to form a commercial thermal fluid. Appropriate commercial thermal fluids of blends of HFC-134a and HFO-1234yf include, but are not limited to, R-451A, R-451B, R-513A and R-513B.

[0166] In another embodiment, the first azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is sold as-is as a reclaimed blending building block, for example for making a commercial thermal fluid containing HFC-32 and HFC-125 and at least one other refrigerant compound, such as, but not limited to, R-427A, R-427B, R-427C, R-438A, R-447A, R-447B, R-448A, R-448B, R-449A, R-449B, R-449C, R-452A, R-452B, R-452C, R-453A, R-458A, R-460A, R-460B, R-460C, R-

462A, R-463A, R-464A, R-466A, R-467A, R-469A, R-470A, R-470B, R-478A and R-481A.

[0167] In another embodiment, the second azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is sold as-is as a reclaimed blending building block, for example for making a commercial thermal fluid containing HFC-134a and HFO-1234yf and at least one other refrigerant compound, such as, but not limited to, R-448A, R-448B, R-449A, R-449B, R-449C, R-475A, R-475B and R-516A.

[0168] In other embodiments, the first azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is combined with virgin, used, or other reclaimed thermal fluids containing HFC-32 and/or HFC-125 and/or at least one other refrigerant compound to form a commercial thermal fluid. Appropriate commercial thermal fluids of blends containing HFC-32 and HFC-125 and at least one other refrigerant compound include, but are not limited to, R-427A, R-427B, R-427C, R-438A, R-447A, R-447B, R-448A, R-448B, R-449A, R-449B, R-449C, R-452A, R-452B, R-452C, R-453A, R-458A, R-460A, R-460B, R-460C, R-462A, R-463A, R-464A, R-466A, R-467A, R-469A, R-470A, R-470B, R-478A and R-481A.

[0169] In another embodiment, the second azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is combined with virgin, used, or other reclaimed thermal fluids containing HFC-134a and/or HFO-1234yf and/or at least one other refrigerant compound to form a commercial thermal fluid. Appropriate commercial thermal fluids of blends containing HFC-134a and HFO-1234yf and at least one other refrigerant compound include, but not limited to, R-448A, R-448B, R-449A, R-449B, R-449C, R-475A, R-475B and R-516A.

Example 4

[0170] A used or spent thermal fluid is recovered, tested and validated to form a consolidated thermal fluid composition.

[0171] In some embodiments, the recovered thermal fluid composition includes at least 1,1,1,2,3,3,3-heptafluoropropane ($\text{CF}_3\text{-CHF-CF}_3$, HFC-227ea) and E-HFO-1234ze. In some embodiments, the recovered thermal fluid composition comprises at least HFC-227ea, E-HFO-1234ze and E-1,1,1,4,4,4-hexafluoro-2-butene ($\text{CF}_3\text{-CH=CH-CF}_3$, E-HFO-1336mzz). In some embodiments, the recovered thermal fluid

composition is R-471A (4.3% HFC-227ea / 78.7% HFO-1234ze(E) / 17% HFO-1336mzz(E)). However, it will be understood by those skilled in the art that the recovered thermal fluid composition may be any commercial thermal fluid comprising HFC-227ea, E-HFO-1234ze, E-HFO-1336mzz and at least one other refrigerant compound, such as but not limited to R-464A, R-470A, R-470B, R-471A and/or R-478A.

[0172] If the impurities are greater than 5%, the composition may be purified to reduce the level of impurities to less than 5%; or if the impurities are greater than 0.5%, the composition may be purified to reduce the level of impurities to less than 0.5%.

[0173] The recovered thermal fluid composition is distilled and at least one distillate stream containing HFC-227ea and E-HFO-1234ze is collected to provide an azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid containing HFC-227ea and E-HFO-1234ze. In one embodiment, the recovered thermal fluid composition is distilled and at least one distillate stream containing R-515A (12% HFC-227ea / 88% E-HFO-1234ze) or R-515B (8.9% HFC-227ea / 91.1% E-HFO-1234ze) is collected. Each distillate stream may comprise one or a plurality of distillate fractions.

[0174] In one embodiment, the recovered thermal fluid composition (e.g., R-471A) is distilled and at least one distillate stream containing R-515A is collected. In one embodiment, the recovered thermal fluid composition (e.g., R-471A) is distilled and at least one distillate stream containing R-515A is collected, and at least one other distillate stream containing E-HFO-1336mzz is collected as a neat reclaimed thermal fluid. Each distillate stream may comprise one or a plurality of distillate fractions.

[0175] In one embodiment, the recovered thermal fluid composition comprises R-471A (4.3% HFC-227ea / 78.7% HFO-1234ze(E) / 17% HFO-1336mzz(E)) and is distilled, such that one distillate stream containing R-515B (8.9% HFC-227ea / 91.1% E-HFO-1234ze) is collected, and another distillate stream containing E-HFO-1336mzz is collected as a neat reclaimed thermal fluid.

[0176] In one embodiment, the recovered thermal fluid composition comprises HFC-227ea, HFO-1234ze(E) and HFO-1336mzz(E) (e.g., the recovered thermal fluid composition may comprise R-471A (4.3% HFC-227ea / 78.7% HFO-1234ze(E) /

17% HFO-1336mzz(E))) and is distilled. A first distillate fraction containing HFC-227ea and E-HFO-1234ze) (e.g., R-515B) is collected, and a second distillate stream containing E-HFO-1336mzz is collected as a neat reclaimed thermal fluid. Table 4 shows distillation requirements for obtaining these first and second distillate fractions as compared with the distillation requirements for obtaining individual fractions of HFC-227ea, HFO-1234ze(E) and HFO-1336mzz(E). The latter requires two distillation columns as compared with one distillation column for obtaining the above-described first and second distillate fractions (see, e.g., Fig. 8). Also, the molar reflux ratio for distilling the individual compounds is about one hundred times that required for obtaining the above-described first and second distillate fractions. Thus, the data show that obtaining separate fractions of HFC-227ea, HFO-1234ze(E) and HFO-1336mzz(E) would require larger distillation columns and a larger number of distillation columns as well as higher energy input, and thus exhibit a much larger environmental footprint, as compared with the present invention.

