

PYROLYSIS TAR UPGRADING

FIELD

[0001] This application claims priority to and the benefit of U.S. Provisional Application No. 62/857,442, filed June 05, 2019, and European Patent Application No. 19206400.4 which
5 was filed October 31, 2019, which are incorporated herein by reference in their entireties.

[0002] Embodiments generally relate to upgrading tar, such as by one or more thermal treatments. More particularly, embodiments relate to processes and apparatus for heat soaking steam cracked tar solids.

BACKGROUND

10 [0003] Hydrocarbon pyrolysis processes, such as steam cracking, crack hydrocarbon feedstocks into a wide range of relatively high value molecules, including ethylene, propene, butenes, steam cracked gas oil ("SCGO"), steam cracked naphtha ("SCN"), or any combination thereof. Besides these useful products, hydrocarbon pyrolysis can also produce a significant amount of relatively low-value heavy products, such as pyrolysis tar. When the pyrolysis is
15 produced by steam cracking, the pyrolysis tar is identified as steam-cracked tar ("SCT"). Economic viability of refining and petrochemical processes relies in part on the ability to incorporate as much of the product and residual fractions, such as SCT, into the value chain. One use of residual fractions and/or relatively low value products is to blend these fractions with other hydrocarbons, e.g., with other feedstreams or products.

20 [0004] SCT, however, generally contains relatively high molecular weight molecules, conventionally called Tar Heavies ("TH"), and an appreciable amount of sulfur. The presence of sulfur and TH make SCT a less desirable blendstock, e.g., for blending with fuel oil blendstocks or different SCTs. Compatibility is generally determined by visual inspection for solids formation, e.g., as described in U.S. Pat. No. 5,871,634. Generally, SCTs have high viscosity
25 and poor compatibility with other heavy hydrocarbons such as fuel oil, or are only compatible in small amounts. Likewise, SCTs produced under specific conditions generally have poor compatibility with SCT produced under different conditions.

[0005] Viscosity and compatibility can be improved, and the amount of sulfur decreased, by catalytically hydroprocessing the SCT. Catalytic hydroprocessing of undiluted SCT,
30 however, leads to appreciable catalyst deactivation and the formation of undesirable deposits (e.g., coke deposits or particles) on the reactor internals. As the amount of these deposits increases, the yield of the desired upgraded pyrolysis tar (upgraded SCT) decreases and the yield of undesirable byproducts increases. The hydroprocessing reactor pressure drop also increases, to a point where the reactor might be inoperable.

[0006] It is conventional to lessen deposit formation by hydroprocessing the SCT in the presence of a fluid, e.g., a solvent having significant aromatics content. The product of the hydroprocessing contains an upgraded SCT product that generally has a decreased viscosity, decreased atmospheric boiling point range, and increased hydrogen content over that of the feed's SCT, resulting in improved compatibility with fuel oil blend-stocks. Additionally, hydroprocessing the SCT in the presence of fluid produces fewer undesirable byproducts and the rate of increase in reactor pressure drop is lessened. Certain forms of SCT processing are disclosed in U.S. Patents Nos. 2,382,260 and 5,158,668, and in U.S. Patent Application Publication No. US2008/0053869. P.C.T. Patent Application Publications Nos. WO 2013/033590, WO 2018/111577, and WO 2019.203981 disclose recycling a portion of the hydroprocessed tar for use as the fluid.

[0007] The presence of solids in SCT represents a significant challenge to effective SCT hydroprocessing. An appreciable amount of the SCT's solids are in the form of particulates, e.g., coke (such as pyrolytic coke), oligomeric and/or polymeric material, inorganic solids (e.g., fines, metal, metal-containing compounds, ash, etc.) aggregates of one or more of these, etc. Although removing SCT particulates, e.g., by filtration, settling, centrifuging, etc., results in an SCT that can be more readily hydroprocessed, doing so undesirably decreases the yield of hydroprocessed SCT. Moreover, managing a significant inventory of removed particulates can adversely affect process financials.

[0008] As an example, coke fines, inorganic fines, and other solids can be present in the SCT. Coke fines or particles can be or include pyrolytic coke and/or polymeric coke. These fines or particles can be formed during polymerization conditions (e.g., $\geq 150^{\circ}\text{C}$) present in a primary fractionator after pyrolysis tar formation (upstream of a hydroprocessor).

[0009] Thus, there is a need for improved tar conversion processes having fewer solids present in hydrocarbon feedstocks to the tar conversion.

SUMMARY

[0010] In certain embodiments, processes are provided for upgrading tar, such as pyrolysis tar. A tar, e.g., one comprising pyrolysis tar such as steam cracker tar, is subjected to a first thermal treatment to produce a tar composition. At least a first higher-density portion and a first lower-density portion are separated from the tar composition. The first higher-density portion is subjected to a second thermal treatment to produce a thermally-treated first higher-density portion. A second higher-density portion and a second lower-density portion are separated from the thermally-treated first higher-density portion. At least a portion of the second lower-density portion can be recycled to one or more of (i) the tar, (ii) the tar

composition, and (iii) the first higher-density portion. The second higher-density portion can be conducted away, e.g., for storage and/or further processing. It is observed that the amount of solids in the thermally-treated first higher-density portion is less than that present in the first higher-density portion. Surprisingly, it is found that the second thermal treatment is effective
5 for converting solids in the first higher-density portion primarily to liquid in the thermally-treated first higher-density portion, with little if any conversion to vapor-phase material. This in turn leads to improved process financials, greater efficiency, an increased amount of desired liquid-phase material, and a decreased amount of less-desired solids in comparison with conventional tar processing. Returning to the process at least a portion of the second lower-
10 density portion (which contains liquid converted from solids in the second thermal treatment) increases the amount of tar available for hydroprocessing, leading to an increased yield in hydroprocessed tar.

[0011] In other embodiments, processes are provided for upgrading steam cracker tar. A steam cracker feed is steam cracked to form a steam cracker effluent comprising steam cracker
15 tar. A steam cracker tar composition is produced by at least (i) separating at least a portion of the steam cracker tar from the steam cracker effluent and (ii) thermally-treating at least a portion of the separated steam cracker tar in a first thermal treatment. A tar-fluid mixture is produced by adding a first utility fluid and/or a first separation fluid to the pyrolysis tar composition. A first separation is carried out in which (i) a first lower-density portion
20 comprising upgraded steam cracker tar and (ii) a first higher-density portion are separated from the thermally-treated steam cracker tar composition. At least a portion of the first lower-density portion is conducted away, e.g., for hydroprocessing. Diluent, typically comprising a second utility fluid and/or second separation fluid, is introduced into the first higher-density portion to form a diluted first higher-density portion. The diluted first higher-density portion is subjected
25 to a second thermal treatment to produce a thermally-treated first higher-density portion. The amount of solids in the thermally-treated first higher-density portion is less than that present in the diluted first higher-density portion. In a second separation, a second lower-density portion and a second higher-density portion are separated from the thermally-treated first higher-density portion. At least a portion of the second lower-density portion is added to one or more
30 of (i) the steam cracker effluent, (ii) the steam cracker tar, (iii) the steam cracker tar composition; (iv) the tar-fluid mixture, (v) the first higher-density portion, and (vi) the first lower-density portion.

[0012] In other embodiments, processes are provided for steam cracking a steam cracker feed comprising heavy oil, e.g., a heavy oil containing resid. The steam cracker effluent

comprises steam cracker tar. The steam cracker includes a convection section and a radiant section. The radiant section includes at least one radiant coil having an inlet and an outlet. The steam cracker feed is preheated in the convection section. A primarily vapor-phase stream and a primarily non-vapor-phase stream are separated from at least a portion of the preheated steam cracker feed, wherein ≥ 50 wt. % of resid in the feed is transferred to the non-vapor-phase stream. At least a portion of the primarily vapor-phase stream is conducted into the radiant coil's inlet. Steam cracking is carried out in the radiant coil in the presence of steam under steam cracking conditions. The steam cracking conditions include a temperature at the radiant coil outlet in the range of from about 760°C to about 1200°C, a steam cracking pressure at the radiant coil outlet in the range of from about 1 bar (absolute) to about 10 bar (absolute), and a steam cracking residence time in the radiant coil in the range of from about 0.1 seconds to about 2 seconds. A steam cracker effluent comprising steam cracker tar is conducted away from the radiant section via the radiant coil outlet. At least a portion of the steam cracker tar is separated from the steam cracker effluent. At least the separated portion of the steam cracker tar is thermally-treated in a first thermal treatment to produce a steam cracker tar composition. A first utility fluid and/or first separation fluid is added to the steam cracker tar composition and/or to produce a tar-fluid mixture. At least two additional separations are carried out. In the first of these separations, at least one centrifuge can be used to separate from the tar-fluid mixture (i) a first lower-density portion comprising upgraded steam cracker tar and (ii) a first higher-density portion. At least a portion of the first lower-density portion is conducted away, e.g., for hydroprocessing. A diluent comprising a second utility fluid and/or second separation fluid is introduced into the first higher-density portion to form a diluted first higher-density portion. The diluted first higher-density portion is subjected to a second thermal treatment to produce a thermally-treated first higher-density portion. The amount of solids in the thermally-treated first higher-density portion is less than that present in the diluted first higher-density portion. The second of these separations, which can also utilize at least one centrifuge, separates from the thermally-treated first higher-density portion (i) a second lower-density portion and (ii) a second higher-density portion. At least a portion of the second lower-density portion is added to one or more of (i) the steam cracker effluent, (ii) the steam cracker tar, (iii) the steam cracker tar composition, (iv) the tar-fluid mixture, (v) the first higher-density portion, and (vi) the first lower-density portion.

[0013] Other aspects of the invention include comminuting (e.g., by grinding) the first higher-density portion before the second thermal treatment. Still other aspects of the invention include separating the primarily vapor-phase stream and the primarily non-vapor-phase stream

from the preheated steam cracker feed in a separation stage that is integrated with the convection section. The separated primarily vapor-phase stream can be exposed to additional heating in the convection section before the cracking in the radiant section.

[0014] Other aspects of the invention relate to systems and apparatus for carrying out any of the forgoing processes, to the upgraded pyrolysis tar, the upgraded steam cracker tar, and to compositions containing one or more of these, to the separated lower-density and higher-density portions, and to the use of any of these or any part thereof as a feed for further processing, e.g., as a feed for tar hydroprocessing.

[0015] These and other features, aspects, and advantages of the processes will become better understood from the following description, appended claims, and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. 1 is a diagram illustrating an apparatus for carrying out certain aspects of the present disclosure.

[0017] FIG. 2 is a graph illustrating the amount of solids loss (wt. %) as a function of the temperature applied in a thermal treatment corresponding to the second thermal treatment, according to an embodiment.

DETAILED DESCRIPTION

[0018] The invention generally relates to separating a pyrolysis tar from a pyrolysis effluent, and upgrading at least the separated pyrolysis tar. More particularly, the invention relates to separating at least a portion of the pyrolysis tar from the pyrolysis effluent, and exposing at least a portion of the separated pyrolysis tar to a first thermal treatment to produce a pyrolysis tar composition. A first lower-density portion (the upgraded pyrolysis tar) and a first higher-density portion are separated from the pyrolysis tar composition. At least a portion of the first higher-density portion is exposed to a second thermal treatment to produce a thermally-treated first higher-density portion having fewer solids (weight basis) than does the first higher-density portion. A second lower-density portion and second higher-density portion are separated from the thermally-treated first higher-density portion. At least a portion of the second lower-density portion can be recycled, e.g., to the separated pyrolysis tar and/or the pyrolysis effluent. At least a portion of the second higher-density portion can be conducted away, e.g. for storage and/or further processing. It has been found that upgrading pyrolysis tar in this manner increases the amount of pyrolysis tar that can be made available for further upgrading, e.g., in one or more hydroprocessing stages, and improves compatibility of the upgraded pyrolysis tar for blending with other hydrocarbon streams, and produces fewer

particulates compared with conventional processes. The invention will now be more particularly described with respect to pyrolysis tar produced by steam cracking (steam cracker tar, or "SCT"). The invention is not limited to processing SCT, and this description is not meant to foreclose upgrading of pyrolysis tar produced by other forms of pyrolysis within the broader scope of the invention.

[0019] In certain aspects, the steam cracker effluent from the steam cracker furnace is cooled, e.g., by an indirect heat transfer in one or more transfer line exchangers. Alternatively or in addition, the steam cracker effluent and/or the cooled steam cracker effluent can be quenched (e.g., by a direct heat transfer). This can be carried out by combining from the steam cracker effluent and/or the cooled steam cracker effluent with a quench oil. SCT is separated from the cooled and/or quenched steam cracker effluent in at least one separation stage. Certain processes for separating SCT from a steam cracker effluent and for thermally-treating the separated SCT will now be described in more detail. The invention is not limited to these aspects, and this description should not be interpreted as foreclosing other processes for separating and thermally-treating SCT within the broader scope of the invention.

[0020] In certain aspects, SCT is separated from the cooled and/or quenched steam cracker effluent in a separation vessel, e.g., a tar knock-out drum. The separated SCT accumulates in the bottom of the drum, and typically combines with (i) material already present in the drum bottoms and (ii) optionally an added flux (e.g., utility fluid), to form an SCT composition. An overhead stream removed from the tar knock-out drum is typically conducted to at least one fractionator, e.g., a primary fractionator. The overhead stream typically comprises (i) ≥ 75 wt. % of what remains of the cooled and/or quenched steam cracker effluent after SCT separation, e.g., ≥ 90 wt. %, such as ≥ 99 wt. %; (ii) ≥ 50 wt. % of any flux as may be present in the tar knock-out drum, such as ≥ 75 wt. %, or ≥ 90 wt. %; and (iii) ≥ 50 wt. % of any quench oil (when used) conducted to the tar knock-out drum with quenched steam cracker effluent, e.g., ≥ 75 wt. %, such as ≥ 90 wt. %. Since the tar knock-out drum is an imperfect separator, (i) the tar knock-out drum overhead stream can contain unseparated SCT, typically ≤ 10 wt. % of the total amount of SCT in the steam cracker effluent, and (ii) the tar knock-out drum bottoms comprises an SCT composition which includes the separated, thermally-treated SCT, ≥ 90 wt. % of any flux remaining after the tar knock-out drum overhead is conducted away, and ≥ 90 wt. % of any quench oil remaining after the tar knock-out drum overhead is conducted away. In these and certain other aspects, the tar knock-out drum overhead is conducted to a primary fractionator, typically for separation from the tar knock-out drum overhead of a process gas stream comprising light olefin, and optionally one or more of (i) a pyrolysis gasoline stream,

(ii) a steam cracker gas oil stream, and (iii) a fractionator bottoms stream. The fractionator bottoms stream or portion thereof can be utilized as quench oil or a quench oil component. In these and certain other aspects, the specified SCT composition is produced by maintaining the tar knock-out drum bottoms at a temperature in the specified temperature range for a residence
5 time in the specified residence time range.

[0021] In other aspects, a tar knock-out drum is not used. In these and certain other aspects, the cooled and/or quenched steam cracker effluent is conducted directly from the effluent's cooling and/or quenching stages to one or more fractionators, e.g., to a primary fractionator. Typically in these aspects the primary fractionator functions to separate from the cooled and/or
10 quenched steam cracker effluent a process gas stream comprising light olefin, and optionally one or more of (i) a pyrolysis gasoline stream, (ii) a steam cracker gas oil stream, (iii) a quench oil stream, and (iv) a bottoms stream comprising an SCT composition that includes separated SCT. In these and certain other aspects, the specified thermally-treated SCT can be produced from the primary fractionator bottoms stream. For example, a bottoms pump-around can be
15 utilized, with the bottoms pump-around having one or more stages for heating and/or cooling via indirect heat transfer to achieve the specified temperature range and specified residence time range for the SCT composition's thermal treatment.

[0022] In aspects which include a primary fractionator, fractionation conditions can be regulated to lessen or substantially ultimate the formation of solids (e.g., polymer) in the
20 primary fractionator's bottoms and/or quench oil streams. For example, the primary fractionator inlet temperature can be preselected in the range of from 150°C to 300°C, e.g., 160°C to 210°C. In conventional processes for upgrading SCT, solids produced in the first thermal treatment and/or in the primary fractionator are conducted away as low-value stream, e.g., from a filter and/or centrifuge. Surprisingly, it has been found that at least a portion of
25 these solids can be converted in the specified second thermal treatment, with the conversion products being separated from the unconverted solids in the second SCT separation, recycled to the tar-fluid mixture, and then transferred in the first SCT separation to the first lower-density portion. Doing so increases the amount of material in the higher-value first lower-density portion, which in turn can the amount of feed to beneficial processes such as SATC.

[0023] Certain aspects of the invention include separating at least a first higher-density
30 portion and a first lower-density portion from the SCT composition. The separation can be carried out in one or more centrifuge stages (collectively, a "first centrifuge"). Since the SCT composition typically exhibits a relatively large viscosity in the specified processing temperature ranges, a stream comprising a first utility fluid and/or a first separation fluid (these

being of lesser viscosity than the SCT) is typically added upstream of at least this separation. In these cases, the first higher-density portion and the first lower-density portion are separated from a tar-fluid mixture that comprises the SCT composition and the added utility fluid/separation fluid stream.

5 **[0024]** The first lower-density portion is typically subjected to additional processing, e.g., in a solvent-assisted tar conversion (SATC) process. Conventional SATC processes are described, e.g., in P.C.T Patent Application Publication No. WO2018/111577 and U.S. Patent Applications Serial Nos. 62/659183 and 62/750636, each of which is incorporated herein by reference.

10 **[0025]** In conventional SATC, a first higher-density portion of the SCT can be conducted away from the process. Instead of doing so, certain aspects of the instant invention include subjecting this stream to further processing, e.g., one or more of (1) comminuting (such as grinding) the first higher-density portion, which achieve a reduction in the size of solids (e.g., particle size) to produce a comminuted first higher-density portion, (2) diluting the first higher-
15 density portion, e.g., by adding before and/or after the comminuting one or more of (a) a second utility fluid, (b) a second separation fluid, and (c) a recycle stream to produce a diluted first higher-density portion, and (3) thermally-treating the comminuted and/or diluted first higher-density portion in a second thermal treatment to produce a thermally-treated first higher-density portion. It has been discovered that diluting the first higher-density portion before the second
20 thermal treatment can lessen or substantially prevent asphaltene-formation (oligomerization) reactions that might otherwise occur during the second thermal treatment. It also has been found that the amount of solids in the thermally-treated first higher-density portion (weight basis, based on the weight of the first higher-density portion) is less than the amount of solids in the first higher-density portion. This decrease in the amount of solids occurs whether or not
25 comminuting is carried out before the second thermal treatment.

[0026] A second lower-density portion and a second higher-density portion are separated from the thermally-treated first higher-density portion, e.g., in one or more centrifuges (collectively “the “second centrifuge”). The second higher-density portion can be sent away. At least a portion of the second lower-density portion can be returned (e.g. recycled) to the
30 process. For example, certain aspects of the invention include adding at least a portion of the second lower-density portion to one or more of (i) the steam cracker effluent, e.g., as quench oil, (ii) the SCT, before and/or during the first thermal treatment, (iii) the SCT composition, (iv) the tar-fluid mixture, before and/or during the separation of the first higher-density portion and the first lower-density portion, (v) the first higher-density portion, and (vi) the first lower-

density portion. Recycling at least a portion of the second lower-density portion to one or more of streams (i) through (vi) results in a very desirable increase in the amount (by weight) of the first lower-density portion that is separated from the thermally-treated SCT.

[0027] In certain aspects, at least a portion of the second lower-density portion is recycled and combined with the SCT composition. Typically, the first utility fluid is also added to the SCT composition. The combination of SCT composition, the recycled portion of the second lower-density portion, and the added first utility fluid if any (collectively in the form of the tar-fluid mixture) are conducted to a separation stage for separation of the first lower-density portion and the first higher-density portion. Doing so increases the weight ratio of the first lower-density portion: the first higher-density portion, and thus increases the amount of the first lower-density portion that is available for further processing, e.g., in a SATC process. This in turn increases the amount of desirable hydroprocessed tar produced by SATC, as compared to conventional SCT conversion processes that do not use the second thermal treatment or the second centrifuging.

[0028] Processes and apparatus of the present disclosure provide the ability to upgrade an increased amount of SCT using downstream hydroprocessing, as compared to conventional processes and apparatus for tar upgrading. Moreover, in aspects which utilize a tar knock-out drum upstream of a primary fractionator, the primary fractionator bottoms section can be maintained at a sufficiently low temperature to lessen the amount of undesirable polymerization that may otherwise occur in a primary fractionator's bottoms section operating at a greater temperature, e.g., $> 160^{\circ}\text{C}$.

DEFINITIONS

[0029] "Hydrocarbon-containing feed" refers to a flowable composition, e.g., liquid phase, high viscosity, and/or slurry compositions, which (i) includes carbon bound to hydrogen and (ii) has a mass density greater than that of gasoline, typically $\geq 0.72 \text{ Kg/L}$, e.g., $\geq 0.8 \text{ Kg/L}$, such as $\geq 0.9 \text{ Kg/L}$, or $\geq 1.0 \text{ Kg/L}$, or $\geq 1.1 \text{ Kg/L}$. Such compositions can include one or more of crude oil, crude oil fraction, and compositions derived therefrom which (i) have a kinematic viscosity $\leq 1.5 \times 10^3 \text{ cSt}$ at 50°C , (ii) contain carbon bound to hydrogen, and (iii) have a mass density $\geq 740 \text{ kg/m}^3$. Hydrocarbon-containing feeds typically have a final boiling point at atmospheric pressure ("atmospheric boiling point", or "normal boiling point") $\geq 430^{\circ}\text{F}$ (220°C). Certain hydrocarbon feeds include components having an atmospheric boiling point $\geq 290^{\circ}\text{C}$, e.g., hydrocarbon feeds containing $\geq 20\%$ (by weight) of components having an atmospheric boiling point $\geq 290^{\circ}\text{C}$, e.g., $\geq 50\%$, such as $\geq 75\%$, or $\geq 90\%$. Certain hydrocarbon feeds appear to have the color black or dark brown when illuminated by sunlight, including

those having a luminance ≤ 7 cd/m², luminance being measured in accordance with CIECAM02, established by the Commission Internationale de l'éclairage. Non-limiting examples of such feeds include pyrolysis tar, SCT, vacuum residual fracturing, atmospheric residual fracturing, vacuum gas oil ("VGO"), atmospheric gas oil ("AGO"), heavy atmospheric gas oil ("HAGO"), steam cracked gas oil ("SCGO"), deasphalted oil ("DAO"), cat cycle oil ("CCO", including light cat cycle oil, "LCCO", and heavy cat cycle oil, "HCCO"), natural and synthetic feeds derived from tar sands, or shale oil, coal.

[0030] The term "pyrolysis tar" means (a) a mixture of hydrocarbons having one or more aromatic components and optionally (b) non-aromatic and/or non-hydrocarbon molecules, the mixture being derived from hydrocarbon pyrolysis, with at least 70% of the mixture having a boiling point at atmospheric pressure that is $\geq$ about 550°F (290°C). Certain pyrolysis tars have an initial boiling point $\geq 200^\circ\text{C}$. For certain pyrolysis tars, ≥ 90.0 wt. % of the pyrolysis tar has a boiling point at atmospheric pressure $\geq 550^\circ\text{F}$ (290°C). Pyrolysis tar can comprise, e.g., ≥ 50.0 wt. %, e.g., ≥ 75.0 wt. %, such as ≥ 90.0 wt. %, based on the weight of the pyrolysis tar, of hydrocarbon molecules (including mixtures and aggregates thereof) having (i) one or more aromatic components and (ii) a number of carbon atoms $\geq$ about 15. Pyrolysis tar generally has a metals content, $\leq 1.0 \times 10^3$ ppmw, based on the weight of the pyrolysis tar, which is an amount of metals that is far less than that found in crude oil (or crude oil components) of the same average viscosity.

[0031] "SCT" means pyrolysis tar obtained from steam cracking. Typically, SCT comprises (a) a mixture of hydrocarbons having one or more aromatic components and optionally (b) non-aromatic and/or non-hydrocarbon molecules, the mixture having a 90% Total Boiling Point $\geq 550^\circ\text{F}$ (290°C) (e.g., ≥ 90.0 wt. % of the SCT molecules have an atmospheric boiling point $\geq 550^\circ\text{F}$ (290°C)). SCT can contain > 50.0 wt. % (e.g., > 75.0 wt. %, such as > 90.0 wt. %), based on the weight of the SCT, of hydrocarbon molecules (including mixtures and aggregates thereof) having (i) one or more aromatic components and (ii) a number of carbon atoms ≥ 15 . SCT generally has a metals content, $\leq 1.0 \times 10^3$ ppmw, based on the weight of the SCT (e.g., an amount of metals that is far less than that found in crude oil (or crude oil components) of the same average viscosity). SCT typically has a mass density ≥ 1.0 Kg/L, e.g., ≥ 1.05 Kg/L, such as ≥ 1.1 Kg/L, or ≥ 1.15 Kg/L.

[0032] The invention is not limited to pyrolysis tars, such as SCT, and this description should not be interpreted as foreclosing other tars or similar compositions within the broader scope of the invention. For example, in certain aspects the tar can be or include one or more tars, pitches, resids, gums, resins, and the like, such as those derived from petroleum processes

such as crude oil processing, resid processing, deasphalting, processing of atmospheric and/or vacuum tower bottoms, processing of compositions derived from catalytic cracking (e.g., processing of main column bottoms), compositions derived from hydroprocessing (e.g., processing of pitch obtained and/or derived from crude oil processing, resid processing
5 including resid hydroprocessing, and the like) etc. Accordingly, the term "tar" encompasses these compositions and pyrolysis tars such as SCT.

[0033] "Solvent assisted tar conversion" or ("SATC") is a process for producing an upgraded tar, such as SCT. The process includes hydroprocessing a tar stream in the presence of a utility fluid, and is generally described in P.C.T. Patent Application Publication No. WO
10 2018-111577. For example, SATC can include hydroprocessing one or more SCT streams, including those that have been subjected to prior pretreatments, in the presence of a utility fluid, to produce a hydroprocessed tar having a lesser viscosity, improved blending characteristics, fewer heteroatom impurities, and a lesser content of solids (e.g., fewer particles) as compared to the SCT.

[0034] "Tar Heavies" ("TH") means a product of hydrocarbon pyrolysis, typically included in a pyrolysis tar such as SCT. The TH typically have an atmospheric boiling point > 565°C, and contain > 5 wt. % of molecules having a plurality of aromatic cores based on the weight of the tar. The TH are typically solid at 25°C and generally include the fraction of SCT that is not
15 soluble in a 5:1 (vol:vol) ratio of n-pentane : SCT at 25°C. TH generally includes asphaltenes and other high molecular weight molecules.

[0035] Tar can contain various forms of solids, where the term "solids" encompasses solid-phase materials and materials such as semi-solids, quasi-solids, and the like having some liquid-like characteristics and some solid-like characteristics. The term "solids" also encompasses material in the form of particles, meaning solids in particulate form. The term
25 particles includes polymeric asphaltene particles, polymeric coke particles, pyrolytic coke particles, inorganic fines, other organic or inorganic particles, or any combination thereof. Particles present in tar typically have a specific gravity from about 1.04 to about 1.5. When a particulate content (whether by weight, volume, or number) of a flowable material, such as tar or upgraded tar, is compared with that of another flowable material, the comparison is made
30 under substantially the same conditions, e.g., substantially the same temperature, pressure, etc. When samples of flowable materials are obtained from a process for comparison elsewhere, e.g., in a laboratory, the particulate content comparison can be carried out under (i) conditions which simulate the process conditions and/or (ii) ambient conditions, e.g., a temperature of 25°C and a pressure of 1 bar (absolute).

- [0036] Coke is a solid composition that can be found in certain tars, e.g., pyrolysis tars such as SCT, "Pyrolytic coke" or "pyrolytic coke particles" means a material generated by pyrolysis of organic molecules present in SCT and/or quench oils. The pyrolytic coke is in solid form, e.g., particle form. "Polymeric coke" or "polymeric coke particles" means a material generated by oligomerization of olefinic molecules that can seed small foulant particles. The olefinic molecules can be present in SCT and/or quench oils. The polymeric coke material or particles typically have a specific gravity of about 1.04 to about 1.1, which is much less than the specific gravity of about 1.2 to about 1.3 for coke solids (non-polymeric materials) typically found in tar.
- 10 [0037] "Solubility blending number (S)" and "insolubility number (I)" are described in U.S. Pat. No. 5,871,634, incorporated herein by reference in its entirety, and determined using n-heptane as the so-called "nonpolar, nonsolvent" and chlorobenzene as the solvent. The S and I numbers are determined at a weight ratio of oil to test liquid mixture in the range of from 1 to 5. Various such values are referred to herein. For example, "I_{TC}" refers to the insolubility number of the pyrolysis tar composition, e.g., of an SCT composition; "I_{TF}" refers to the insolubility number of the tar-fluid mixture; "I_{LD}" refers to the insolubility number of the first lower-density portion separated from the tar-fluid mixture; "I_{FHD}" refers to the insolubility number of the first higher-density portion, particularly the liquid-phase part thereof; "S_{Fluid}" refers to the solubility blending number of the fluid or the fluid-enriched stream, as appropriate.
- 15 20 In conventional notation, these I and S values are frequently identified as I_N and S_{BN}.
- [0038] The terms "higher-density portion" and "lower-density portion" are relative terms meaning that a higher-density portion has a mass density (ρ_2) that is higher than the density of the lower-density portion (ρ_1), e.g., $\rho_2 \geq 1.01 * \rho_1$, such as $\rho_2 \geq 1.05 * \rho_1$, or $\rho_2 \geq 1.10 * \rho_1$. In some aspects, the higher-density portion contains primarily solid components and the lower-density portion contains primarily liquid phase components. The higher-density component may also include liquid phase components that have segregated from the lower-density portion. Likewise, the lower-density portion can contain solids (even in particulate form), e.g., those having a density similar to that of the pyrolysis tar's liquid hydrocarbon component.
- 25 30 [0039] The term "portion" generally refers to one or more components derived from a mixture, e.g., from the tar-fluid mixture.
- [0040] Except for its use with respect to parts-per-million, the term "part" is used with respect to a designated process stream, generally indicating that less than the entire designated stream may be selected.

[0041] In this description, the particle size in a hydrocarbon can be characterized by laser diffraction. It is noted that particle size distributions can vary between types of equipment when performing laser diffraction for particle size characterization. Particle size distributions can be characterized using a Mastersizer from Malvern Instruments. If needed, the particle size distribution of a sample can be determined according to a suitable ASTM method, such as ASTM D4464.

Pyrolysis and Pyrolysis Tar

[0042] Pyrolysis tar is a product or by-product of hydrocarbon pyrolysis, e.g., steam cracking. Steam cracking will now be described in more detail. The present disclosure is not limited to use of pyrolysis tars produced by steam cracking, and this description is not meant to foreclose utilization of pyrolysis tar formed by other pyrolysis methods within the broader scope of the present disclosure.

Steam Cracking

[0043] A steam cracking plant typically comprises a furnace facility for producing steam cracking effluent and a recovery facility for removing from the steam cracking effluent a plurality of products and by-products, e.g., light olefin and SCT. The furnace facility generally includes a plurality of steam cracking furnaces. Steam cracking furnaces typically include two main sections: a convection section and a radiant section, the radiant section typically containing fired heaters. Flue gas from the fired heaters is conveyed out of the radiant section to the convection section. The flue gas flows through the convection section and is then conducted away, e.g., to one or more treatments for removing combustion by-products such as NO_x. A hydrocarbon-containing feed is introduced into tubular coils (convection coils) located in the convection section for pre-heating. Steam is added to the preheated hydrocarbon-containing feed to produce a steam cracking feed (also called steam cracker feed). The steam cracking feed is typically re-introduced into the convection section, e.g., via additional convection coils, to produce a heated steam cracking feed. The combination of indirect heating by the flue gas in the convection section and direct heating by the added steam leads may lead to vaporization, or to additional vaporization when the hydrocarbon feed is already at least partially in the vapor phase when the hydrocarbon is first introduced into the convection section. Optionally, at least a portion of any heated steam cracking feed that is not in the vapor phase is separated and conducted away. The heated steam cracking feed or a vapor-phase component separated therefrom may be transferred from the convection coils to one or more tubular radiant coils located in the radiant section. Indirect heating of the steam cracking feed in the radiant tubes results in cracking of at least a portion of the steam cracking feed's

hydrocarbon component. Steam cracking conditions in the radiant section, can include, e.g., one or more of (i) a temperature in the range of 760°C to about 1200°C, such as from about 760°C to about 880°C, (ii) a pressure in the range of from 1 to 5 bars (absolute), or (iii) a cracking residence time in the range of from 0.10 to 2 seconds.

- 5 **[0044]** In certain aspects, the hydrocarbon-containing feed comprises crude oil or a crude oil fraction, such as those comprising ≥ 1 wt. % of hydrocarbons having a normal boiling point $\geq 566^\circ\text{C}$ (about 1050°F) based on the weight of the hydrocarbon-containing feed, e.g., ≥ 5 wt. %, or ≥ 10 wt. %. In these aspects it is typically beneficial to utilize a steam cracking furnace that further comprises a vapor-liquid separation stage, e.g., a vapor-liquid separation drum that
- 10 is thermally-integrated with (but typically located external to) the steam cracking furnace's convection section.

- [0045]** When such a vapor-liquid separation stage is used, a primarily vapor-phase stream and a primarily non-vapor-phase stream are separated from the steam cracking feed in the vapor-liquid separation stage. For example, ≥ 50 wt. % of that portion of the crude oil (or
- 15 crude oil fraction) having a normal boiling point $\geq 566^\circ\text{C}$ can be transferred to the non-vapor-phase stream. The separated primarily vapor-phase stream is typically exposed to additional heating in the convection section before the cracking. For the primarily vapor-phase stream, ≥ 70 wt. %, such as ≥ 90 wt. % of the stream is in the vapor phase. For the primarily non-vapor-phase stream, ≥ 70 wt. %, such as ≥ 90 wt. % of the stream is not in the vapor phase.