TABLE 4

	Example 4		
	Column (B21)		
Column Stages	40		
Molar reflux ratio	3		
Stream	Feed	Overhead	Bottom
Temp (°C)	25.0	41.23004293	72.57666957
Pressure (psia)	114.69595	114.6959488	114.6959488
1234ze(E) wt fraction	0.78700	0.948029	0.000567352
1336mzz(E) wt fraction	0.17000	0.000183	0.999352799
227ea wt fraction	0.043	0.051788	0.000

	Comparative Example 4					
	Column 1 (B22)			Column 2 (B23)		
Column Stages	40			200		
Molar reflux ratio	4			300		
Stream	Feed	Overhead	Bottom	Feed	Overhead	Bottom
Temp (°C)	25	41.22738	72.60950056	41.22738	41.223231	41.23102005
Pressure (psia)	114.69595	114.69595	114.6959488	114.69595	114.69595	114.6959488
1234ze(E) wt fraction	0.78700	0.9481746	6.27639E-05	0.94817	0.9719278	0.933441889
1336mzz(E) wt fraction	0.17000	2.027E-05	0.999928218	0.00002	1.425E-33	0.0000
227ea wt fraction	0.04300	0.0518051	0.000	0.05181	2.81E-02	0.066525263

[0177] In one embodiment, the neat reclaimed thermal fluid comprising E-HFO-1336mzz may be used directly in a heat transfer system as a single thermal fluid or may be packaged and sold as-is as a suitable refrigerant. In another embodiment, the neat reclaimed thermal fluid comprising E-HFO-1336mzz may be disposed of as waste. Alternatively, the neat reclaimed thermal fluid comprising E-HFO-1336mzz may be sold as-is as a reclaimed blending building block, or may be combined with virgin, used, or other reclaimed thermal fluids containing at least one other refrigerant compound in order to form a commercial thermal fluid.

[0178] In one embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-227ea; HFO-1234ze(E); one or more additional compounds selected from HFC-23, FC-1216, HFC-143a, HFC-134a, HCFC-22, HCFC-124, FC-218, HFC-236fa and HFO-1225zc; and one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225yf(E), HFO-1225yf(Z), HFO-1225zc, HFC-236fa, HFC-152a, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, R-2223, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb and HFC-134.

[0179] In one embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-227ea; HFO-1234ze(E); E-HFO-1336mzz; and one or more additional compounds selected from HC-30, HCFC-114, HCFC-114a, HCFC-133, HCFC-133a, HFC-245fa, HFC-338mee, HFC-338mf, HFC-347mef, HCO-1140, HCFO-1224 isomers, HCFO-1224yd, HCFO-1224yb, HCFO-1233xf, HCFO-1233zd, HFO-1243zf, HFO-1327mz, HFO-1336ft, HCFO-1326mxz, HFC-23, HFC-32, HFC-143a, HFC-134a, CFC-115, CFCO-1113, HFC-41, HCFC-22, CFC-12 and HCC-40.

[0180] In one embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is used as-is in a heat transfer system, or is packaged and sold as-is as a suitable refrigerant (e.g., R-515B) for a heat transfer system.

[0181] In one embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is combined with virgin, used, or other reclaimed thermal fluids of HFC-227ea and/or HFO-1234ze(E) to adjust the ratio of HFC-227ea to HFO-1234ze(E) to form a commercial thermal fluid. Appropriate commercial thermal

fluids of blends of HFC-227ea and HFO-1234ze(E) include, but are not limited to, R-515A and R-515B.

[0182] In another embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is sold as-is as a reclaimed blending building block, for example for making a commercial thermal fluid containing HFC-227ea and HFO-1234ze(E) and at least one other refrigerant compound, such as, but not limited to, R-464A, R-470A, R-470B, R-471A and/or R-478A.

[0183] In other embodiments, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is combined with virgin, used, or other reclaimed thermal fluids containing HFC-227ea and/or HFO-1234ze(E) and/or at least one other refrigerant compound to form a commercial thermal fluid. Appropriate commercial thermal fluids of blends containing HFC-227ea and HFO-1234ze(E) and at least one other refrigerant compound include, but are not limited to, R-464A, R-470A, R-470B, R-471A and/or R-478A.

Example 5

[0184] A used or spent thermal fluid is recovered, tested and validated to form a consolidated thermal fluid composition.

[0185] In some embodiments, the recovered thermal fluid composition includes at least HFC-32 and (E)-1,2-difluoroethylene (CHF=CHF, HFO-1132(E)). In some embodiments, the recovered thermal fluid composition comprises at least HFC-32, E-HFO-1132 and HFO-1234yf. In some embodiments, the recovered thermal fluid composition is R-479A (21.5% HFC-32 / 28% HFO-1132(E) / 50.5% HFO-1234yf). However, it will be understood by those skilled in the art that the recovered thermal fluid composition may be any commercial thermal fluid comprising HFC-32, E-HFO-1132 and HFO-1234yf, and at least one other refrigerant compound.

[0186] If the impurities are greater than 5%, the composition may be purified to reduce the level of impurities to less than 5%; or if the impurities are greater than 0.5%, the composition may be purified to reduce the level of impurities to less than 0.5%.

[0187] The recovered thermal fluid composition is distilled and at least one distillate stream containing HFC-32 and E-HFO-1132 is collected to provide an azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid containing HFC-32 and E-HFO-1132. Each distillate stream may comprise one or a plurality of distillate fractions.

[0188] In one embodiment, the recovered thermal fluid composition (e.g., R-479A) is distilled and at least one distillate stream containing HFC-32 and E-HFO-1132 is collected as an azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid. In one embodiment, the recovered thermal fluid composition (e.g., R-479A) is distilled and at least one distillate stream containing HFC-32 and E-HFO-1132 is collected as an azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid, and at least one other distillate stream containing HFO-1234yf is collected as a neat reclaimed thermal fluid. Each distillate stream may comprise one or a plurality of distillate fractions.