- 20 **[0046]** At least a portion of the primarily vapor-phase stream is conducted into an inlet of at least one radiant coil located in the radiant section for cracking under steam cracking conditions. The radiant coil includes an inlet and an outlet, and the steam cracking conditions include one or more of: a temperature at the radiant coil outlet in the range of from about 760°C to about 1200°C (such as about 880°C to about 1,200°C, such as about 1,000°C to about
- 25 1,200°C); a steam cracking pressure at the radiant coil outlet in the range of from about 1 bar (absolute) to about 10 bar (absolute) (such as about 1 bar (absolute) to about 5 bar (absolute), alternatively about 6 bar (absolute) to about 10 bars(absolute)); and/or a steam cracking residence time in the radiant coil in the range of from about 0.1 seconds to about 2 seconds. A steam cracker effluent is conducted away from the radiant section for cooling and/or quenching.
- 30 At least a portion of the SCT is separated from the cooled and/or quenched steam cracker effluent to produce the SCT composition.

[0047] Certain hydrocarbon-containing feeds will now be described in more detail. The invention is not limited to these hydrocarbon-containing feeds, and this description should not

be interpreted as foreclosing the steam cracking of other hydrocarbon-containing feeds within the broader scope of the invention.

5 [0048] Although the hydrocarbon-containing feed can comprise one or more light hydrocarbons such as methane, ethane, propane, butane etc., SCT yield is greater when the hydrocarbon-containing feed includes a significant amount of higher molecular weight hydrocarbon. For example, the hydrocarbon-containing feed can comprise ≥ 1.0 wt. %, e.g., ≥ 10 wt. %, such as ≥ 25.0 wt. %, or ≥ 50.0 wt. % (based on the weight of the hydrocarbon-containing feed) of hydrocarbon compounds that are in the liquid and/or solid phase at 25°C and a pressure of 1 bar absolute.

10 [0049] The hydrocarbon portion of the hydrocarbon-containing feed typically comprises ≥ 10.0 wt. %, e.g., ≥ 50.0 wt. %, such as ≥ 90.0 wt. % (based on the weight of the hydrocarbon portion) of one or more of naphtha, gas oil, vacuum gas oil, waxy residues, atmospheric residues, residue admixtures, crude oil and SCT. Certain hydrocarbon-containing feeds comprise $\geq$ about 0.1 wt. % asphaltenes. When the hydrocarbon-containing feed includes crude
15 oil and/or one or more fractions thereof, the crude oil is optionally a desalted crude oil. Suitable crude oil include e.g., high-sulfur virgin crude oils, such as those rich in polycyclic aromatics. A crude oil fraction can be produced by separating atmospheric pipestill (“APS”) bottoms from a crude oil followed by vacuum pipestill (“VPS”) treatment of the APS bottoms. Suitable crude oils include, For example, the hydrocarbon-containing feed can include ≥ 90.0 wt. % of one or
20 more crude oil fractions, such as those obtained from an atmospheric APS and/or VPS; waxy residues; atmospheric residues; naphthas contaminated with crude; various residue admixtures.

[0050] The steam cracking feed is typically produced by heating the hydrocarbon-containing feed in one or more convection coils and combining the heated hydrocarbon-containing feed with steam. Steam cracking feed typically comprises ≥ 10.0 wt. %
25 hydrocarbon, based on the weight of the steam cracking feed, e.g., ≥ 25.0 wt. %, ≥ 50.0 wt. %, such as ≥ 65 wt. %. Typically, ≥ 90 wt. % of the balance of the steam cracker feed is steam.

[0051] In certain aspects, SCT is separated from the cooled and/or quenched steam cracker effluent in one or more separation stages. Conventional separation equipment can be used for separating SCT and other products and by-products from the cooled and/or quenched steam
30 cracking effluent, e.g., one or more flash drums, knock out drums, fractionators, water-quench towers, indirect condensers, etc. Suitable separation stages are described in U.S. Patent No. 8,083,931, and in P.C.T. Patent Application Publication No. WO 2018-111574, which are incorporated by reference herein in their entireties. SCT can be separated from the quenched effluent itself and/or from one or more streams that have been separated from the cooled and/or

quenched effluent. For example, SCT can be separated from a flash-drum bottoms (e.g., the bottoms of one or more tar knock out drums located downstream of the steam cracking furnace and upstream of the primary fractionator). Certain SCTs are a mixture of primary fractionator bottoms and tar knock-out drum bottoms.

- 5 [0052] Representative SCTs will now be described in more detail. Embodiments are not limited to use of these SCTs, and this description is not meant to foreclose the processing of other SCTs, or of other pyrolysis tars within the broader scope of the present disclosure.

Steam Cracker Tar (“SCT”)

- 10 [0053] Typically, cooled and/or quenched steam cracker effluent includes steam, molecular hydrogen, hydrocarbon (saturated and unsaturated), non-hydrocarbon compositions, and solids (typically hydrocarbonaceous solids, e.g., TH, and non-hydrocarbon solids) including particulates. For example, the cooled and/or quenched steam cracker effluent can include ≥ 1.0 wt. % of C_2 unsaturates and ≥ 0.1 wt. % of TH, the weight percents being based on the weight of the cooled and/or quenched steam cracker effluent. It is also typical for the cooled and/or quenched steam cracker effluent to comprise ≥ 0.5 wt. % of TH, such as ≥ 1.0 wt. % TH. The SCT in the cooled and/or quenched steam cracker effluent typically includes ≥ 50.0 wt. %, e.g., ≥ 75.0 wt. %, such as ≥ 90.0 wt. % of the total TH in the cooled and/or quenched steam cracker effluent. The TH are typically in the form of aggregates which include hydrogen and carbon and which have an average size in the range of 10.0 nm to 300.0 nm in at least one dimension and an average number of carbon atoms ≥ 50 . Generally, the TH comprise ≥ 50.0 wt. %, e.g., ≥ 80.0 wt. %, such as ≥ 90.0 wt. % of aggregates having a C:H atomic ratio in the range of from 1.0 to 1.8, a molecular weight in the range of 250 to 5000, and a melting point in the range of 100°C to 700°C. The SCT typically includes ≥ 50.0 wt. %, e.g., ≥ 75.0 wt. %, such as ≥ 90.0 wt. % of the quenched effluent's TH, based on the total weight TH in the quenched effluent.

- 25 [0054] Representative SCTs typically have (i) a TH content in the range of from 5.0 wt. % to 40.0 wt. %, based on the weight of the SCT, (ii) an API gravity (measured at a temperature of 15.8°C) of $\leq 8.5^\circ\text{API}$, such as $\leq 8.0^\circ\text{API}$, or $\leq 7.5^\circ\text{API}$; and (iii) a 50°C viscosity in the range of 200 cSt to 1.0×10^7 cSt, e.g., 1×10^3 cSt to 1.0×10^7 cSt, as determined by A.S.T.M. D445. The SCT can have, e.g., a sulfur content that is > 0.5 wt. %, or > 1 wt. %, or more, e.g., in the range of 0.5 wt. % to 7.0 wt. %, based on the weight of the SCT. In aspects where steam cracking feed does not contain an appreciable amount of sulfur, the SCT can comprise ≤ 0.5 wt. % sulfur, e.g., ≤ 0.1 wt. %, such as ≤ 0.05 wt. % sulfur, based on the weight of the SCT.

[0055] The SCT can have, e.g., (i) a TH content in the range of from 5.0 wt. % to 40.0 wt. %, based on the weight of the SCT; (ii) a density at 15°C in the range of 1.01 g/cm³ to 1.19 g/cm³, e.g., in the range of 1.07 g/cm³ to 1.18 g/cm³; and (iii) a 50°C viscosity $\geq$ 200 cSt, e.g., $\geq$ 600 cSt, or in the range of from 200 cSt to 1.0×10^7 cSt. The specified hydroprocessing is particularly advantageous for SCTs having 15°C density that is $\geq$ 1.10 g/cm³, e.g., $\geq$ 1.12 g/cm³, $\geq$ 1.14 g/cm³, $\geq$ 1.16 g/cm³, or $\geq$ 1.17 g/cm³. Optionally, the SCT has a 50°C kinematic viscosity $\geq$ 1.0×10^4 cSt, such as $\geq$ 1.0×10^5 cSt, or $\geq$ 1.0×10^6 cSt, or even $\geq$ 1.0×10^7 cSt. Optionally, the SCT has an $I_N > 80$ and > 70 wt. % of the pyrolysis tar's molecules have an atmospheric boiling point of $\geq$ 290°C. Typically, the SCT has an insoluble content ("IC_T") $\geq$ 0.5 wt. %, e.g., $\geq$ 1 wt. %, such as $\geq$ 2 wt. %, or $\geq$ 4 wt. %, or $\geq$ 5 wt. %, or $\geq$ 10 wt. %.

[0056] In at least one embodiment, the SCT includes a mixture of hydrocarbons having one or more aromatic components and optionally non-aromatics and/or non-hydrocarbons, with at least 70% of the mixture having a boiling point at atmospheric pressure that is about 550°F (290°C) or more. The SCT typically comprises hydrocarbon (including mixtures and aggregates thereof) having (i) one or more aromatic components and (ii) a number of carbon atoms greater than about 15. The SCT generally has a metals content of 1000 ppmw or less, based on the weight of the pyrolysis tar, which is an amount of metals that is far less than that found in crude oil (or crude oil components) of the same average viscosity. Optionally, the SCT has a normal boiling point $\geq$ 290°C, a viscosity at 15°C $\geq$ 1×10^4 cSt, and a density $\geq$ 1.1 g/cm³. The SCT can be a mixture which includes a first SCT and one or more additional pyrolysis tars, e.g., a combination of the first SCT and one or more additional SCTs. When the SCT is a mixture, it is typical for at least 70 wt. % of the mixture to have a normal boiling point of at least 290°C, and include olefinic hydrocarbon which contribute to the tar's reactivity under hydroprocessing conditions. When the mixture comprises first and second pyrolysis tars (one or more of which is optionally an SCT) $\geq$ 90 wt. % of the second pyrolysis tar optionally has a normal boiling point $\geq$ 290°C.

[0057] It has been found that an increase in reactor fouling occurs during hydroprocessing of a tar-fluid mixture comprising an SCT having an excessive amount of olefinic hydrocarbon. In order to lessen the amount of reactor fouling, it is beneficial for the SCT to have an olefin content of $\leq$ 10.0 wt. % (based on the weight of the SCT), e.g., $\leq$ 5.0 wt. %, such as $\leq$ 2.0 wt. %. More particularly, it has been observed that less reactor fouling occurs during the hydroprocessing when the SCT has (i) an amount of vinyl aromatics of $\leq$ 5.0 wt. % (based on the weight of the SCT), e.g., $\leq$ 3 wt. %, such as $\leq$ 2.0 wt. % and/or (ii) an amount of aggregates

which incorporate vinyl aromatics of ≤ 5.0 wt. % (based on the weight of the SCT), e.g., ≤ 3 wt. %, such as ≤ 2.0 wt. %.

The SCT Composition

[0058] The SCT composition generally comprises ≥ 40 wt. % of SCT that has been
5 separated from the steam cracker effluent, based on the weight of the SCT composition, e.g., $\geq$
60 wt. %, such as ≥ 70 wt. %, or more. The SCT composition may further comprise
compositions formed during thermal treatment of the SCT. In certain aspects, e.g., aspects
where (i) quench oil is not used to quench the steam cracker effluent and (ii) utility fluid is not
added to the tar knock-out drum, the SCT composition can comprise ≥ 90 wt. % of thermally-
10 treated SCT, e.g., ≥ 95 wt. %, or ≥ 99 wt. %, or more. The SCT composition typically comprises
 ≥ 90.0 wt. % SCT that has been (i) separated from the cooled and/or quenched steam cracker
effluent, and (ii) thermally-treated. SCT may further include material derived SCT that has
been recycled to the first thermal treatment or a location upstream thereof (e.g., a recycled
portion of the second lower-density portion. An SCT composition obtained from one or more
15 of the specified SCT sources may contain ≥ 50.0 wt. % of SCT, based on the weight of the
stream, e.g., ≥ 75.0 wt. %, such as ≥ 90.0 wt. %, or more. In aspects where ≥ 50 wt. %, or $\geq$
75 wt. %, or ≥ 90 wt. %, or more of the SCT in the SCT composition is SCT separated in a tar
knock-out drum, more than 90 wt. % of the remainder of the SCT stream's weight (e.g., the
part of the stream that is not SCT, if any) typically comprises one or more of (i) any flux (e.g.,
20 utility fluid) remaining with the SCT after the tar knock-out drum overhead is conducted away,
in aspects where flux is added to the tar knock-out drum; (ii) any quench oil as may remain
with the SCT after the tar knock-out drum overhead is conducted away, in aspects where a
quench oil is introduced into the steam cracker effluent and/or the cooled steam cracker
effluent; (iii) material formed during or as a result of the first thermal treatment; and (iv)
25 particulates.

[0059] Aspects in which the first thermal treatment includes heat soaking in a tar knock
out drum will now be described in more detail. The invention is not limited to these aspects,
and this description should not be interpreted as foreclosing (i) other forms of thermal
treatment, such as a thermal treatment of an SCT composition in a primary fractionator, or (ii)
30 thermal treatments of other forms of pyrolysis tar.

Thermal treatment of the SCT by Heat Soaking

[0060] During heat soaking, at least the separated SCT is maintained in a heat soaking
location, e.g., in a bottoms region of the tar knock-out drum, or in one or more soaker vessels
adapted to this purpose and located external to the tar knock-out drum. Conventional

equipment for heat soaking SCT can be used, but the invention is not limited thereto. Conventional equipment configuration for heat soaking SCT is disclosed in P.C.T. Patent Application Publication No. WO 2018-111574, which discloses heat soaking an SCT in a bottoms region of a tar knock-out drum and optionally in the presence of utility fluid added as a flux. Flux may be used as an aid in the separation and heat soaking, e.g., a flux having substantially the same composition as the first utility fluid. The separating and heat soaking of the SCT can be carried out before, during, and/or after adding the flux. Since aspects of the invention include at least one additional thermal treatment of a stream derived from the SCT composition (the second thermal treatment), the thermal treatment of the separated SCT is called a “first thermal treatment” or “first heat soak”.

[0061] Using, e.g., the heat soaking configuration disclosed in P.C.T. Patent Application Publication No. WO 2018-111574, at least the separated SCT can independently be heated and/or cooled to achieve a desired heat soak temperature (T_{HS1}) and for a desired period of time (t_{HS1}). Temperature T_{HS1} is typically in a range of about 200°C, about 220°C, about 230°C, about 240°C, about 250°C, about 260°C, about 270°C, about 275°C, about 280°C, or about 290°C to about 295°C, about 300°C, about 310°C, about 320°C, about 325°C, about 330°C, about 340°C, about 350°C, about 360°C, about 375°C, about 400°C, about 450°C, about 500°C, or higher. For example, T_{HS1} can be in a range of about 200°C to about 500°C, about 230°C to about 500°C, about 250°C to about 500°C, about 280°C to about 500°C, about 290°C to about 500°C, about 300°C to about 500°C, about 320°C to about 500°C, about 350°C to about 500°C, about 250°C to about 450°C, about 280°C to about 450°C, about 290°C to about 450°C, about 300°C to about 450°C, about 320°C to about 450°C, about 350°C to about 450°C, about 250°C to about 400°C, about 280°C to about 400°C, about 290°C to about 400°C, about 300°C to about 400°C, about 320°C to about 400°C, about 350°C to about 400°C, about 250°C to about 350°C, about 280°C to about 350°C, about 290°C to about 350°C, about 300°C to about 350°C, about 320°C to about 350°C, or about 330°C to about 350°C. Although it is not required to maintain the separated SCT at a substantially-constant temperature during the heat soak (i.e., a substantially constant temperature within the specified range of T_{HS1}), it is typical to do so.

[0062] The first heat soaking is typically carried out for a predetermined time t_{HS1} in a range of about 2 min, about 5 min, about 10 min, about 12 min, or about 15 min to about 20 min, about 25 min, about 30 min, about 45 min, about 60 min, about 90 min, about 2 hr, about 3 hr, about 5 hr, or longer. For example, t_{HS1} can be in a range of about 5 min to about 5 hr, about 5 min to about 3 hr, about 5 min to about 2 hr, about 5 min to about 1 hr, about 5 min to about

45 min, about 5 min to about 30 min, or about 5 min to about 20 min. In one or more examples, t_{HS1} is in a range of about 2 min, about 5 min, about 10 min, about 15 min, or about 20 min to about 30 min, about 45 min, about 60 min, about 90 min, about 2 hr, about 3 hr, or about 5 hr to dissolve and/or decompose at least a portion of particles present in the separated SCT.

- 5 [0063] While not wishing to be bound by any theory or model, it is believed that the first heat soaking dissolves and/or decomposes particles in the separated SCT, or otherwise reduces particle content. It is also observed that after maintaining the separated SCT at temperature T_{HS1} for the predetermined time t_{HS1} , the SCT composition typically contains fewer particles than the separated SCT. In one or more embodiments, about 25 wt. %, about 30 wt. %, about 10 35 wt. %, or about 40 wt. % to about 45 wt. %, about 50 wt. %, about 60 wt. %, about 70 wt. %, about 75 wt. %, about 80 wt. %, about 85 wt. %, about 90 wt. %, about 92 wt. %, about 95 wt. %, about 97 wt. %, about 98 wt. %, about 99 wt. %, or more of the particles in the separated SCT are dissolved and/or decomposed during and/or as a result of the first heat soak. In some examples, at least 25 wt. %, at least 30 wt. %, at least 35 wt. %, at least 40 wt. %, at least 45 15 wt. %, at least 50 wt. %, at least 60 wt. %, at least 70 wt. %, at least 75 wt. %, at least 80 wt. % to about 85 wt. %, about 90 wt. %, about 92 wt. %, about 95 wt. %, about 97 wt. %, about 98 wt. %, about 99 wt. %, or more of the particles in the separated SCT are dissolved and/or decomposed during and/or as a result of the first heat soak. For example, about 25 wt. % to about 99 wt. %, about 30 wt. % to about 99 wt. %, about 35 wt. % to about 99 wt. %, about 40 20 wt. % to about 99 wt. %, about 45 wt. % to about 99 wt. %, about 50 wt. % to about 99 wt. %, about 60 wt. % to about 99 wt. %, about 70 wt. % to about 99 wt. %, about 75 wt. % to about 99 wt. %, about 25 wt. % to about 95 wt. %, about 30 wt. % to about 95 wt. %, about 35 wt. % to about 95 wt. %, about 40 wt. % to about 95 wt. %, about 45 wt. % to about 95 wt. %, about 50 wt. % to about 95 wt. %, about 60 wt. % to about 95 wt. %, about 70 wt. % to about 95 wt. %, about 75 wt. % to about 95 wt. %, about 25 wt. % to about 90 wt. %, about 30 wt. % to about 90 wt. %, about 35 wt. % to about 90 wt. %, about 40 wt. % to about 90 wt. %, about 45 25 wt. % to about 90 wt. %, about 50 wt. % to about 90 wt. %, about 60 wt. % to about 90 wt. %, about 70 wt. % to about 90 wt. %, about 75 wt. % to about 90 wt. %, about 25 wt. % to about 80 wt. %, about 30 wt. % to about 80 wt. %, about 35 wt. % to about 80 wt. %, about 40 wt. % to about 80 wt. %, about 45 wt. % to about 80 wt. %, about 50 wt. % to about 80 wt. %, about 60 wt. % to about 80 wt. %, about 70 wt. % to about 80 wt. %, or about 75 wt. % to about 80 30 wt. % of the particles in the separated SCT are dissolved and/or decomposed during and/or as a result of the first heat soak.

[0064] The SCT composition typically comprises separated SCT that is now thermally-treated, plus any added flux, minus that portion of the separated SCT as may convert during or as a result of the first thermal treatment, plus at least a portion of certain conversion products as may form during or as a result of the first thermal treatment (e.g., solids, such as polymeric particulate). Other examples of the latter category include certain compositions (e.g., those having a normal boiling point range similar to that of SCT) as might result from decomposition during the first thermal treatment of any solids present in the separated SCT. Certain solids, e.g., particulate solids, have been found to form during and/or as a result of the first thermal treatment, e.g., by polymerization of separated SCT in a tar knock-out drum and/or primary fractionator.

[0065] The SCT composition is subjected to further processing, including separating a first higher-density portion and a first lower-density portion in a first stage of SCT separation (the "first SCT separation stage"). At least a portion of any solids formed during and/or as a result of the first thermal treatment typically reside in the first higher-density portion.

[0066] Although the SCT composition can be the feed to the first SCT separation stage, it is typical to combine the SCT composition with a recycled portion of the second lower-density portion to form a tar-fluid mixture upstream of the first SCT separation stage. Certain representative tar-fluid mixtures will now be described in more detail. The invention is not limited to these tar-fluid mixtures, and this description should not be interpreted as excluding other tar-fluid mixtures within the broader scope of the invention.

The Tar-Fluid Mixture

[0067] The tar-fluid mixture typically comprises the SCT composition and fluid. The fluid comprises a recycled portion of the second lower-density portion, and typically further comprises the first utility fluid and/or the first separation fluid. The amount (e.g., by weight) of fluid in the tar-fluid mixture is typically in the range of from 20 wt. % to 60 wt. %, e.g., 30 wt. % to 50 wt. %. The amount (e.g., by weight) of the recycled portion of the second lower-density portion in the fluid is typically substantially equal to the weight of material (typically particles) converted to lesser density during or as a result of the second thermal treatment (e.g., using Fig. 2), plus the weight of diluent (e.g., second utility fluid and/or second separation fluid) added to the first higher-density portion, comminuted first higher-density portion, diluted first higher-density portion, and/or thermally-treated first higher-density portion. Typically ≥ 50 wt. % of the remainder of the fluid (e.g., the part of the fluid that is not recycled second lower-density portion) is the first utility fluid and/or first separation fluid, e.g., ≥ 75 wt. %, such as ≥ 90 wt. %, or ≥ 99 wt. %. The first utility fluid (and/or first separation fluid) when used

may be added to (i) the SCT composition (which may already contain at least some of the utility fluid as flux) and/or (ii) to a mixture of the SCT composition and the recycled portion of the second lower-density portion. In other words, the first utility fluid and/or the first separation fluid can be added to the SCT composition before, during, and/or after the combining of the SCT composition with the recycled portion of the second lower-density portion. The tar-fluid mixture has a lesser viscosity than does the SCT composition.

[0068] The tar-fluid mixture generally contains ≥ 5 wt. % of the SCT composition, e.g., ≥ 10 wt. %, ≥ 20 wt. %, ≥ 30 wt. %, ≥ 40 wt. %, ≥ 50 wt. %, ≥ 60 wt. %, ≥ 70 wt. %, ≥ 80 wt. %, or ≥ 90 wt. % SCT composition, based on the total weight of the tar-fluid mixture (e.g., a combined weight of all of the components of the tar-fluid mixture). Additionally or alternatively, the tar-fluid mixture may include ≤ 10 wt. % of the SCT composition, e.g., ≤ 20 wt. %, ≤ 30 wt. %, ≤ 40 wt. %, ≤ 50 wt. %, ≤ 60 wt. %, ≤ 70 wt. %, ≤ 80 wt. %, ≤ 90 wt. %, or ≤ 95 wt. % of the SCT composition, based on the total weight of the tar-fluid mixture. Ranges expressly disclosed include combinations of any of the above-enumerated values, e.g., about 5 wt. % to about 95 wt. %, about 5 wt. % to about 90 wt. %, about 5 wt. % to about 80 wt. %, about 5 wt. % to about 70 wt. %, about 5 wt. % to about 60 wt. %, about 5 wt. % to about 50 wt. %, about 5 wt. % to about 40 wt. %, about 5 wt. % to about 30 wt. %, about 5 wt. % to about 20 wt. %, or about 5 wt. % to about 10 wt. % of the SCT composition.

[0069] In addition to the SCT composition, the tar-fluid mixture typically further comprises ≥ 5 wt. % of utility fluid, e.g., ≥ 10 wt. %, ≥ 20 wt. %, ≥ 30 wt. %, ≥ 40 wt. %, ≥ 50 wt. %, ≥ 60 wt. %, ≥ 70 wt. %, ≥ 80 wt. %, or ≥ 90 wt. %, based on the total weight of the tar-fluid mixture (e.g., a combined weight of all of the components of the tar-fluid mixture). Additionally or alternatively, the tar-fluid mixture may include ≤ 10 wt. % of utility fluid, e.g., ≤ 20 wt. %, ≤ 30 wt. %, ≤ 40 wt. %, ≤ 50 wt. %, ≤ 60 wt. %, ≤ 70 wt. %, ≤ 80 wt. %, ≤ 90 wt. %, or ≤ 95 wt. % utility fluid, based on the total weight of the tar-fluid mixture. Ranges expressly disclosed include combinations of any of the above-enumerated values, e.g., about 5 wt. % to about 95 wt. %, about 5 wt. % to about 90 wt. %, about 5 wt. % to about 80 wt. %, about 5 wt. % to about 70 wt. %, about 5 wt. % to about 60 wt. %, about 5 wt. % to about 50 wt. %, about 5 wt. % to about 40 wt. %, about 5 wt. % to about 30 wt. %, about 5 wt. % to about 20 wt. %, or about 5 wt. % to about 10 wt. % utility fluid.

[0070] In certain aspects, the tar-fluid mixture includes (i) the SCT composition, (ii) the recycled portion of the second lower-density portion, and (iii) any first utility fluid added to the SCT composition before the first SCT separation stage. For example, the tar-fluid mixture can contain about 15 wt. %, about 20 wt. %, about 25 wt. %, 30 wt. %, about 35 wt. %, about

40 wt. %, about 45 wt. %, or about 50 wt. % to about 55 wt. %, about 60 wt. %, about 65 wt. %, about 70 wt. %, about 75 wt. %, about 80 wt. %, about 85 wt. %, or about 90 wt. %, or more of the utility fluid, based on a combined weight of the tar-fluid mixture (e.g., a combined weight of all of the components of the tar-fluid mixture). Typically, the tar-fluid mixture contains

5 about 15 wt. % to about 90 wt. %, about 20 wt. % to about 90 wt. %, about 20 wt. % to about 80 wt. %, about 20 wt. % to about 70 wt. %, about 20 wt. % to about 60 wt. %, about 20 wt. % to about 50 wt. %, about 20 wt. % to about 50 wt. %, about 20 wt. % to about 40 wt. %, about 20 wt. % to about 30 wt. %, about 25 wt. % to about 90 wt. %, about 30 wt. % to about 85 wt. %, about 30 wt. % to about 80 wt. %, about 35 wt. % to about 80 wt. %, about 40 wt. % to about 80 wt. %, about 40 wt. % to about 75 wt. %, about 40 wt. % to about 70 wt. %, about 40 wt. % to about 65 wt. %, about 40 wt. % to about 60 wt. %, about 40 wt. % to about 55 wt. %, about 40 wt. % to about 50 wt. %, about 40 wt. % to about 45 wt. %, about 45 wt. % to about 80 wt. %, about 45 wt. % to about 75 wt. %, about 45 wt. % to about 70 wt. %, about 45 wt. % to about 65 wt. %, about 45 wt. % to about 60 wt. %, about 45 wt. % to about 55 wt. %, about 45 wt. % to about 50 wt. %, about 50 wt. % to about 80 wt. %, about 50 wt. % to about 75 wt. %, about 50 wt. % to about 70 wt. %, about 50 wt. % to about 65 wt. %, about 50 wt. % to about 60 wt. %, about 50 wt. % to about 55 wt. %, about 55 wt. % to about 80 wt. %, about 55 wt. % to about 75 wt. %, about 55 wt. % to about 70 wt. %, about 55 wt. % to about 65 wt. %, or about 55 wt. % to about 60 wt. % of the utility fluid, based on the total weight of the tar-fluid mixture.

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[0071] The combining of the SCT composition, the utility fluid, and the recycled portion of the second lower-density portion is carried out under conditions which lessen or substantially prevent asphaltene precipitation. Those skilled in the art will appreciate that in doing so one can make use of blend information for these compositions, such as insolubility number I_{TF} and solubility blending number S_{TF} . Accordingly, in some aspects, the tar-fluid mixture has an S_{TF} ≤ 150 , such as ≤ 140 , or ≤ 130 , or ≤ 120 , or ≤ 115 , or ≥ 110 , or ≥ 105 , or ≥ 100 , or ≥ 95 , or ≥ 90 . In some examples, the tar-fluid mixture has an S_{TF} of about 70, about 80, about 85, about 90, about 95, about 100, about 105, about 110, about 115, about 120, about 130, about 140, or about 150. For example, the tar-fluid mixture can have an S_{TF} in a range of about 70 to about 150, about 70 to about 130, about 70 to about 125, about 70 to about 120, about 70 to about 115, about 70 to about 110, about 70 to about 105, about 70 to about 100, about 70 to about 95, about 70 to about 90, about 70 to about 85, about 80 to about 130, about 80 to about 125, about 80 to about 120, about 80 to about 115, about 80 to about 110, about 80 to about 105, about 80 to about 100, about 80 to about 95, about 80 to about 90, about 85 to about 130, about 85 to

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about 125, about 85 to about 120, about 85 to about 115, about 85 to about 110, about 85 to about 105, about 85 to about 100, about 85 to about 95, about 85 to about 90, about 90 to about 130, about 90 to about 125, about 90 to about 120, about 90 to about 115, about 90 to about 110, about 90 to about 105, about 90 to about 100, or about 90 to about 95.

5 [0072] Particularly in aspects where tar-fluid mixture components are not subjected to subsequent hydroprocessing, the fluid of the tar-fluid mixture may further comprise a first separation fluid, with “fluid” in this sense meaning the total amount of first utility fluid in the tar-fluid mixture plus the total amount of first separation fluid in the tar-fluid mixture. Separation fluids may be used as an aid in separating the first higher-density and lower-density
 10 portion and in separating the second higher-density and lower-density portions. Although the separation fluid can have substantially the same composition as that of the utility fluid, it is typically of different composition. The tar-fluid mixture may optionally include a first separation fluid, typically in an amount of ≤ 35 wt. %, e.g., ≤ 30 wt. %, ≤ 25 wt. %, ≤ 20 wt. %, ≤ 15 wt. %, ≤ 10 wt. %, ≤ 5 wt. %, ≤ 2.5 wt. %, or ≤ 1.5 wt. %, based on the total weight of
 15 fluid (e.g., utility fluid plus separation fluid) in the tar-fluid mixture. Additionally or alternatively, the separation fluid may be present in an amount $\geq$ to 0 wt. %, e.g., ≥ 1.5 wt. %, ≥ 2.5 wt. %, ≥ 5 wt. %, ≥ 10 wt. %, ≥ 15 wt. %, ≥ 20 wt. %, ≥ 25 wt. %, or ≥ 30 wt. %, based on the total weight of the fluid in the tar-fluid mixture. Ranges include combinations of any of the above-enumerated values, e.g., 0 to about 35 wt. %, 0 to about 30 wt. %, 0 to about 25 wt. %, 0 to about 20 wt. %, 0 to about 15 wt. %, 0 to about 10 wt. %, 0 to about 5 wt. %, 0 to about 2.5 wt. %, 0 to about 1.5 wt. % separation fluid, based on the total weight of fluid in the tar-fluid mixture.

[0073] Thus, in some aspects, the fluid comprises ≥ 50 wt. % of the separation fluid, e.g., ≥ 60 wt. %, ≥ 70 wt. %, ≥ 80 wt. %, ≥ 90 wt. %, ≥ 95 wt. %, ≥ 97.5 wt. %, ≥ 99 wt. %, or about
 25 100 wt. % separation fluid, based on the total weight of the tar-fluid mixture. Additionally or alternatively, the tar-fluid mixture may include ≤ 99 wt. % of the separation fluid, e.g., ≤ 97.5 wt. %, ≤ 95 wt. %, ≤ 90 wt. %, ≤ 80 wt. %, ≤ 70 wt. %, or ≤ 60 wt. % separation fluid, based on the total weight of the tar-fluid mixture. Ranges expressly disclosed include combinations of any of the above-enumerated values, e.g., about 50 wt. % to about 100 wt. %, about 60 wt. %, about 70 wt. % to about 100 wt. %, about 80 wt. % to about 100 wt. %, about 90 wt. % to about 100 wt. %, about 95 wt. % to about 100 wt. %, about 97.5 wt. % to about 100 wt. %, or about 99 wt. % to about 100 wt. % of the separation fluid.

[0074] The dynamic viscosity of the tar-fluid mixture is typically less than that of the SCT composition. In some aspects, the dynamic viscosity of the tar-fluid mixture may be ≥ 0.5

cPoise, e.g., ≥ 1 cPoise, ≥ 2.5 cPoise, ≥ 5 cPoise, ≥ 7.5 cPoise, at a temperature of about 50°C to about 250°C, such as about 100°C. Additionally or alternatively, the dynamic viscosity of the tar-fluid mixture may be ≤ 10 cPoise, e.g., ≤ 7.5 cPoise, ≤ 5 cPoise, ≤ 2.5 cPoise, ≤ 1 cPoise, ≤ 0.75 cPoise, at a temperature of about 50°C to about 250°C, such as about 100°C. Ranges
5 can include combinations of any of the above-enumerated values, e.g., about 0.5 cPoise to about 10 cPoise, about 1 cPoise to about 10 cPoise, about 2.5 cPoise to about 10 cPoise, about 5 cPoise to about 10 cPoise, or about 7.5 cPoise to about 10 cPoise, at a temperature of about 50°C to about 250°C, such as about 100°C.