[0189] In one embodiment, the recovered thermal fluid composition comprises R-479A (21.5% HFC-32 / 28% HFO-1132(E) / 50.5% HFO-1234yf) and is distilled, such that one distillate stream containing HFC-32 and E-HFO-1132 is collected as an azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid, and another distillate stream containing HFO-1234yf is collected as a neat reclaimed thermal fluid.

[0190] In one embodiment, the neat reclaimed thermal fluid comprising HFO-1234yf may be used directly in a heat transfer system as a single thermal fluid or may be packaged and sold as-is as a suitable refrigerant. In another embodiment, the neat reclaimed thermal fluid comprising HFO-1234yf may be disposed of as waste. Alternatively, the neat reclaimed thermal fluid comprising HFO-1234yf may be sold as-is as a reclaimed blending building block, or may be combined with virgin, used, or other reclaimed thermal fluids containing at least one other refrigerant compound in order to form a commercial thermal fluid.

[0191] In one embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-32, HFO-1132(E); one or more additional compounds selected from HFC-143a, HFC-41, HFC-134a, HCFC-22, CFC-12 and HCC-40; and one or more additional compounds selected from HFC-32, HFC-125,

HCFO-E-1122a, HCFO-Z-1122a, HFO-1123, HFO-1141, HCFC-133, HCFC-133b, HCFC-123, HFC-152, HFC-143, HFC-41, HCFC-22, ethylene, HCFC-142a, HFO-1132a, HCFO-1131a, HCFO-E-1131, HCFO-Z-1131, HCFO-1122, acetylene and HCO-1140.

[0192] In one embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-32, HFO-1132(E); HFO-1234yf; and one or more additional compounds selected from HFC-143a, HFC-41, HFC-134a, HCFC-22, CFC-12, HCC-40, HFC-125, HCFO-E-1122a, HCFO-Z-1122a, HFO-1123, HFO-1141, HCFC-133, HCFC-133b, HCFC-123, HFC-152, HFC-143, ethylene, HCFC-142a, HFO-1132a, HCFO-1131a, HCFO-E-1131, HCFO-Z-1131, HCFO-1122, acetylene, HCO-1140, HFO-1225ye, HFO-1243zf, E-HFO-1234ze, HFC-236ea, HCFC-244bb, HFC-245fa, HFC-245eb, HFC-245cb, 3,3,3-trifluoropropyne, HFC-152a, FO-1114, HCFO-1214ya, FO-1216, HCFO-1224yd, HFO-1252 isomers, HCFC-225, HFC-254eb, HFC-263fb, HFC-236fa, HCFC-142b, HCFC-244cc, HCFO-1223.

[0193] In one embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is used as-is in a heat transfer system, or is packaged and sold as-is as a suitable refrigerant for a heat transfer system.

[0194] In one embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is combined with virgin, used, or other reclaimed thermal fluids of HFC-32 and/or HFO-1132(E) to adjust the ratio of HFC-32 to HFO-1132(E) to form a commercial thermal fluid.

[0195] In another embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is sold as-is as a reclaimed blending building block, for example for making a commercial thermal fluid containing HFC-32 and HFO-1132(E) and at least one other refrigerant compound.

[0196] In other embodiments, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is combined with virgin, used, or other reclaimed thermal fluids containing HFC-32 and/or HFO-1132(E) and/or at least one other refrigerant compound to form a commercial thermal fluid.

Example 6

[0197] A used or spent thermal fluid is recovered, tested and validated to form a consolidated thermal fluid composition.

[0198] In some embodiments, the recovered thermal fluid composition includes at least 1,1-difluoroethane ($\text{CHF}_2\text{-CH}_3$, HFC-152a) and E-HFO-1234ze. In some embodiments, the recovered thermal fluid composition comprises at least HFC-152a, E-HFO-1234ze and HFC-32. In some embodiments, the recovered thermal fluid composition is R-444A (12% HFC-32 / 5% HFC-152a / 83% E-HFO-1234ze) or R-444B (41.5% HFC-32 / 10% HFC-152a / 48.5% E-HFO-1234ze). However, it will be understood by those skilled in the art that the recovered thermal fluid composition may be any commercial thermal fluid comprising HFC-152a, E-HFO-1234ze, and at least one other refrigerant compound, including but not limited to R-478A.

[0199] If the impurities are greater than 5%, the composition may be purified to reduce the level of impurities to less than 5%; or if the impurities are greater than 0.5%, the composition may be purified to reduce the level of impurities to less than 0.5%.

[0200] The recovered thermal fluid composition is distilled and at least one distillate stream containing HFC-152a and E-HFO-1234ze is collected to provide an azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid containing HFC-152a and E-HFO-1234ze. Each distillate stream may comprise one or a plurality of distillate fractions.

[0201] In one embodiment, the recovered thermal fluid composition (e.g., R-444A or R-444B) is distilled and at least one distillate stream containing HFC-152a and E-HFO-1234ze is collected as an azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid. In one embodiment, the recovered thermal fluid composition (e.g., R-444A or R-444B) is distilled and at least one distillate stream containing HFC-152a and E-HFO-1234ze is collected as an azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid, and at least one other distillate stream containing HFC-32 is collected as a neat reclaimed thermal fluid. Each distillate stream may comprise one or a plurality of distillate fractions.

[0202] In one embodiment, the recovered thermal fluid composition comprises R-444A (12% HFC-32 / 5% HFC-152a / 83% E-HFO-1234ze) or R-444B (41.5% HFC-32 / 10% HFC-152a / 48.5% E-HFO-1234ze), and is distilled such that one distillate stream containing HFC-152a and E-HFO-1234ze is collected as an azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid, and another distillate stream containing HFC-32 is collected as a neat reclaimed thermal fluid.