Utility Fluids

10 **[0075]** The first and second utility fluids can be selected independently. Each can be selected from among conventional utility fluids, such as those used as a process aid for hydroprocessing tar such as SCT, but the invention is not limited thereto. Suitable utility fluids include those disclosed in U.S. Provisional Patent Application No. 62/716754; U.S. Patent Nos. 9,090,836; 9,637,694; and 9,777,227; and 9,809,756; these being incorporated by reference
15 herein in their entireties, and in P.C.T. Patent Application Publication No. WO 2018-111574. Although it is not required, the first and second utility fluids can have substantially the same composition and can be referred to as “utility fluid”.

[0076] The utility fluid typically comprises ≥ 40 wt. %, of at least one aromatic or non-aromatic ring-containing compound, e.g., ≥ 45 wt. %, ≥ 50 wt. %, ≥ 55 wt. %, or ≥ 60 wt. %, based on the weight of the utility fluid. Particular utility fluids contain ≥ 40 wt. %, ≥ 45 wt. %, ≥ 50 wt. %, ≥ 55 wt. %, or ≥ 60 wt. % of at least one multi-ring compound, based on the weight of the utility fluid. The compounds contain a majority of carbon and hydrogen atoms, but can also contain a variety of substituents and/or heteroatoms.

[0077] In certain aspects, the utility fluid contains aromatics, e.g., ≥ 70 wt. % aromatics, based on the weight of the utility fluid, such as ≥ 80 wt. %, or ≥ 90 wt. %. Typically, the utility fluid contains ≤ 10 wt. % of paraffin, based on the weight of the utility fluid. For example, the utility fluid can contain ≥ 95 wt. % of aromatics, ≤ 5 wt. % of paraffin. Optionally, the utility fluid has a final boiling point $\leq 750^\circ\text{C}$ (1,400°F), e.g., $\leq 570^\circ\text{C}$ (1,050°F), such as $\leq 430^\circ\text{C}$ (806°F). Such utility fluids can contain ≥ 25 wt. % of 1-ring and 2-ring aromatics (e.g., those
30 aromatics having one or two rings and at least one aromatic core), based on the weight of the utility fluid. Utility fluids having a relatively low final boiling point can be used, e.g., a utility fluid having a final boiling point $\leq 400^\circ\text{C}$ (750°F). The utility fluid can have an 10% (weight basis) total boiling point $\geq 120^\circ\text{C}$, e.g., $\geq 140^\circ\text{C}$, such as $\geq 150^\circ\text{C}$ and/or a 90% total boiling point $\leq 430^\circ\text{C}$, e.g., $\leq 400^\circ\text{C}$. Suitable utility fluids include those having a true boiling point

distribution generally in the range from 175°C (350°F) to about 400°C (750°F). A true boiling point distribution can be determined, e.g., by conventional methods such as the method of A.S.T.M. D7500, which can be extended by extrapolation when the true boiling point distribution has a final boiling point that is outside the range encompassed by the A.S.T.M. method. In certain aspects, the utility fluid has a mass density ≤ 0.91 g/mL, e.g., ≤ 0.90 g/mL, such as ≤ 0.89 g/mL, or ≤ 0.88 g/mL, e.g., in the range of 0.87 g/mL to 0.90 g/mL.

- [0078]** The utility fluid typically contains aromatics, e.g., ≥ 95.0 wt. % aromatics, such as ≥ 99.0 wt. %. For example, the utility fluid can contain ≥ 75 wt. % based on the weight of the utility fluid of one or more of benzene, ethylbenzene, trimethylbenzene, xylenes, toluene, naphthalenes, alkylnaphthalenes (e.g., methylnaphtalenes), tetralins, or alkyltetralins (e.g., methyltetralins), e.g., ≥ 90 wt. %, or ≥ 95 wt. %, or ≥ 99.0 wt. %, such as ≥ 99.9 wt. %. It is generally desirable for the utility fluid to be substantially free of molecules having alkenyl functionality, particularly in aspects utilizing a hydroprocessing catalyst having a tendency for coke (e.g., pyrolytic and/or polymeric particles) formation in the presence of such molecules.
- [0079]** In some examples, the utility fluid contains ≤ 10.0 wt. % of ring compounds having C₁-C₆ sidechains with alkenyl functionality, based on the weight of the utility fluid.

- [0079]** In some examples, the utility fluid can include ≥ 90 wt. % of a single-ring aromatic, including those having one or more hydrocarbon substituents, such as from 1 to 3 or 1 to 2 hydrocarbon substituents. Illustrative hydrocarbon substituents or hydrocarbon groups can be or include, but are not limited to, C₁-C₆ alkyls, where the hydrocarbon groups can be branched or linear and the hydrocarbon groups can be the same or different.

- [0080]** In some examples, the utility fluid can be substantially free of molecules having terminal unsaturates, for example, vinyl aromatics. As used herein, the term "substantially free" means that the utility fluid includes 10 wt. % or less, e.g., 5 wt. % or less or 1 wt. % or less, of terminal unsaturates, based on the weight of the utility fluid. The utility fluid can include ≥ 50 wt. % of molecules having at least one aromatic core, e.g., ≥ 60 wt. % or ≥ 70 wt. %, based on the weight of the utility fluid. In some examples, the utility fluid can include ≥ 60 wt. % of molecules having at least one aromatic core and 1 wt. % or less of terminal unsaturates, e.g., vinyl aromatics, based on the weight of the utility fluid.

- [0081]** In aspects where hydroprocessing is envisioned, e.g., hydroprocessing of the first lower-density portion, the utility fluid typically contains sufficient amount of molecules having one or more aromatic cores as a processing aid, e.g., to effectively increase run length of the tar hydroprocessing process. For example, the utility fluid can contain ≥ 50.0 wt. % of molecules having at least one aromatic core (e.g., ≥ 60.0 wt. %, such as ≥ 70 wt. %) based on

the total weight of the utility fluid. In an aspect, the utility fluid contains (i) ≥ 60.0 wt. % of molecule having at least one aromatic core and (ii) ≤ 1.0 wt. % of vinyl aromatics, the weight percent being based on the weight of the utility fluid.

[0082] The utility fluid can be one having a high solvency, as measured by solubility
5 blending number ("S_{Fluid}"). For example, the utility fluid can have a S_{Fluid} ≥ 90 , e.g., ≥ 100 , ≥ 110 , ≥ 120 , ≥ 150 , ≥ 175 , or ≥ 200 . Additionally or alternatively, S_{Fluid} can be ≤ 200 , e.g., ≤ 175 , ≤ 150 , ≤ 125 , ≤ 110 , or ≤ 100 . Ranges expressly disclosed include combinations of any of the above-enumerated values.

[0083] Additionally or alternatively, the utility fluid may be characterized by a dynamic
10 viscosity of that is typically less than that of the tar-fluid mixture. In particular aspects, the dynamic viscosity of the tar-fluid mixture may be ≥ 0.1 cPoise, e.g., ≥ 0.5 cPoise, ≥ 1 cPoise, ≥ 2.5 cPoise or, ≥ 4 cPoise, at a temperature of about 50°C to about 250°C, such as about 100°C. Additionally or alternatively, the dynamic viscosity of the tar-fluid mixture may be ≤ 5 cPoise, e.g., ≤ 4 cPoise, ≤ 2.5 cPoise, ≤ 1 cPoise, ≤ 0.5 cPoise, or ≤ 0.25 cPoise, at a temperature of
15 about 50°C to about 250°C, such as about 100°C. Ranges expressly disclosed include combinations of any of the above-enumerated values. In some aspects, the dynamic viscosity of the utility fluid is adjusted so that when combined with the SCT composition to produce the tar-fluid mixture, solids having a size larger than 25 μm settle out of the tar-fluid mixture to provide the solids-enriched portion (the extract) and solids-depleted portions (the raffinate)
20 described herein, more particularly to adjust the viscosity to also enable the amount of solids removal and throughput of the solids-depleted portion from the process.

Optional Separation Fluids

[0084] The first and second separation fluids each can be selected independently. Each can be selected from among hydrocarbon liquid having a mass density that is less than that of
25 the SCT composition, e.g., $\leq 1\%$ that of the feed, such as $\leq 5\%$, or $\leq 10\%$. Although it is not required, the first and second separation fluids can have substantially the same composition and can be referred to as "separation fluid". The separation fluid can be any hydrocarbon liquid, typically a non-polar hydrocarbon, or mixture thereof. In some aspects, the separation fluid may be a paraffinic hydrocarbon or a mixture of paraffinic hydrocarbons. Particular paraffinic fluids
30 include C₅ to C₂₀ hydrocarbons and mixtures thereof, particularly C₅ to C₁₀ hydrocarbons, e.g. hexane, heptane, and octane. Such fluids may be particularly useful when subsequent hydroprocessing is not desired. In certain aspects, the separation fluid has a mass density ≤ 0.91

g/mL, e.g., ≤ 0.90 g/mL, such as ≤ 0.89 g/mL, or ≤ 0.88 g/mL, e.g., in the range of 0.87 to 0.90 g/mL.

[0085] When a distinct separation fluid is used in producing the tar-fluid mixture (namely, a separation fluid having a substantially different composition from that of the utility fluid) the separation fluid can be present in the tar-fluid mixture in an amount ≤ 35 wt. %, e.g., ≤ 30 wt. %, ≤ 25 wt. %, ≤ 20 wt. %, ≤ 15 wt. %, ≤ 10 wt. %, ≤ 5 wt. %, ≤ 2.5 wt. %, or ≤ 1.5 wt. %, based on the total weight of fluid in the tar-fluid mixture. Additionally or alternatively, the separation fluid may be present in an amount $\geq$ to 0 wt. %, e.g., ≥ 1.5 wt. %, ≥ 2.5 wt. %, ≥ 5 wt. %, ≥ 10 wt. %, ≥ 15 wt. %, ≥ 20 wt. %, ≥ 25 wt. %, or ≥ 30 wt. %, based on the total weight of the fluid in the tar-fluid mixture. Ranges expressly disclosed include combinations of any of the above-enumerated values. It is typical in these and other aspects for separation fluid (when used) and SCT composition together to be ≥ 50 wt. % of the balance of the tar-fluid mixture (the balance being the part of the tar-fluid mixture that is not utility fluid + the recycled portion of the second lower-density portion), e.g., ≥ 75 wt. %, such as ≥ 90 wt. %, or ≥ 95 wt. %, or ≥ 99 wt. %.

[0086] The tar-fluid mixture can contain both utility fluid and separation fluid. Particularly in aspects where tar-fluid mixture components are not subjected to subsequent hydroprocessing, the tar-fluid mixture may comprise ≥ 30 wt. % of a separation fluid. Thus, in some aspects, the fluid of the tar-fluid mixture (i.e., any utility fluid present in the tar-fluid mixture plus any separation fluid present in the tar-fluid mixture) may contain ≥ 50 wt. % separation fluid, e.g., ≥ 60 wt. %, ≥ 70 wt. %, ≥ 80 wt. %, ≥ 90 wt. %, ≥ 95 wt. %, ≥ 97.5 wt. %, ≥ 99 wt. %, or 100 wt. % separation fluid, based on the total weight of the tar-fluid mixture. Additionally or alternatively, the tar-fluid mixture may include ≤ 99 wt. % separation fluid, e.g., ≤ 97.5 wt. %, ≤ 95 wt. %, ≤ 90 wt. %, ≤ 80 wt. %, ≤ 70 wt. %, or ≤ 60 wt. % separation fluid, based on the total weight of the tar-fluid mixture. Ranges expressly disclosed include combinations of any of the above-enumerated values.

[0087] Aspects of the invention which include separating from the tar-fluid mixture a first higher-density portion and a first lower-density portion in a first SCT separation stage will now be described in more detail. The invention is not limited to these aspects, and this description should not be interpreted as excluding other forms of separation.

First SCT Separation -- Separating the First Higher-Density and First Lower-Density Portions from the Tar-Fluid Mixture

[0088] The first higher-density and lower-density portions can be separated from the tar-fluid mixture by any means suitable for achieving the specified separation, including one or

more of sedimentation, filtration, and extraction. Conventional separations technology can be utilized, but embodiments are not limited thereto. For example, the first lower-density portion may be separated from the tar-fluid mixture by decantation, filtration and/or boiling point separation (e.g., one or more distillation towers, splitters, flash drums, or any combination thereof). The first higher-density portion may be separated from the tar-fluid mixture in a similar manner, e.g., by removing the first higher-density portion from the separation stage as a bottoms portion. The first higher-density portion and the first lower-density portion can be separated from the tar-fluid mixture in any order, e.g., substantially simultaneously, by first separating the first higher-density portion and then separating the first lower-density portion from the first higher-density portion, or *vice versa*. In some aspects the first lower-density portion and the first higher-density portion are separated by exposing the tar-fluid mixture to a centrifugal force, e.g., by employing one or more centrifuges in the separation stage.

Inducing the Centrifugal Force

[0089] In some aspects, the tar-fluid mixture containing the SCT, solids (e.g., pyrolytic coke, polymeric coke, and/or inorganics), and the first utility fluid and/or first separation fluid is provided to a centrifuge for exposing the tar-fluid mixture to a centrifugal force sufficient to form at least a higher-density portion and a lower-density portion. Optionally, the tar-fluid mixture is subjected to one or more stages of filtration, e.g., to remove solids having a size $\geq 5000\text{ }\mu\text{m}$, e.g., $\geq 3000\text{ }\mu\text{m}$, such as $\geq 2000\text{ }\mu\text{m}$, or $\geq 1000\text{ }\mu\text{m}$. In certain aspects, solids present in the tar-fluid mixture have sizes in the range of from less than $1\text{ }\mu\text{m}$ to $3000\text{ }\mu\text{m}$, e.g., in a range of about $0.5\text{ }\mu\text{m}$ to $2000\text{ }\mu\text{m}$. Typically, $\geq 75\text{ wt. \%}$ of the solids have a size $\leq 2000\text{ }\mu\text{m}$, e.g., $\geq 90\text{ wt. \%}$, such as $\geq 95\text{ wt. \%}$, or $\geq 99\text{ wt. \%}$. Typically, $\geq 75\text{ wt. \%}$ of the solids have a size in the range of from $50\text{ }\mu\text{m}$ to $88\text{ }\mu\text{m}$, e.g., $\geq 90\text{ wt. \%}$, such as $\geq 95\text{ wt. \%}$, or $\geq 99\text{ wt. \%}$.

[0090] Typically, the tar-fluid mixture in the centrifuge exhibits a substantially uniform circular motion as a result of an applied central force. Depending on reference-frame choice, the central force can be referred to as a centrifugal force (in the reference-frame of the tar-fluid mixture) or a centripetal force (in the reference frame of the centrifuge). The process may be performed in a batch, semi-batch or continuous manner.

[0091] The centrifuge may be configured to apply heat to the tar-fluid mixture, e.g., by heating the tar-fluid mixture to an elevated temperature. In some aspects, inducing the centrifugal force also includes heating the tar-fluid mixture to a temperature of about 20°C , about 25°C , about 30°C , about 40°C , about 50°C , about 55°C , or about 60°C to about 65°C ,

about 70°C, about 80°C, about 85°C, about 90°C, about 95°C, about 100°C, about 110°C, about 120°C, or greater. For example, while centrifuging, the tar-fluid mixture can be heated to a temperature of about 20°C to about 120°C, about 20°C to about 100°C, about 30°C to about 100°C, about 40°C to about 100°C, about 50°C to about 100°C, about 60°C to about 100°C, about 70°C to about 100°C, about 80°C to about 100°C, about 90°C to about 100°C, about 20°C to about 80°C, about 30°C to about 80°C, about 40°C to about 80°C, about 50°C to about 80°C, about 60°C to about 80°C, or about 70°C to about 80°C.

[0092] The centrifugal force may be applied for any amount of time. Typically the centrifugal force is applied for ≥ 1 minute, e.g., ≥ 5 minutes, ≥ 10 minutes, ≥ 30 minutes, ≥ 60 minutes, or ≥ 120 minutes. Additionally or alternatively, the centrifugal force may be applied for ≤ 120 minutes, ≤ 60 minutes, ≤ 30 minutes, ≤ 10 minutes, or ≤ 5 minutes. Ranges expressly disclosed include combinations of any of the above-enumerated values; e.g., about 1 minute to about 120 minutes, about 5 minutes to about 120 minutes, about 10 minutes to about 120 minutes, about 30 minutes to about 120 minutes, or about 60 minutes to about 120 minutes.

The centrifugal force may be applied for any amount of force or speed. For example, a sufficient force will be provided by a centrifuge operating at about 1,000 rpm to about 10,000 rpm, about 2,000 rpm to about 7,500 rpm, or about 3,000 rpm to about 5,000 rpm.

[0093] Centrifuging the tar-fluid mixture typically results in separating from the tar-fluid mixture at least (i) an extract comprising, consisting essentially of, or consisting of a first higher-density portion of the tar-fluid mixture and (ii) a raffinate comprising, consisting essentially of, or consisting of a first lower-density portion. In other words, exposing the tar-fluid mixture to the centrifugal force results in the removal of at least the higher-density portion (the extract) from the tar-fluid mixture. When the process is operated continuously or semi-continuously, at least two streams can be conducted away from the centrifuging: one stream containing the extract and another stream containing the raffinate. Centrifuges with such capabilities are commercially available, but the invention is not limited thereto.

[0094] Typically centrifuging is sufficient to segregate ≥ 80 wt. %, ≥ 90 wt. %, ≥ 95 wt. %, ≥ 99 wt. % of solids in the tar-fluid mixture (including the particles in the tar-fluid mixture) having size ≥ 2 μm , e.g., ≥ 10 μm , such as ≥ 20 μm , or ≥ 25 μm , into the first higher-density portion (e.g., the extract), the wt. % being based on the total weight of solids in the higher-density and lower-density portions. Where subsequent hydroprocessing of the raffinate is envisioned, the higher-density portion contains ≥ 95 wt. %, particularly ≥ 99 wt. %, of solids having a size of ≥ 2 μm , e.g., ≥ 10 μm , such as ≥ 20 μm , or ≥ 25 μm . In other aspects, e.g.,

where the first lower-density portion (e.g., the raffinate) is not subjected to hydroprocessing, filtration should be sufficient to segregate at least 80 wt. % of the solids into the first higher-density portion.

[0095] While the description focuses on separating a first higher-density portion and a first lower-density portion, other embodiments envision that the components of the first tar-fluid mixture may be more discretely segregated and extracted, e.g., very light components segregating to the top of the mixture, a portion that contains primarily the fluid therebelow, an upgraded tar portion, tar heavies, or solids at the bottom of the centrifuge chamber. Each of these portions, or combinations thereof, may be selectively removed from the mixture as one or more raffinates.

The First Lower-Density Portion

[0096] The first lower-density portion can be conducted away for one or more of storage, blending with other hydrocarbons, or further processing, e.g., for SATC. The first lower-density portion generally has a desirable insolubility number, e.g., an insolubility number that is less than that of the SCT composition and/or less than that of the higher-density portion. Typically, the insolubility number of the first lower-density portion (I_{FLD}) is ≥ 20 , e.g., ≥ 30 , ≥ 40 , ≥ 50 , ≥ 60 , ≥ 70 , ≥ 80 , ≥ 90 , ≥ 100 , ≥ 110 , ≥ 120 , ≥ 130 , ≥ 140 , or ≥ 150 . Additionally or alternatively, the I_{FLD} may be ≤ 150 , e.g., ≤ 140 , ≤ 130 , ≤ 120 , ≤ 110 , ≤ 100 , ≤ 90 , ≤ 80 , ≤ 70 , ≤ 60 , ≤ 50 , ≤ 40 , or ≤ 30 . Ranges expressly disclosed include combinations of any of the above-enumerated values; e.g., about 20 to about 150, about 20 to about 140, about 20 to about 130, about 20 to about 120, about 20 to about 110, about 20 to about 100, about 20 to about 90, about 20 to about 80, about 20 to about 70, about 20 to about 60, about 20 to about 50, about 20 to about 40, or about 20 to about 30. Those skilled in the art will appreciate that hydrocarbon separations technology is imperfect, and, consequently, a small amount of solids may be present in the first lower-density portion, e.g., an amount of solids that is ≤ 0.1 times the amount of solids in the tar-fluid mixture, such as ≤ 0.01 times. In aspects where at least part of the first lower-density portion is hydroprocessed, e.g., by a SATC process, solids-removal means (e.g., one or more filters) are typically employed between the separation stage and the hydroprocessing stage.

[0097] The ratio of the insolubility number of the first lower-density portion, I_{FLD} , to the insolubility number of the SCT composition, I_{TC} , is ≤ 0.95 , e.g., ≤ 0.90 , ≤ 0.85 , ≤ 0.80 , ≤ 0.75 , ≤ 0.70 , ≤ 0.65 , ≤ 0.60 , ≤ 0.55 , ≤ 0.50 , ≤ 0.40 , ≤ 0.30 , ≤ 0.20 , or ≤ 0.10 . Additionally or alternatively, the ratio of I_{FLD} to I_{TC} may be ≥ 0.10 , e.g., ≥ 0.20 , ≥ 0.30 , ≥ 0.40 , ≥ 0.50 , ≥ 0.55 ,

≥ 0.60 , ≥ 0.65 , ≥ 0.70 , ≥ 0.75 , ≥ 0.80 , ≥ 0.85 , or ≥ 0.90 . Ranges expressly disclosed include combinations of any of the above-enumerated values, e.g., about 0.10 to 0.95, about 0.20 to 0.95, about 0.30 to 0.95, about 0.40 to 0.95, about 0.50 to 0.95, about 0.55 to 0.95, about 0.60 to 0.95, about 0.65 to 0.95, about 0.70 to 0.95, about 0.75 to 0.95, about 0.80 to 0.95, about 0.85 to 0.95, or about 0.90 to 0.95.

The First Higher-Density Portion

[0098] The first higher density portion typically comprises solids having a size ≤ 5000 μm , e.g., ≤ 2000 μm , such as ≤ 1000 μm ; and optionally contains liquid such as utility fluid and/or separation fluid carried over from the separation (e.g., from the centrifuging). For example, the first higher density portion can contain solids in an amount in the range of 1 wt. % to 25 wt. % of solids having a size ≤ 5000 μm (or ≤ 3000 μm , or ≤ 2000 μm) such as 5 wt. % to 15 wt. % based on the weight of the first higher density portion. In certain aspects, the first higher density portion contains solids having a size in a range of ≤ 1 μm to 5000 μm , e.g., from 0.1 μm to 3000 μm , e.g., in a range of about 0.5 μm to 2000 μm . Typically, ≥ 75 wt. % of the solids have a size ≤ 2000 μm , e.g., ≥ 90 wt. %, such as ≥ 95 wt. %, or ≥ 99 wt. %. Typically, ≥ 75 wt. % of the solids have a size in the range of from 50 μm to 88 μm , e.g., ≥ 90 wt. %, such as ≥ 95 wt. %, or ≥ 99 wt. %.

[0099] The first higher-density portion, particularly the liquid-phase part thereof, may have an insolubility number, I_{FHD} , ≥ 20 , ≥ 40 , ≥ 70 , ≥ 90 , ≥ 100 , ≥ 110 , ≥ 120 , ≥ 130 , ≥ 140 , or ≥ 150 . Additionally or alternatively, I_{FHD} may be ≤ 40 , ≤ 70 , ≤ 90 , ≤ 100 , ≤ 110 , ≤ 120 , ≤ 130 , ≤ 140 , or ≤ 150 . Ranges expressly disclosed include combinations of any of the above-enumerated values; e.g., about 20 to about 150, about 40 to about 150, about 70 to about 150, about 90 to about 150, about 100 to about 150, about 110 to about 150, about 120 to about 150, about 130 to about 150, or about 140 to about 150.

[00100] Additionally or alternatively, the first higher-density portion can contain asphaltenes and/or tar heavies. In some aspects, the first higher-density portion, particularly the liquid portion thereof, contains ≥ 50 wt. % asphaltenes, e.g., ≥ 60 wt. %, ≥ 75 wt. %, based on the total weight of the first higher-density portion. The first higher-density portion may include ≤ 10 wt. %, e.g., ≤ 7.5 wt. %, ≤ 5 wt. %, ≤ 2.5 wt. %, ≤ 2 wt. %, ≤ 1.5 wt. %, or ≤ 1 wt. %, of the total asphaltene content of the SCT composition. The first higher-density portion may include ≥ 1 wt. %, e.g., ≥ 1.5 wt. %, ≥ 2 wt. %, ≥ 2.5 wt. %, ≥ 5 wt. %, or ≥ 7.5 wt. %, of the total asphaltene content of the SCT composition. Ranges expressly disclosed include

combinations of any of the above-enumerated values; e.g., 1 wt. % to 10 wt. %, 1 wt. % to 7.5 wt. %, 1 wt. % to 5 wt. %, 1 wt. % to 2.5 wt. %, 1 wt. % to 2 wt. %, or 1 wt. % to 1.5 wt. % of the total asphaltene content of the SCT composition. Removal of lower amounts of the asphaltene content may be preferred. For example, it has been surprisingly found that the segregation of even small amounts of asphaltenes into the higher-density portion has a surprising impact on the insolubility number of the first lower-density portion. While not wishing to be bound by any theory or model, it is believed that the presence of relatively high-density asphaltenes in the SCT composition have a much greater impact on insolubility number than do lower-density asphaltenes. Thus, a relatively large amount of problematic molecules can be separated, leaving in the first lower-density portion molecules that will contribute to the over-all yield of the process.

[00101] The benefits of the process may be obtained even when the first higher-density portion contains a relatively small fraction of the SCT composition. The first higher-density portion may contain ≤ 10 wt. %, e.g., ≤ 7.5 wt. %, ≤ 5 wt. %, ≤ 2.5 wt. %, ≤ 2 wt. %, ≤ 1.5 wt. %, or ≤ 1 wt. % of the total weight of the SCT composition. Ranges expressly disclosed include combinations of any of the above-enumerated values; e.g., 1 wt. % to 10 wt. %, 1 wt. % to 7.5 wt. %, 1 wt. % to 5 wt. %, 1 wt. % to 2.5 wt. %, 1 wt. % to 2 wt. %, or 1 wt. % to 1.5 wt. % of the total weight of the SCT composition. The removal of a relatively small weight fraction may surprisingly be accompanied by a relatively large improvement in the insolubility number of the first lower-density portion. Solids present in the extract optionally have a mass density ≥ 1.05 g/mL, e.g., ≥ 1.10 g/mL, such as ≥ 1.2 g/mL, or ≥ 1.3 g/mL, or in the range of from about 1.05 g/mL to 1.5 g/mL.

[00102] The first higher-density portion typically comprises ≥ 50 wt. % of any SCT solids remaining after the first thermal treatment, e.g., ≥ 75 wt. %, such as ≥ 90 wt. %, or ≥ 99 wt. %. The first higher density portion typically further comprises ≥ 50 wt. % of any of any solids in the SCT composition that formed during or as a result of the first thermal treatment, e.g., ≥ 75 wt. %, such as ≥ 90 wt. %, or ≥ 99 wt. %. The first higher-density portion is processed in a second thermal treatment and optional physical reduction in the size of solids present in the first higher-density portion (e.g., by comminuting, such as grinding) in order to lessen the amount of solids. This processing can be carried out in the presence of diluent.

Optional Size Reduction – Physical Processes

[00103] Physical processes for size reduction of solids such as particles (grinding, etc.—collectively referred to as comminuting) are optionally carried out on the first higher-density portion to form a comminuted higher-density portion. Examples of physical processes for size

reduction can include grinding, ball milling, ablation in an ablation drum, and/or other mechanical size reduction processes. Physical processes for size reduction can be in contrast to chemical processes for size reduction. For example, as described herein, at least a portion of sufficiently small solids (e.g., particles) in a SCT fraction (or other pyrolysis tar fraction) can be hydroprocessed (such as under SATC conditions) to convert the small solids to liquid products. During certain SATC processes, a combination of elevated temperature, elevated pressure, the presence of chemical reagents, and/or the presence of catalysts are used to induce chemical reactions. The chemical reactions result in changes in chemical compositions that can then result in a size reduction. By contrast, in some aspects, the physical size reduction can result in solids with roughly similar compositions (with possible exception of surface layers) both before and after the size reduction.

[00104] After performing a first physical size reduction process on the first higher-density portion, the weight of solids having a size of 25 μm or more in the comminuted higher-density portion can be further decreased in one or more additional stages. Effluent from these stages can have a weight of solids having a size of 25 μm or more that is 85% or less relative to the weight of such solids in the first higher-density portion or diluted first higher-density portion (as the case may be), or 75% or less, or 65% or less, or 50% or less, such as down to 10% or possibly still lower.

[00105] Suitable equipment for reducing the size of solids is commercially available, but the invention is not limited thereto. Grinders, ball mills, and ablaters are suitable. More generally, any convenient process for reducing the size of solids, such as coke fines, can be used.

[00106] Since the first higher-density portion is typically leaner in total fluid (any first utility fluid + any first separation fluid) in comparison with the tar-fluid mixture, a diluted first higher-density portion may be formed by introducing into the first higher-density portion a second utility fluid and/or a second separation fluid. These diluents are optional, and may be added to the first higher-density portion, e.g., as a flux and/or as an aid in (i) the second thermal treatment and/or (ii) the separation of the second higher-density and second lower-density portions. These diluents can be added before and/or after the optional size reduction (e.g., optional grinding). For example, the second utility fluid can be added before and/or after optional grinding. The second utility fluid can be selected from among the same compositions specified for the first utility fluid, and typically the first and second utility fluids have substantially the same composition.

Diluted First Higher-Density Portion

[00107] When desired, e.g., as an aid to process-ability of the first higher-density portion, diluent (typically comprising the second utility fluid and/or the second separation fluid) may be added to the first higher-density portion to form a diluted first higher-density portion. Diluent, when used can correspond to 20 wt. % to 60 wt. % of diluted first higher-density
5 portion, or 20 wt. % to 50 wt. %, or 30 wt. % to 60 wt. %. Even if diluent is added to the first higher-density portion before a size reduction process, additional diluent can be added after size reduction to further facilitate heat soaking of the first higher-density portion (or
10 comminuted higher-density portion) present in the diluted first higher-density portion. Typically, the diluent comprises ≥ 50 wt. % of utility fluid, based on the weight of the diluent, e.g., ≥ 75 wt. %, such as ≥ 90 wt. %. Typically, ≥ 90 wt. % of the balance of the diluent
comprises separation fluid.

[00108] In certain aspects, the diluent does not contain the second separation fluid. It has been discovered that processing the diluted first higher-density portion in the second thermal treatment before separation of the second higher-density portion and the second lower-density
15 portion can obviate the need for the second separation fluid.

[00109] It has been found to be advantageous for the diluent to include a second utility fluid, and to carry out the second thermal treatment under different conditions than the first thermal treatment. Doing so has been found to provide for dissolution of at least a portion of the polymeric solids in the first higher-density portion, such as those formed during and/or as
20 a result of the first thermal treatment, and on-purpose depolymerization of these polymeric solids. In addition, the second utility fluid dilutes the depolymerized products of the second thermal treatment which is observed to lessen or eliminate repolymerization of these products. The second utility fluid can be selected from among utility fluids comprising a reactive composition such as SCGO. When such a second utility fluid is present in the diluted first
25 higher-density portion during the second thermal treatment, a reactivity decrease (e.g., a decrease in SCGO reactivity) is observed. This feature simulates the use of (and obviates the need for) a higher-value diluent, such as utility fluid recovered from a SATC process (e.g., a mid-cut). In other words, the diluent can comprise SCGO, mid-cut, or a combination thereof.

[00110] In some aspects, the diluent can contain ≥ 65 wt. % of utility fluid, e.g., ≥ 75 wt. %, ≥ 80 wt. %, ≥ 85 wt. %, ≥ 90 wt. %, or ≥ 95 wt. % utility fluid, based on the total weight of the diluent. Additionally or alternatively, the diluent may contain ≤ 100 wt. % utility fluid, e.g., ≤ 95 wt. %, ≤ 90 wt. %, ≤ 85 wt. %, ≤ 80 wt. %, ≤ 75 wt. %, or ≤ 70 wt. % utility fluid, based on the total weight of the diluent. Ranges expressly disclosed include combinations of any of the above-enumerated values, e.g., about 65 wt. % to about 100 wt. %, about 75 wt. %

to about 100 wt. %, about 80 wt. % to about 100 wt. %, about 85 wt. % to about 100 wt. %, about 90 wt. % to about 100 wt. %, or about 95 wt. % to about 100 wt. % utility fluid. In certain aspects, the diluent is utility fluid.

[00111] In the following description of the diluted first higher-density portion and the second thermal treatment, it should be understood that the first higher-density portion can be the comminuted first higher-density portion in aspects where an optional comminuting step is carried out. Typically, the diluted first higher-density portion contains ≥ 5 wt. % of the first higher-density portion, e.g., ≥ 10 wt. %, ≥ 20 wt. %, ≥ 30 wt. %, ≥ 40 wt. %, ≥ 50 wt. %, ≥ 60 wt. %, ≥ 70 wt. %, ≥ 80 wt. %, or ≥ 90 wt. %, based on the total weight of the diluted first higher-density portion. Those skilled in the art will appreciate that the amount of utility fluid in the diluted first higher-density portion includes (i) any residual first utility fluid transferred from the tar-fluid mixture to the first higher-density portion and (ii) the second utility fluid.