[0203] In one embodiment, the recovered thermal fluid composition comprises HFC-152a, E-HFO-1234ze and HFC-32 (e.g., the recovered thermal fluid composition may comprise 444A (12% HFC-32 / 5% HFC-152a / 83% E-HFO-1234ze)) and is distilled. A first distillate fraction containing HFC-152a and E-HFO-1234ze is collected, and a second distillate stream containing HFC-32 is collected as a neat reclaimed thermal fluid. Table 5 shows distillation requirements for obtaining these first and second distillate fractions as compared with the distillation requirements for obtaining individual fractions of HFC-152a, E-HFO-1234ze and HFC-32. The latter requires two distillation columns as compared with one distillation column for obtaining the above-described first and second distillate fractions (see, e.g., Fig. 9). Also, the molar reflux ratio for distilling the individual compounds is more than thirty times that required for obtaining the above-described first and second distillate fractions. Thus, the data show that obtaining separate fractions of HFC-152a, E-HFO-1234ze and HFC-32 would require larger distillation columns and a larger number of distillation columns as well as higher energy input, and thus exhibit a much larger environmental footprint, as compared with the present invention.

Table 5

	Example 6		
	Column (B13)		
Column Stages	25		
Molar reflux ratio	2.9		
Stream	Feed	Overhead	Bottom
Temp (°C)	25.0	-0.812078419	39.44912394
Pressure (psia)	113.6546	114.6959488	114.6959488
32 wt fraction	0.12	0.995000	0.005000002
1234ze(E) wt fraction	0.83	0.004412	0.938505859
152a wt fraction	0.05	0.000588	0.056

	Comparative Example 6					
	Column 1 (B14)			Column 2 (B15)		
Column Stages	25			120		
Molar reflux ratio	7.3			91		
Stream	Feed	Overhead	Bottom	Feed	Overhead	Bottom
Temp (°C)	25.0	-0.8090426	40.25800966	40.25801	34.893424	41.12889679
Pressure (psia)	113.6546	114.69595	114.6959488	114.69595	114.69595	114.6959488
32 wt fraction	0.12	0.9950001	1.99946E-05	0.00002	0.0003827	3.02536E-18
1234ze(E) wt fraction	0.83	0.0039907	0.943262389	0.94326	0.0046174	0.9950
152a wt fraction	0.05	0.0010092	0.057	0.05672	9.95E-01	0.005000005

[0204] In one embodiment, the neat reclaimed thermal fluid comprising HFC-32 may be used directly in a heat transfer system as a single thermal fluid or may be packaged and sold as-is as a suitable refrigerant. In another embodiment, the neat reclaimed thermal fluid comprising HFC-32 may be disposed of as waste. Alternatively, the neat reclaimed thermal fluid comprising HFC-32 may be sold as-is as a reclaimed blending building block, or may be combined with virgin, used, or other reclaimed thermal fluids containing at least one other refrigerant compound in order to form a commercial thermal fluid.

[0205] In one embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-152a; E-HFO-1234ze; one or more additional compounds selected from HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a; and one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225yf(E), HFO-1225yf(Z), HFO-1225zc, HFC-236fa, HFC-152a, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, R-2223, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb and HFC-134.

[0206] In one embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-152a; E-HFO-1234ze; HFC-32; and one or more additional compounds selected from HFC-161, HCC-40, isobutane, HCO-1140, HCC-160, CFC-114a, HFO-1234yf, HFC-245cb, HFO-1225yf(E), HFO-1225yf(Z), HFO-1225zc, HFC-236fa, HFC-152a, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, R-2223, HFO-1234ze(Z),

HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb, HFC-134, HFC-41, HCFC-22 and CFC-12.

[0207] In one embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is used as-is in a heat transfer system or is packaged and sold as-is as a suitable refrigerant for a heat transfer system.

[0208] In one embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is combined with virgin, used, or other reclaimed thermal fluids of HFC-152a and/or E-HFO-1234ze to adjust the ratio of HFC-152a to E-HFO-1234ze to form a commercial thermal fluid.

[0209] In another embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is sold as-is as a reclaimed blending building block, for example for making a commercial thermal fluid containing HFC-152a and E-HFO-1234ze and at least one other refrigerant compound.

[0210] In other embodiments, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is combined with virgin, used, or other reclaimed thermal fluids containing HFC-152a and E-HFO-1234ze and/or at least one other refrigerant compound to form a commercial thermal fluid, such as but not limited to R-444A, R-444B and/or R-478A.

Example 7

[0211] A used or spent thermal fluid is recovered, tested, and validated to form a consolidated thermal fluid composition.

[0212] In some embodiments, the recovered thermal fluid composition includes at least HFC-125 and 1,1,1-trifluoroethane (HFC-143a). In some embodiments, the recovered thermal fluid composition comprises at least HFC-125, HFC-143a and HFC-134a. In some embodiments, the recovered thermal fluid composition is R-404A (44% HFC-125 / 4% HFC-134a / 52% HFC-143a). However, it will be understood by those skilled in the art that the recovered thermal fluid composition may be any commercial thermal fluid comprising HFC-125, HFC-143a, and at least one other refrigerant compound, including but not limited to R-404A.

[0213] If the impurities are greater than 5%, the composition may be purified to reduce the level of impurities to less than 5%; or if the impurities are greater than 0.5%, the composition may be purified to reduce the level of impurities to less than 0.5%.

[0214] The recovered thermal fluid composition is distilled and at least one distillate stream containing HFC-125 and HFC-143a is collected to provide an azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid containing HFC-125 and HFC-143a. In one embodiment, the recovered thermal fluid composition is distilled and at least one distillate stream containing R-507 (50% HFC-125 / 50% HFC-143a) is collected. Each distillate stream may comprise one or a plurality of distillate fractions.

[0215] In one embodiment, the recovered thermal fluid composition (e.g., R-404A) is distilled and at least one distillate stream containing HFC-125 and HFC-143a is collected as an azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid, and at least one other distillate stream containing HFC-134a is collected as a neat reclaimed thermal fluid. In one embodiment, the recovered thermal fluid composition (e.g., R-404A) is distilled and at least one distillate stream containing R-507 is collected as an azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid, and at least one other distillate stream containing HFC-134a is collected as a neat reclaimed thermal fluid. Each distillate stream may comprise one or a plurality of distillate fractions.

[0216] In one embodiment, the recovered thermal fluid composition comprises HFC-125, HFC-143a and HFC-134a (e.g., the recovered thermal fluid composition may comprise 404A) and is distilled. A first distillate fraction containing HFC-125 and HFC-143a is collected, and a second distillate stream containing HFC-134a is collected as a neat reclaimed thermal fluid. Table 6 shows distillation requirements for obtaining these first and second distillate fractions as compared with the distillation requirements for obtaining individual fractions of HFC-125, HFC-143a and HFC-134a. The latter requires two distillation columns as compared with one distillation column for obtaining the above-described first and second distillate fractions (see, e.g., Fig. 10). Also, the molar reflux ratio for distilling the individual compounds is more than one hundred times that required for obtaining the above-

described first and second distillate fractions. Thus, the data show that obtaining separate fractions of HFC-125, HFC-143a and HFC-134a would require larger distillation columns and a larger number of distillation columns as well as higher energy input, and thus exhibit a much larger environmental footprint, as compared with the present invention.

Table 6

	Example 7		
	Column (B10)		
Column Stages	25		
Molar reflux ratio	1.6		
Stream	Feed	Overhead	Bottom
Temp (°C)	25.0	7.946943468	30.78091154
Pressure (psia)	180.94133	114.6959488	114.6959488
125 wt fraction	0.44	0.456085	0.001104306
134a wt fraction	0.04	0.005000	0.994999743
143a wt fraction	0.52	0.538915	0.004

	Comparative Example 7					
	Column 1 (B11)			Column 2 (B12)		
Column Stages	30			120		
Molar reflux ratio	1.7			200		
Stream	Feed	Overhead	Bottom	Feed	Overhead	Bottom
Temp (°C)	25.0	7.8884633	30.78034278	7.8884633	5.3462317	8.123226918
Pressure (psia)	180.94133	114.69595	114.6959488	114.69595	114.69595	114.6959488
125 wt fraction	0.44	0.457465	0.001073977	0.45747	0.995	0.228672421
134a wt fraction	0.04	0.0020007	0.994985547	0.00200	3.631E-21	0.0029
143a wt fraction	0.52	0.5405342	0.004	0.54053	5.00E-03	0.768475257

[0217] In one embodiment, the neat reclaimed thermal fluid comprising HFC-134a may be used directly in a heat transfer system as a single thermal fluid or may be packaged and sold as-is as a suitable refrigerant. In another embodiment, the neat reclaimed thermal fluid comprising HFC-134a may be disposed of as waste. Alternatively, the neat reclaimed thermal fluid comprising HFC-134a may be sold as-is as a reclaimed blending building block, or may be combined with virgin, used, or other reclaimed thermal fluids containing at least one other refrigerant compound in order to form a commercial thermal fluid.

[0218] In one embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-125; HFC-143a; one or more additional

compounds selected from HFC-23, HFC-32, HFC-143a, HFC-134a, CFC-115, CFCO-1113 and HCC-40; and one or more additional compounds selected from CFC-115, HFC-134a, HFC-152a, HCFC-22, CFC-12, HCFC-124, CFC-114a and HCFC-133a.

[0219] In one embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-125; HFC-143a; HFC-134a; and one or more additional compounds selected from HFC-23, HFC-32, CFC-115, CFCO-1113, HCC-40, HFC-152a, HCFC-22, CFC-12, HCFC-124, CFC-114a and HCFC-133a.

[0220] In one embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is used as-is in a heat transfer system, or is packaged and sold as-is as a suitable refrigerant for a heat transfer system.

[0221] In one embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is combined with virgin, used, or other reclaimed thermal fluids of HFC-125 and/or HFC-143a to adjust the ratio of HFC-125 to HFC-143a to form a commercial thermal fluid.

[0222] In another embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is sold as-is as a reclaimed blending building block, for example for making a commercial thermal fluid containing HFC-125 and HFC-143a and at least one other refrigerant compound.

[0223] In other embodiments, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is combined with virgin, used, or other reclaimed thermal fluids containing HFC-125 and HFC-143a and/or at least one other refrigerant compound to form a commercial thermal fluid, such as but not limited to R-404A.

Example 8

[0224] A used or spent thermal fluid is recovered, tested and validated to form a consolidated thermal fluid composition.

[0225] In some embodiments, the recovered thermal fluid composition includes at least HFC-32 and E-HFO-1132. In some embodiments, the recovered thermal fluid composition comprises at least HFC-32, E-HFO-1132 and E-HFO-1234ze.

[0226] If the impurities are greater than 5%, the composition may be purified to reduce the level of impurities to less than 5%; or if the impurities are greater than 0.5%, the composition may be purified to reduce the level of impurities to less than 0.5%.

[0227] The recovered thermal fluid composition is distilled and at least one distillate stream containing HFC-32 and E-HFO-1132 is collected to provide an azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid containing HFC-32 and E-HFO-1132. Each distillate stream may comprise one or a plurality of distillate fractions.

[0228] In one embodiment, the recovered thermal fluid composition is distilled and at least one distillate stream containing HFC-32 and E-HFO-1132 is collected as an azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid. In one embodiment, the recovered thermal fluid composition is distilled and at least one distillate stream containing HFC-32 and E-HFO-1132 is collected as an azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid, and at least one other distillate stream containing E-HFO-1234ze is collected as a neat reclaimed thermal fluid. Each distillate stream may comprise one or a plurality of distillate fractions.

[0229] In one embodiment, the recovered thermal fluid composition comprises HFC-32, E-HFO-1132 and E-HFO-1234ze and is distilled, such that one distillate stream containing HFC-32 and E-HFO-1132 is collected as an azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid, and another distillate stream containing E-HFO-1234ze is collected as a neat reclaimed thermal fluid.