[00112] In addition to the first higher-density portion, the diluted higher-density portion generally contains ≥ 5 wt. % diluent, e.g., ≥ 10 wt. %, ≥ 20 wt. %, ≥ 30 wt. %, ≥ 40 wt. %, ≥ 50 wt. %, ≥ 60 wt. %, ≥ 70 wt. %, ≥ 80 wt. %, or ≥ 90 wt. %, based on the total weight of the diluted higher-density portion (e.g., a combined weight of the first higher-density portion, any residual first utility fluid carried over from the tar-fluid mixture, any first separation fluid carried over from the tar-fluid mixture, any second utility fluid, and any second separation fluid. Additionally or alternatively, the diluted first higher-density portion may include ≤ 10 wt. % fluid, e.g., ≤ 20 wt. %, ≤ 30 wt. %, ≤ 40 wt. %, ≤ 50 wt. %, ≤ 60 wt. %, ≤ 70 wt. %, ≤ 80 wt. %, ≤ 90 wt. %, or ≤ 95 wt. % diluent, based on the total weight of the diluted first higher-density portion. Ranges expressly disclosed include combinations of any of the above-enumerated values, e.g., about 5 wt. % to about 95 wt. %, about 5 wt. % to about 90 wt. %, about 5 wt. % to about 80 wt. %, about 5 wt. % to about 70 wt. %, about 5 wt. % to about 60 wt. %, about 5 wt. % to about 50 wt. %, about 5 wt. % to about 40 wt. %, about 5 wt. % to about 30 wt. %, about 5 wt. % to about 20 wt. %, or about 5 wt. % to about 10 wt. % fluid.

[00113] In some aspects, the diluted first higher-density portion has a solubility blending number of less than 150, such as about 140 or less, about 130 or less, about 120 or less, as about 115 or less, about 110 or less, about 105 or less, about 100 or less, about 95 or less, or about 90 or less. In some examples, the diluted first higher-density portion has a solubility blending number of about 70, about 80, about 85, about 90, about 95, about 100, about 105, about 110, about 115, about 120, about 130, about 140, or about 150. For example, the diluted first higher-density portion has a solubility blending number of about 70 to about 150, about 70 to about 130, about 70 to about 125, about 70 to about 120, about 70 to about 115, about 70 to about 110,

about 70 to about 105, about 70 to about 100, about 70 to about 95, about 70 to about 90, about 70 to about 85, about 80 to about 130, about 80 to about 125, about 80 to about 120, about 80 to about 115, about 80 to about 110, about 80 to about 105, about 80 to about 100, about 80 to about 95, about 80 to about 90, about 85 to about 130, about 85 to about 125, about 85 to about 120, about 85 to about 115, about 85 to about 110, about 85 to about 105, about 85 to about 100, about 85 to about 95, about 85 to about 90, about 90 to about 130, about 90 to about 125, about 90 to about 120, about 90 to about 115, about 90 to about 110, about 90 to about 105, about 90 to about 100, or about 90 to about 95.

[00114] The dynamic viscosity of the diluted first higher-density portion can be less than that of the first higher-density portion. In some aspects, the dynamic viscosity of the diluted first higher-density portion may be ≥ 0.5 cPoise, e.g., ≥ 1 cPoise, ≥ 2.5 cPoise, ≥ 5 cPoise, ≥ 7.5 cPoise, at a temperature of about 50°C to about 250°C, such as about 100°C. Additionally or alternatively, the dynamic viscosity of the tar-fluid mixture may be ≤ 10 cPoise, e.g., ≤ 7.5 cPoise, ≤ 5 cPoise, ≤ 2.5 cPoise, ≤ 1 cPoise, ≤ 0.75 cPoise, at a temperature of about 50°C to about 250°C, such as about 100°C. Ranges can include combinations of any of the above-enumerated values, e.g., about 0.5 cPoise to about 10 cPoise, about 1 cPoise to about 10 cPoise, about 2.5 cPoise to about 10 cPoise, about 5 cPoise to about 10 cPoise, or about 7.5 cPoise to about 10 cPoise, at a temperature of about 50°C to about 250°C, such as about 100°C.

[00115] The diluted first higher-density portion is subjected to an additional thermal treatment. Aspects in which the second thermal treatment includes a second heat soak will now be described in more detail. The invention is not limited to these aspects, and this description should not be interpreted as excluding forms of thermal treatment that do not include heat soaking.

Second Thermal Treatment

[00116] In other embodiments, the first higher-density portion or diluted first higher-density portion (as the case may be) is subjected to a second thermal treatment, e.g., a second heat soaking. The second thermal treatment can be carried out by heat soaking in at least one vessel or drum. The heat soaking can include pyrolysis, e.g., thermal pyrolysis.

[00117] Certain forms of solids are present in the SCT when SCT is separated from the steam cracker effluent. Other forms of solids, e.g., certain particulates, form during and/or as a result of the first thermal treatment, such as by polymerization of separated SCT in a tar knock-out drum and/or primary fractionator. It has been found that (i) the SCT composition can contain both forms of solids, and (ii) when operating the first SCT separation under the specified conditions that ≥ 50 wt. % of solids in the SCT composition are transferred to the first higher-

density portion, e.g., ≥ 75 wt. %, such as ≥ 90 wt. %, or ≥ 95 wt. %, or ≥ 99 wt. %. Surprisingly, it has been found that such solids can be converted during and/or as a result of the second thermal treatment to form conversion products (typically in the liquid phase) having a mass density that is in substantially the same range as that of the first lower-density portion. The amount of material residing in the first lower-density portion thus can be increased by (i) transferring at least a portion of these conversion products of the second thermal treatment to a second lower-density portion, and then recycling the second lower-density portion to (i) the first lower density portion and/or (ii) a location in the process that is upstream of the separation from the SCT composition of the first lower-density portion. Typically, ≥ 50 wt. % of solids in the first higher-density portion are those produced during the first thermal treatment, e.g., ≥ 75 wt. %, such as ≥ 90 wt. %, or more. Fig. 2 can be utilized to determine the amount of these solids that are converted in the specified second thermal treatment. While not wishing to be bound by any theory or model, it is believed that the second thermal treatment at least partially-converts (e.g., dissolves or decomposes) solids present in the diluted first higher-density portion, particularly those solids produced (e.g., by polymerization) during and/or as a result of the first thermal treatment. For a typical SCT, Fig. 2 indicates the amount of solids that are converted from a greater mass density to a lesser mass density (e.g., from a more dense solid phase and/or semi-solid phase to a less dense liquid phase) during or as a result of the second thermal treatment as a function of second thermal treatment temperature for a time in the range of from 30 minutes to 60 minutes. Those skilled in the art will appreciate that a similar curve can be produced for other tars without undue experimentation. Conventional heat-soaking equipment can be used for carrying out the second heat soaking, e.g., one or more soaker drums, but the invention is not limited thereto. The second heat soaking can be carried out for a desired temperature ("T_{HS2}") and for a desired period of time ("t_{HS2}"), which are typically predetermined. T_{HS2} is typically about 200°C, about 220°C, about 230°C, about 240°C, about 250°C, about 260°C, about 270°C, about 275°C, about 280°C, or about 290°C to about 295°C, about 300°C, about 310°C, about 320°C, about 325°C, about 330°C, about 340°C, about 350°C, about 360°C, about 375°C, about 400°C, about 450°C, about 500°C, or higher. For example, T_{HS2} can be in a range of from about 200°C to about 500°C, about 230°C to about 500°C, about 250°C to about 500°C, about 280°C to about 500°C, about 290°C to about 500°C, about 300°C to about 500°C, about 320°C to about 500°C, about 350°C to about 500°C, about 250°C to about 450°C, about 280°C to about 450°C, about 290°C to about 450°C, about 300°C to about 450°C, about 320°C to about 450°C, about 350°C to about 450°C, about 250°C to about 400°C, about 280°C to about 400°C, about 290°C to about 400°C, about 300°C to about 400°C, about 320°C to about 400°C, about

350°C to about 400°C, about 250°C to about 350°C, about 280°C to about 350°C, about 290°C to about 350°C, about 300°C to about 350°C, about 320°C to about 350°C, or about 330°C to about 350°C. Although it is not required to maintain the diluted first higher-density portion at a substantially-constant temperature during the second heat soak (i.e., a substantially constant temperature within the specified range of T_{HS2}), it is typical to do so. Time t_{HS2} can be about 2 min, about 5 min, about 10 min, about 12 min, or about 15 min to about 20 min, about 25 min, about 30 min, about 45 min, about 60 min, about 90 min, about 2 hr, about 3 hr, about 5 hr, or longer. For example, t_{HS2} can be in a range of about 5 min to about 5 hr, about 5 min to about 3 hr, about 5 min to about 2 hr, about 5 min to about 1 hr, about 5 min to about 45 min, about 5 min to about 30 min, or about 5 min to about 20 min. In one or more examples, t_{HS2} is in a range of about 2 min, about 5 min, about 10 min, about 15 min, or about 20 min to about 30 min, about 45 min, about 60 min, about 90 min, about 2 hr, about 3 hr, or about 5 hr to convert (e.g., dissolve or decompose) solids (e.g., polymeric solids) in the first higher-density portion or the diluted first higher-density portion (as the case may be) to material of a lesser density during or as a result of the second thermal treatment.

[00118] It is observed that the second heat soak produces a thermally-treated, first higher-density portion having fewer solids than does the first higher-density portion before the second thermal treatment. In aspects where a diluent is used, the second heat soak produces a thermally-treated, diluted first higher-density portion having fewer solids than does the diluted first higher-density portion. In one or more embodiments, about 25 wt. %, about 30 wt. %, about 35 wt. %, or about 40 wt. % to about 45 wt. %, about 50 wt. %, about 60 wt. %, about 70 wt. %, about 75 wt. %, about 80 wt. %, about 85 wt. %, about 90 wt. %, about 92 wt. %, about 95 wt. %, about 97 wt. %, about 98 wt. %, about 99 wt. %, or more of the solids (e.g., polymeric solids formed from the first thermal treatment) in the first higher-density portion or the diluted first higher-density portion (as the case may be) are converted (e.g., dissolved or decomposed) to a liquid material (typically of lesser density) during or as a result of the second thermal treatment. In some examples, at least 25 wt. %, at least 30 wt. %, at least 35 wt. %, at least 40 wt. %, at least 45 wt. %, at least 50 wt. %, at least 60 wt. %, at least 70 wt. %, at least 75 wt. %, at least 80 wt. % to about 85 wt. %, about 90 wt. %, about 92 wt. %, about 95 wt. %, about 97 wt. %, about 98 wt. %, about 99 wt. %, or more of the solids (e.g., particles) in the first higher-density portion or the diluted first higher-density portion (as the case may be) are converted during or as a result of the second thermal treatment. For example, about 25 wt. % to about 99 wt. %, about 30 wt. % to about 99 wt. %, about 35 wt. % to about 99 wt. %, about 40 wt. % to about 99 wt. %, about 45 wt. % to about 99 wt. %, about 50 wt. % to about 99 wt. %, about 60 wt. % to about 99 wt. %.

- %, about 70 wt. % to about 99 wt. %, about 75 wt. % to about 99 wt. %, about 25 wt. % to about 95 wt. %, about 30 wt. % to about 95 wt. %, about 35 wt. % to about 95 wt. %, about 40 wt. % to about 95 wt. %, about 45 wt. % to about 95 wt. %, about 50 wt. % to about 95 wt. %, about 60 wt. % to about 95 wt. %, about 70 wt. % to about 95 wt. %, about 75 wt. % to about 95 wt. %.
- 5 %, about 25 wt. % to about 90 wt. %, about 30 wt. % to about 90 wt. %, about 35 wt. % to about 90 wt. %, about 40 wt. % to about 90 wt. %, about 45 wt. % to about 90 wt. %, about 50 wt. % to about 90 wt. %, about 60 wt. % to about 90 wt. %, about 70 wt. % to about 90 wt. %, about 75 wt. % to about 90 wt. %, about 25 wt. % to about 80 wt. %, about 30 wt. % to about 80 wt. %, about 35 wt. % to about 80 wt. %, about 40 wt. % to about 80 wt. %, about 45 wt. % to about 80 wt. %, about 50 wt. % to about 80 wt. %, about 60 wt. % to about 80 wt. %, about 70 wt. % to about 80 wt. %, or about 75 wt. % to about 80 wt. % of the of the solids (e.g., polymeric solids, such as polymeric particulates) formed from the first thermal treatment) in the first higher-density portion or the diluted first higher-density portion (as the case may be) are converted (e.g., dissolved or decomposed) during or as a result of the second thermal treatment.
- 15 **[00119]** In certain aspects, the amount of solids (wt. %) in the thermally-treated first higher-density portion (“A₂”, based on the weight of the thermally-treated first higher-density portion) is less than the amount of solids (wt. %) in the first higher-density portion (“A₁”, based on the weight of the first higher-density portion), e.g., $A_2 \leq R * A_1$, where R is a real number < 1, e.g., one of 0.9, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, and 0.1. In other aspects, the amount of solids (wt. %)
- 20 %) in the thermally-treated first higher-density portion (“A₂”, based on the weight of the thermally-treated first higher-density portion) is less than the amount of solids (wt. %) in the diluted first higher-density portion (“A_{1d}”, based on the weight of the diluted first higher-density portion), e.g., $A_2 \leq R * A_{1d}$. It has been found that the relationships $A_2 \leq R * A_1$ and $A_2 \leq R * A_{1d}$ are achieved whether or not the comminuting is carried out on first higher-density portion
- 25 before the second thermal treatment, although a lesser value of R (“R_c”) can be achieved when the comminuting is carried out. R_c can be, e.g., $R * 0.9$, such as $R * 0.8$, or $R * 0.7$. With or without comminuting, for example, A₂ is in the range of from 10% of A₁ to 40% of A₁, such as 15% of A₁ to 30% of A₁, or 20% of A₁ to 25% of A₁.

[00120] The solids converted in the second thermal treatment are typically converted mainly to liquid-phase compositions, e.g., ≥ 75 wt. % of the products of the solids conversion are in the liquid phase, such as ≥ 90 wt. %, or ≥ 95 wt. %, or ≥ 99 wt. %.

[00121] The second thermal treatment, e.g., the second heat soaking, is observed to improve the properties of the first higher-density portion contained in the diluted first higher-density portion. Although at least a portion of the thermally-treated first higher-density portion is

typically subjected to further processing (e.g., separation and recycle of a second lower-density portion), the thermally-treated first higher-density portion is itself a useful product, e.g., as a fuel oil. This is so because the thermally-treated first higher-density portion typically has a lesser reactivity and a lesser solids content as compared to the first higher-density portion.

- 5 [00122] Representative thermally-treated first higher-density portions will now be described in more detail. The present disclosure is not limited to these, and this description is not meant to foreclose other thermally-treated first higher-density portions within the broader scope of the present disclosure, such as those produced by forms of the second thermal treatment that do not include a second hat soaking.

10 **Thermally-Treated First Higher-Density Portion**

[00123] The thermally-treated first higher-density portion typically has a final boiling point of at least about 550°F+ (~288°C+). Boiling points and/or fractional weight distillation points can be determined by, for example, ASTM D2892. The final boiling point of the thermally-treated first higher-density portion can be dependent on the nature of the higher-density portion,
15 which in turn can depend on the steam cracking feed's composition and steam cracking conditions.

- [00124] That part of the thermally-treated first higher-density portion having a boiling point at atmospheric pressure $\geq 550^{\circ}\text{F}$ ($\geq 288^{\circ}\text{C}+$) typically has a relatively low hydrogen content compared to other heavy oil fractions, e.g., those generally processed in a refinery or
20 petrochemical setting. For example, that part of the thermally-treated first higher-density portion can have a hydrogen content of about 8.0 wt. % or less, about 7.5 wt. % or less, or about 7.0 wt. % or less, or about 6.5 wt. % or less, e.g., in a range of about 5.5 wt. % to about 8.0 wt. %, or about 6.0 wt. % to about 7.5 wt. %.

- [00125] That part of the thermally-treated first higher-density portion having a boiling point
25 at atmospheric pressure $\geq 550^{\circ}\text{F}$ ($\geq 288^{\circ}\text{C}+$) is typically highly aromatic in nature. The paraffin content of that part of the thermally-treated first higher-density portion can be about 2.0 wt. % or less, or about 1.0 wt. % or less, such as having substantially no paraffin content. The naphthene content of that part of the thermally-treated first higher-density portion can also be about 2.0 wt. % or less or about 1.0 wt. % or less, such as having substantially no naphthene
30 content. In some aspects, the combined paraffin and naphthene content of that part of the thermally-treated first higher-density portion can be about 1.0 wt. % or less.

[00126] Aspects of the invention which include separating from the thermally-treated first higher-density portion a second higher-density portion and a second lower-density portion will now be described in more detail. The invention is not limited to these aspects, and this

description should not be interpreted as excluding other forms of separation within the broader scope of the invention. For simplicity, this separation is called a “second SCT separation”. Those skilled in the art will appreciate that this identifier is used because the thermally-treated first higher-density portion is derived from an SCT. The use of this identifier should not be
5 interpreted as limiting the second separation to separating streams from an SCT itself, e.g., an SCT that has not been subjected to a first thermal treatment or a first SCT separation.