[0230] In one embodiment, the neat reclaimed thermal fluid comprising E-HFO-1234ze may be used directly in a heat transfer system as a single thermal fluid or may be packaged and sold as-is as a suitable refrigerant. In another embodiment, the neat reclaimed thermal fluid comprising E-HFO-1234ze may be disposed of as waste. Alternatively, the neat reclaimed thermal fluid comprising E-HFO-1234ze may be sold as-is as a reclaimed blending building block, or may be combined with virgin, used, or other reclaimed thermal fluids containing at least one other refrigerant compound in order to form a commercial thermal fluid.

[0231] In one embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-32, HFO-1132(E); one or more additional

compounds selected from HFC-143a, HFC-41, HFC-134a, HCFC-22, CFC-12 and HCC-40; and one or more additional compounds selected from HFC-32, HFC-125, HCFO-E-1122a, HCFO-Z-1122a, HFO-1123, HFO-1141, HCFC-133, HCFC-133b, HCFC-123, HFC-152, HFC-143, HFC-41, HCFC-22, ethylene, HCFC-142a, HFO-1132a, HCFO-1131a, HCFO-E-1131, HCFO-Z-1131, HCFO-1122, acetylene and HCO-1140.

[0232] In one embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-32, HFO-1132(E); E-HFO-1234ze; and one or more additional compounds selected from HFC-143a, HFC-41, HFC-134a, HCFC-22, CFC-12, HCC-40, HFC-125, HCFO-E-1122a, HCFO-Z-1122a, HFO-1123, HFO-1141, HCFC-133, HCFC-133b, HCFC-123, HFC-152, HFC-143, ethylene, HCFC-142a, HFO-1132a, HCFO-1131a, HCFO-E-1131, HCFO-Z-1131, HCFO-1122, acetylene, HCO-1140, HFO-1225ye, HFO-1243zf, E-HFO-1234ze, HFC-236ea, HCFC-244bb, HFC-245fa, HFC-245eb, HFC-245cb, 3,3,3-trifluoropropyne, HFC-152a, FO-1114, HCFO-1214ya, FO-1216, HCFO-1224yd, HFO-1252 isomers, HCFC-225, HFC-254eb, HFC-263fb, HFC-236fa, HCFC-142b, HCFC-244cc, HCFO-1223.

[0233] In one embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is used as-is in a heat transfer system or is packaged and sold as-is as a suitable refrigerant for a heat transfer system.

[0234] In one embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is combined with virgin, used, or other reclaimed thermal fluids of HFC-32 and/or HFO-1132(E) to adjust the ratio of HFC-32 to HFO-1132(E) to form a commercial thermal fluid.

[0235] In another embodiment, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is sold as-is as a reclaimed blending building block, for example for making a commercial thermal fluid containing HFC-32 and HFO-1132(E) and at least one other refrigerant compound.

[0236] In other embodiments, the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is combined with virgin, used, or other reclaimed thermal fluids containing HFC-32 and/or HFO-1132(E) and/or at least one other refrigerant compound to form a commercial thermal fluid.

[0237] For blends containing one or more HFOs, a stabilizer package may be added to the reclaimed thermal fluid to stabilize the HFO in the thermal fluid.

[0238] While this specification contains many specific implementation details, these should not be construed as limitations on the scope of any inventions or of what may be claimed, but rather as descriptions of features specific to particular implementations of particular inventions. Certain features that are described in this specification in the context of separate implementations can also be implemented in combination in a single implementation. Conversely, various features that are described in the context of a single implementation can also be implemented in multiple implementations separately or in any suitable sub-combination. Moreover, although features may be described above as acting in certain combinations and even initially claimed as such, one or more features from a claimed combination can in some cases be excised from the combination, and the claimed combination may be directed to a sub-combination or variation of a sub-combination.

[0239] Similarly, while operations are depicted in the drawings in a particular order, this should not be understood as requiring that such operations be performed in the particular order shown or in sequential order, or that all illustrated operations be performed, to achieve desirable results. In certain circumstances, multitasking and parallel processing may be advantageous. Moreover, the separation of various system components in the implementations described above should not be understood as requiring such separation in all implementations, and it should be understood that the described program components and systems can generally be integrated together in a single software product or packaged into multiple software products.

[0240] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which example embodiments belong. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0241] While the disclosure 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 disclosure. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the disclosure without departing from the essential scope thereof. While various aspects and embodiments have been disclosed herein, other aspects and embodiments will be apparent to those skilled in the art. The various aspects and embodiments disclosed herein are for purposes of illustration and are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

CLAIMS OF THE INVENTION

What is claimed is:

1. A process of thermal fluid reclamation comprising:
 - recovering a thermal fluid comprising at least a first refrigerant compound, a second refrigerant compound and a third refrigerant compound;
 - testing the recovered thermal fluid and validating that the recovered thermal fluid has greater than about 95 wt%, preferably greater than about 99 wt%, most preferably greater than about 99.5 wt% organic purity; and
 - distilling the recovered thermal fluid to form at least one distillate comprising the first refrigerant compound and the second refrigerant compound as a reclaimed thermal fluid, wherein the reclaimed thermal fluid is azeotropic, near-azeotrope, or close-boiling.
2. The process of claim 1, wherein the reclaimed thermal fluid is a thermal fluid product, the process further comprising supplying the reclaimed thermal fluid to a heat transfer system for use therein.
3. The process of claim 1, further comprising packaging the reclaimed thermal fluid for commercial sale as a thermal fluid product for use in a heat transfer system.
4. The process of claim 1, further comprising supplying the reclaimed thermal fluid for formation of a thermal fluid product.
5. The process of any of claims 1 to 4, the process further comprising adjusting a ratio of the first refrigerant compound to the second refrigerant compound of the reclaimed thermal fluid by adding an additional amount of at least one of the first refrigerant compound and the second refrigerant compound to the reclaimed thermal fluid.
6. The process of any of claims 1 to 5, wherein the validating comprises removing one or more impurities from the recovered thermal fluid before distilling such that the recovered thermal fluid has greater than about 95 wt%, preferably greater than about 99 wt%, most preferably greater than about 99.5 wt% organic purity.
7. The process of claim 6, wherein the one or more impurities comprises an oil.

8. The process of any of claims 1 to 7, further comprising adding a stabilizer package to the reclaimed thermal fluid.
9. The process of any of claims 1 to 8, wherein the reclaimed thermal fluid is azeotropic.
10. The process of any of claims 1 to 9, further comprising testing the reclaimed thermal fluid and validating that the reclaimed thermal fluid has greater than about 95 wt%, preferably greater than about 99 wt%, most preferably greater than about 99.5 wt% organic purity
11. The process of claim 10, wherein validating of the reclaimed thermal fluid comprises removing one or more impurities from the reclaimed thermal fluid such that the reclaimed thermal fluid has greater than about 95 wt%, preferably greater than about 99 wt%, most preferably greater than about 99.5 wt% organic purity.
12. The process of any of claims 1 to 11, further comprising purifying the reclaimed thermal fluid to a state that meets AHRI Standard 700 purity specifications.
13. The process of any of claims 1 to 12, wherein the distilling of the recovered thermal fluid forms a further distillate comprising the third refrigerant compound as a second reclaimed thermal fluid, wherein the second reclaimed thermal fluid is a neat reclaimed thermal fluid.
14. The process of any of claims 1 to 12, wherein the recovered thermal fluid further comprises a fourth refrigerant compound, and wherein the distilling of the recovered thermal fluid forms a further distillate comprising the third refrigerant compound and the fourth refrigerant compound as a second reclaimed thermal fluid, wherein the first reclaimed thermal fluid and the second reclaimed thermal fluid are azeotropic, near-azeotrope, or close-boiling.
15. The process of any of claims 1 to 12, wherein the recovered thermal fluid further comprises a fourth refrigerant compound and a fifth refrigerant compound, and wherein the distilling of the recovered thermal fluid forms a second distillate comprising the third refrigerant compound and the fourth refrigerant compound as a second reclaimed thermal fluid and a third distillate comprising the fifth refrigerant compound as a third reclaimed thermal fluid,

wherein the first reclaimed thermal fluid and the second reclaimed thermal fluid are azeotropic, near-azeotrope, or close-boiling and wherein the third reclaimed thermal fluid is a neat reclaimed thermal fluid.

16. The process of any of claims 1 to 15, wherein the first refrigerant compound and the second refrigerant compound are HFC-125 and HFC-32.
17. The process of claim 16, wherein the recovered thermal fluid is selected from the group consisting of R-407A, R-407B, R-407C, R-407D, R-407E, R-407F, R-407G, R407H and R407I, preferably R-407C.
18. The process of claim 17, wherein the third refrigerant compound is HFC-134a.
19. The process of any of claims 16 to 18, wherein near-azeotrope or close-boiling reclaimed thermal fluid is R-410A (50% HFC-125 / 50% HFC-32).
20. The process of any of claims 16 to 19, wherein the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-125; HFC-32; one or more additional compounds selected from HFC-23, HFC-32, HFC-143a, HFC-134a, HFC-134, CFC-115, CFCO-1113 and HCC-40; and one or more additional compounds selected from HFC-143a, HFC-41, HFC-134a, HCFC-22, CFC-12 and HCC-40.
21. The process of claim 14, wherein the first refrigerant compound and the second refrigerant compound are HFC-125 and HFC-32, and wherein the third refrigerant compound and the fourth refrigerant compound are HFC-134a and HFO-1234yf.
22. The process of claim 21, wherein the recovered thermal fluid is R-449A.
23. The process of any of claims 21 to 22, wherein the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is R-410A (50% HFC-125 / 50% HFC-32), and wherein the second azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is selected from the group consisting of R-513A (44% HFC-134a / 56% HFO-1234yf) and R-513B (41.5% HFC-134a / 58.5% HFO-1234yf).
24. The process of any of claims 21 to 23,

wherein the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-125; HFC-32; one or more additional compounds selected from HFC-23, HFC-32, HFC-143a, HFC-134a, HFC-134, CFC-115, CFCO-1113 and HCC-40; and one or more additional compounds selected from HFC-143a, HFC-41, HFC-134a, HCFC-22, CFC-12 and HCC-40; and

wherein the second azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-134a; HFO-1234yf; one or more additional compounds selected from HFC-143a, HFO-1225zc, HFC-245cb, HFC-134, HFC-152a, HFO-1225ye, HFC-161, E-HFO-1234ze, HCFC-22, HFO-1243zf, CHFC-124, HCC-40, CHFO-1122, HCFC-31, CFC-114, CFC-114a and HCO-1140; and one or more additional compounds selected from HFO-1225ye, HFO-1243zf, E-HFO-1234ze, HFC-236ea, HCFC-244bb, HFC-245fa, HFC-245eb, HFC-245cb, 3,3,3-trifluoropropyne, HFC-152a, FO-1114, HFO-1123, HCFO-1131a, trans-HCFO-1131, HCO-1140, HCFO-1214ya, FO-1216, HCFO-1224yd, HFO-1252 isomers, HFC-143a, HCFC-225, HFC-254eb, HFC-263fb, HFC-236fa, HCFC-142b, HCFC-244cc, HCFO-1223, HFO-1132a and HCC-40.

25. The process of claim 15, wherein the first refrigerant compound and the second refrigerant compound are HFC-125 and HFC-32, wherein the third refrigerant compound and the fourth refrigerant compound are HFC-134a and HFO-1234yf, wherein the fifth refrigerant compound is E-HFO-1234ze.
26. The process of claim 25, wherein the recovered thermal fluid is R-448A.
27. The process of any of claims 25 to 26, wherein the near-azeotrope or close-boiling reclaimed thermal fluid is R-410A (50% HFC-125 / 50% HFC-32), wherein the second azeotropic reclaimed thermal fluid is selected from the group consisting of R-513A (44% HFC-134a / 56% HFO-1234yf) and R-513B (41.5% HFC-134a/58.5% HFO-1234yf), and wherein the third reclaimed fluid comprises E-HFO-1234ze.
28. The process of any of claims 25 to 27,

wherein the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-125; HFC-32; one or more additional compounds selected from HFC-23, HFC-32, HFC-143a, HFC-134a, CFC-115, CFCO-

1113 and HCC-40; and one or more additional compounds selected from HFC-143a, HFC-41, HFC-134a, HCFC-22, CFC-12 and HCC-40; and

wherein the second azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-134a; HFO-1234yf; one or more additional compounds selected from HFC-143a, HFO-1225zc, HFC-245cb, HFC-134, HFC-152a, HFO-1225ye, HFC-161, E-HFO-1234ze, HCFC-22, HFO-1243zf, CHFC-124, HCC-40, CHFO-1122, HCFC-31, CFC-114, CFC-114a and HCO-1140; and one or more additional compounds selected from HFO-1225ye, HFO-1243zf, E-HFO-1234ze, HFC-236ea, HCFC-244bb, HFC-245fa, HFC-245eb, HFC-245cb, 3,3,3-trifluoropropyne, HFC-152a, FO-1114, HFO-1123, HCFO-1131a, trans-HCFO-1131, HCO-1140, HCFO-1214ya, FO-1216, HCFO-1224yd, HFO-1252 isomers, HFC-143a, HCFC-225, HFC-254eb, HFC-263fb, HFC-236fa, HCFC-142b, HCFC-244cc, HCFO-1223, HFO-1132a and HCC-40.

29. The process of any of claims 1 to 15, wherein the first refrigerant compound and the second refrigerant compound are HFC-227ea and E-HFO-1234ze.
30. The process of claim 29, wherein the recovered thermal fluid is R-471A.
31. The process of any of claims 29 to 30, wherein the third refrigerant compound is E-HFO-1336mzz.
32. The process of any of claims 29 to 31, wherein the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid is R-515B (8.9% HFC-227ea / 91.1% E-HFO-1234ze).
33. The process of any of claims 29 to 32, wherein the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-227ea; E-HFO-1234ze; one or more additional compounds selected from HFC-23, FC-1216, HFC-143a, HFC-134a, HCFC-22, HCFC-124, FC-218, HFC-236fa and HFO-1225zc; and one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225yf(E), HFO-1225yf(Z), HFO-1225zc, HFC-236fa, HFC-152a, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, R-2223, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb and HFC-134.

34. The process of any of claims 1 to 15, wherein the first refrigerant compound and the second refrigerant compound are HFC-32 and E-HFO-1132.
35. The process of claim 34, wherein the recovered thermal fluid is R-479A.
36. The process of any of claims 34 to 35, wherein the third refrigerant compound is HFO-1234yf or E-HFO-1234ze.
37. The process of any of claims 34 to 36, wherein the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-32; E-HFO-1132; one or more additional compounds selected from HFC-143a, HFC-41, HFC-134a, HCFC-22, CFC-12 and HCC-40; and one or more additional compounds selected from HFC-32, HFC-125, HCFO-E-1122a, HCFO-Z-1122a, HFO-1123, HFO-1141, HCFC-133, HCFC-133b, HCFC-123, HFC-152, HFC-143, HFC-41, HCFC-22, ethylene, HCFC-142a, HFO-1132a, HCFO-1131a, HCFO-E-1131, HCFO-Z-1131, HCFO-1122, acetylene and HCO-1140.
38. The process of any of claims 1 to 15, wherein the first refrigerant compound and the second refrigerant compound are HFC-152a and E-HFO-1234ze.
39. The process of claim 38, wherein the recovered thermal fluid is R-444A or R-444B.
40. The process of any of claims 38 to 39, wherein the third refrigerant compound is HFC-32.
41. The process of any of claims 38 to 40, wherein the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-152a; E-HFO-1234ze; one or more additional compounds selected from HFC-161, HCC-40, isobutane, HCO-1140, HCC-160 and CFC-114a; and one or more additional compounds selected from HFO-1234yf, HFC-245cb, HFO-1225yf(E), HFO-1225yf(Z), HFO-1225zc, HFC-236fa, HFC-152a, HFC-143a, HFC-125, HFC-134a, HFO-1234zc, HFO-1233xf, HFO-1233zd, CFC-114, HCFC-124, R-2223, HFO-1234ze(Z), HFC-245fa, HFC-227ea, HFO-1243zf, HFC-263fb and HFC-134.
42. The process of any of claims 1 to 15, wherein the first refrigerant compound and the second refrigerant compound are HFC-125 and HFC-143a.

43. The process of claim 42, wherein the recovered thermal fluid is R-404A.
44. The process of any of claims 42 to 43, wherein the third refrigerant compound is HFC-134a.
45. The process of any of claims 42 to 44, wherein the azeotropic, near-azeotrope, or close-boiling reclaimed thermal fluid comprises HFC-125; HFC-143a; one or more additional compounds selected from HFC-23, HFC-32, HFC-134a, CFC-115, CFCO-1113 and HCC-40; and one or more additional compounds selected from CFC-115, HFC-134a, HFC-152a, HCFC-22, CFC-12, HCFC-124, CFC-114a and HCFC-133a.
46. The process of any of claims 1 to 45, wherein the recovered thermal fluid and/or the at least one distillate comprises at least one acid scavenger and/or at least one inhibitor selected from the group consisting of hydrocarbons including at least cyclic monoterpene; lipophilic organic compounds; and phenols, aromatic organic compounds having at least one chemical moiety -C₆H₄(OH), preferably at least one member selected from the group consisting of D-limonene, pinene, α -pinene, β -pinene, α -terpinene, α -tocopherol, butylated hydroxytoluene, 4-methoxyphenol, benzene-1,4-diol, and mixtures thereof.
47. A reclaimed thermal fluid formed by the process of any of claims 1 to 46.