Second SCT Separation -- Separating the Second Higher-Density and Second Lower-Density Portions from the Thermally-Treated First Higher-Density Portion

[00127] The second higher-density and lower-density portions can be separated from the
10 thermally-treated first higher-density portion by any means suitable for achieving the specified separation, including one or more of sedimentation, filtration, and extraction. Conventional separations technology can be utilized, but embodiments are not limited thereto. For example, the second lower-density portion may be separated from the thermally-treated first higher-density portion by decantation, filtration and/or boiling point separation (e.g., one or more
15 distillation towers, splitters, flash drums, or any combination thereof). The second higher-density portion may be separated from the thermally-treated first higher-density portion in a similar manner, e.g., by removing the second higher-density portion from the separation stage as a bottoms portion. The second higher-density portion and the second lower-density portion can be separated from the thermally-treated first higher-density portion in any order, e.g.,
20 substantially simultaneously, by first separating the second higher-density portion and then separating the second lower-density portion from the second higher-density portion, or *vice versa*. In some aspects, the second higher-density portion and the second lower-density portion are separated by exposing the thermally-treated first higher-density portion to a centrifugal force, e.g., by employing one or more centrifuges in the separation stage.

25 [00128] The second higher-density portion and the second lower-density portion may be separated from the thermally-treated first higher-density portion by any means suitable for forming the second higher-density and second lower-density portions. Aspects using one or more centrifuge separations in the second SCT separation stage will now be described in more detail. Embodiments are not limited to these aspects, as well as this description is not to be
30 interpreted as foreclosing the use of additional and/or alternative separations technologies, such as those that do not involve exposing the thermally-treated first higher-density portion to a centrifugal force.

Inducing the Centrifugal Force

[00129] In some aspects, the thermally-treated first higher-density portion containing thermally-treated SCT, any diluent, and any solids remaining after the second thermal treatment is provided to a second centrifuge for exposing the thermally-treated first higher-density portion to a centrifugal force sufficient to form at least a second higher-density portion and a second lower-density portion. Typically, the thermally-treated first higher-density portion in the centrifuge exhibits a substantially uniform circular motion as a result of an applied central force. Depending on reference-frame choice, the central force can be referred to as a centrifugal force (in the reference-frame of the thermally-treated first higher-

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10 -density portion) or a centripetal force (in the reference frame of the centrifuge). The process may be performed in a batch, semi-batch or continuous manner.

[00130] The centrifuge may be configured to apply heat to the thermally-treated first higher-density portion, e.g., by heating the thermally-treated first higher-density portion to an elevated temperature. In some aspects, inducing the centrifugal force also includes heating the thermally-treated first higher-density portion to a temperature of about 20°C, about 25°C, about 30°C, about 40°C, about 50°C, about 55°C, or about 60°C to about 65°C, about 70°C, about 80°C, about 85°C, about 90°C, about 95°C, about 100°C, about 110°C, about 120°C, or greater. For example, while centrifuging, the thermally-treated first higher-density portion can be heated to a temperature of about 20°C to about 120°C, about 20°C to about 100°C, about 30°C to about 100°C, about 40°C to about 100°C, about 50°C to about 100°C, about 60°C to about 100°C, about 70°C to about 100°C, about 80°C to about 100°C, about 90°C to about 100°C, about 20°C to about 80°C, about 30°C to about 80°C, about 40°C to about 80°C, about 50°C to about 80°C, about 60°C to about 80°C, or about 70°C to about 80°C.

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[00131] The centrifugal force may be applied for any amount of time. Typically the centrifugal force is applied for ≥ 1 minute, e.g., ≥ 5 minutes, ≥ 10 minutes, ≥ 30 minutes, ≥ 60 minutes, or ≥ 120 minutes. Additionally or alternatively, the centrifugal force may be applied for ≤ 120 minutes, ≤ 60 minutes, ≤ 30 minutes, ≤ 10 minutes, or ≤ 5 minutes. Ranges expressly disclosed include combinations of any of the above-enumerated values; e.g., about 1 minute to about 120 minutes, about 5 minutes to about 120 minutes, about 10 minutes to about 120 minutes, about 30 minutes to about 120 minutes, or about 60 minutes to about 120 minutes. The centrifugal force may be applied for any amount of force or speed. For example, a

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sufficient force will be provided by a centrifuge operating at about 1,000 rpm to about 10,000 rpm, about 2,000 rpm to about 7,500 rpm, or about 3,000 rpm to about 5,000 rpm.

[00132] Centrifuging the thermally-treated first higher-density portion typically results in separating from the thermally-treated first higher-density portion at least (i) an extract
5 containing a second higher-density portion of the thermally-treated first higher-density portion and (ii) a second raffinate or a second lower-density portion. In other words, exposing the thermally-treated first higher-density portion to the centrifugal force results in the removal of at least the second higher-density portion (the second extract) from the thermally-treated first higher-density portion. When the process is operated continuously or semi-continuously, at
10 least two streams can be conducted away from the centrifuging: one stream containing the second extract and another stream containing the second raffinate. Centrifuges with such capabilities are commercially available.

[00133] Typically centrifuging is sufficient to segregate ≥ 80 wt. %, ≥ 90 wt. %, ≥ 95 wt. %, ≥ 99 wt. % of solids having size ≥ 2 μm , e.g., ≥ 10 μm , such as ≥ 20 μm , or ≥ 25 μm , into
15 the second higher-density portion (e.g., the second extract), the wt. % being based on the total weight of solids in the second higher-density and second lower-density portions. Where subsequent hydroprocessing of the second raffinate is envisioned, the second higher-density portion contains ≥ 95 wt. %, particularly ≥ 99 wt. %, of solids having a size ≥ 2 μm , e.g., ≥ 10 μm , such as ≥ 20 μm , or ≥ 25 μm . In other aspects, filtration should be sufficient to segregate
20 at least 80 wt. % of the solids into the higher-density portion.

[00134] While the description focuses on a second higher-density portion and a second lower-density portion, other embodiments envision that the components of the thermally-treated first higher-density portion may be more discretely segregated and extracted, e.g., very light components segregating to the top of the mixture, a portion that contains primarily the diluent,
25 an upgraded tar portion, tar heavies, or solids at the bottom of the centrifuge chamber. One or more of these portions may be selectively removed from the mixture as one or more raffinates. Typically, at least a portion of the second lower-density portion is recycled (directly or indirectly) to the first centrifuge. The second higher-density portion can be sent away from the process, e.g., for storage and/or further processing, including additional centrifuging.

30 **The Second Lower-Density Portion**

[00135] The second lower-density portion is generally removed from the separation stage as a second raffinate, a portion of which (e.g., ≥ 50 wt. %, ≥ 75 wt. %, ≥ 90 wt. %) can be conducted away for recycle, e.g., as a component of the tar-fluid mixture. In certain aspects,

the second lower-density portion is recycled and combined with one or more of (i) the steam cracker effluent, (ii) the SCT, (iii) the SCT composition, (iv) the tar-fluid mixture, before and/or during the separation of the first higher-density portion and the first lower-density portion, (v) the first higher-density portion, and (vi) the first lower-density portion. In certain aspects, the second lower-density portion can added to the SCT composition in an amount sufficient to from a part of or the entirety of the fluid utilized to form the tar-fluid mixture. In aspects where the first lower-density portion is subjected to hydroprocessing (e.g., SATC hydroprocessing), the recycling of at least a portion of the second lower-density portion provides for a greater yield of upgraded (e.g., hydroprocessed) tar, provides material and cost savings for tar upgrading processes, and produces fewer solids to be conducted away as compared to conventional tar upgrading processes.

[00136] The second lower-density portion generally has a desirable insolubility number, e.g., an insolubility number that is less than that of one or more of (i) the SCT, (ii) the SCT composition, (iii) tar-fluid mixture, (iii) the first higher-density portion, and the second higher-density portion. Typically, the insolubility number of the second lower-density portion (I_{LD}) is ≥ 20 , e.g., $\geq 30, \geq 40, \geq 50, \geq 60, \geq 70, \geq 80, \geq 90, \geq 100, \geq 110, \geq 120, \geq 130, \geq 140$, or ≥ 150 . Additionally or alternatively, the I_{LD} may be ≤ 150 , e.g., $\leq 140, \leq 130, \leq 120, \leq 110, \leq 100, \leq 90, \leq 80, \leq 70, \leq 60, \leq 50, \leq 40$, or ≤ 30 . Ranges expressly disclosed include combinations of any of the above-enumerated values; e.g., about 20 to about 150, about 20 to about 140, about 20 to about 130, about 20 to about 120, about 20 to about 110, about 20 to about 100, about 20 to about 90, about 20 to about 80, about 20 to about 70, about 20 to about 60, about 20 to about 50, about 20 to about 40, or about 20 to about 30. Those skilled in the art will appreciate that hydrocarbon separations technology is imperfect, and, consequently, a small amount of solids may be present in the second lower-density portion, e.g., an amount of solids that is ≤ 0.1 times the amount of solids in the thermally-treated first higher-density portion, such as ≤ 0.01 times. The ratio of the insolubility number of the second lower-density portion, I_{LD} , to the insolubility number of the tar-fluid mixture, I_{TF} , is ≤ 0.95 , e.g., $\leq 0.90, \leq 0.85, \leq 0.80, \leq 0.75, \leq 0.70, \leq 0.65, \leq 0.60, \leq 0.55, \leq 0.50, \leq 0.40, \leq 0.30, \leq 0.20$, or ≤ 0.10 . Additionally or alternatively, the ratio of I_{LD} to I_{TF} may be ≥ 0.10 , e.g., $\geq 0.20, \geq 0.30, \geq 0.40, \geq 0.50, \geq 0.55, \geq 0.60, \geq 0.65, \geq 0.70, \geq 0.75, \geq 0.80, \geq 0.85$, or ≥ 0.90 . Ranges expressly disclosed include combinations of any of the above-enumerated values, e.g., about 0.10 to 0.95, about 0.20 to 0.95, about 0.30 to 0.95, about 0.40 to 0.95, about 0.50 to 0.95, about 0.55 to

0.95, about 0.60 to 0.95, about 0.65 to 0.95, about 0.70 to 0.95, about 0.75 to 0.95, about 0.80 to 0.95, about 0.85 to 0.95, or about 0.90 to 0.95.

[00137] Typically at least a portion of the second lower density portion is in the liquid phase, e.g., ≥ 25 wt. % such as ≥ 50 wt. %, or ≥ 75 wt. %, or ≥ 90 wt. %. Typically ≥ 50 wt. % of solids converted (e.g., from particulate form) during and/or as a result of the second thermal treatment resides in the second lower-density portion, e.g., ≥ 75 wt. %, such as ≥ 90 wt. %, or ≥ 99 wt. %. Typically, ≥ 50 wt. % of diluent in the diluted first higher-density portion resides in the second lower-density portion, e.g., ≥ 50 wt. %, such as ≥ 75 wt. %, or ≥ 90 wt. %, or ≥ 99 wt. %.

10 Examples of Configurations for Heat Soaking Cracked Tar Solids

[00138] FIG. 1 is a diagram illustrating an apparatus for carrying out certain aspects of the invention. More generally, a configuration similar to FIG. 1 can be used for heat soaking a higher-density portion of a pyrolysis tar composition.

[00139] In FIG. 1, a steam cracker effluent **102** comprising SCT is introduced to first thermal treatment stage **124**, e.g., the bottoms section of a tar knock-out drum. A primarily vapor-phase stream is conducted away from stage **124** via line **128** to primary fractionator **126** for separation of at least a quench oil stream **160** and a process gas **170**. An SCT composition comprising thermally-treated (e.g., heat-soaked) SCT is conducted away from stage **124** via line **105**.

20 **[00140]** A recycle stream **104** and an optional stream **103** (comprising an optional first utility fluid and/or an optional first separation fluid provided by a source (not shown)) are added to the SCT composition to produce a tar-fluid mixture. The tar-fluid mixture is introduced to a first SCT separation stage **120**, which typically includes at least one centrifuge, such as a decanter centrifuge. A first higher-density portion (conducted away via line **125**) and a first lower-density portion (conducted away via line **122**) are separated from the tar-fluid mixture in stage **120**. In continuous operation, the first higher-density portion conducted via line **125** typically comprises ≥ 50 wt. % of first higher-density portion available for further processing in heat soak vessel 116, e.g., ≥ 75 wt. %, such as ≥ 90 wt. %.

[00141] In the configuration shown in FIG. 1, at least a portion of the first lower-density portion is conducted via line **122** to an optional stage **140** hydroprocessing, e.g., SATC hydroprocessing. The first higher-density portion can be passed to one or more optional stages, e.g., at least one optional size reduction stage **130**, to produce a comminuted first higher-density portion. The first higher-density portion is combined with diluent (comprising a

second utility fluid and/or second separation fluid provided by one or more sources (not shown)) via lines **127** and/or **135**, e.g., before and/or after the comminuting. The diluted first higher-density portion via line **114** is introduced to second thermal treatment stage **116** (e.g., a second heat soak vessel). Second thermal treatment stage **116** provides a thermally-treated first higher-density portion which is introduced via line **118** to second SCT separation stage **150**, which typically includes at least one centrifuge, such as a decanter centrifuge. Stage **150** provides a second higher-density portion which can be sent away via line **122**, such as for storage, additional thermal treatments, and/or additional separations. A second lower-density portion is recycled via line **104**.

10 **EXAMPLES**

High temperature dissolution/decomposition exemplification of the second thermal treatment.

[00142] 0.5 g of solids obtained from a representative tar (in this case a representative SCT) is mixed with approx. 50 mL toluene in a bomb reactor. The toluene corresponds to the second utility fluid of line **127**. The mixture is thermally-treated (heat soaked) at a temperature in a range of from 250°C-350°C (sand bath temperature) for 30 mins under 500 psig N₂. The reactor was quenched quickly with cold water, and filtered through a 1.5 um filter. The reactor was washed with excess toluene to ensure complete solids recovery. The weight of remaining solids is measured after the thermal treatment, and solids loss wt. % is reported.

[00143] Figure 2 is a graph illustrating the amount of solids loss (wt. %) as a function of the temperature applied in the process, using toluene as a solvent. The experimental results indicate that at least 80% or more of the solids (a relatively low-value material) can be upgraded to a higher-value liquid-phase material that is suitable for use as a SATC Feed. Accordingly, the key operating parameters include temperature, residence time, and a suitable solvent. It is observed that 30 minutes to 60 minutes of heat soaking, at a temperature of 275°C-300°C is sufficient.

[00144] All documents described herein are incorporated by reference herein for purposes of all jurisdictions where such practice is allowed, including any priority documents and/or testing procedures to the extent they are not inconsistent with this text, provided however that any priority document not named in the initially filed application or filing documents is not incorporated by reference herein. Although forms of embodiments have been illustrated and described, various modifications can be made without departing from the spirit and scope of the present disclosure. Accordingly, it is not intended that the present disclosure be limited thereby. Likewise, the term "comprising" is considered synonymous with the terms "including" and "containing". Likewise whenever a composition, an element or a group of elements is preceded

with the transitional phrase "comprising," it is understood that we also contemplate the same composition or group of elements with transitional phrases "consisting essentially of," "consisting of," "selected from the group of consisting of," or "is" preceding the recitation of the composition, element, or elements and vice versa.

- 5 **[00145]** Certain embodiments and features have been described using a set of numerical upper limits and a set of numerical lower limits. It should be appreciated that ranges including the combination of any two values, e.g., the combination of any lower value with any upper value, the combination of any two lower values, and/or the combination of any two upper values are contemplated unless otherwise indicated. Certain lower limits, upper limits and ranges
- 10 appear in one or more claims below.

CLAIMS:

1. A tar upgrading process, comprising:
 - 5 thermally-treating a tar in a first thermal treatment to produce a tar composition;
separating from at least a portion of the tar composition a first lower-density portion
and a first higher-density portion, wherein the first higher density portion comprises solids in
an amount A_1 wt. % based on the weight of the first higher density portion;
conducting away an upgraded pyrolysis tar composition comprising at least a portion
10 of the first lower-density portion;
thermally-treating at least a portion of the first higher-density portion in a second
thermal treatment to form a thermally-treated first higher-density portion, wherein (i) the
thermally-treated first higher density portion comprises solids in an amount A_2 wt. % based on
the weight of thermally-treated first higher density portion and (ii) $A_2 < A_1$;
15 separating from at least a portion of the thermally-treated first higher-density portion a
second lower-density portion and second higher-density portion; and
adding at least a portion of the second lower-density portion to one or more of (i) the
pyrolysis tar before and/or during the first thermal treatment, (ii) the pyrolysis tar composition,
(iii) the first higher-density portion, and (iv) the first lower-density portion.
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2. The process of claim 1, further comprising adding a fluid to the tar composition, wherein $\geq$
90 wt. % of the added fluid is transferred to the first lower-density portion.
3. The process of claims 1 or 2, further comprising adding a diluent to the first higher-density
25 portion, and wherein $\geq$ 90 wt. % of the added diluent resides in the second lower-density
portion.
4. The process of any of claims 1 to 3, wherein the first thermal treatment includes maintaining
the tar at a temperature $\leq 350^\circ\text{C}$ for a time in the range of from 10 minutes to 60 minutes.
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5. The process of any of claims 1 to 4, wherein the first thermal treatment includes maintaining
the tar at a temperature in the in the range of from 150°C to 300°C for a time in the range of
from 15 minutes to 30 minutes.

6. The process of any of claims 1 to 5, wherein (i) the second thermal treatment includes maintaining the first higher-density portion at a temperature in the range of from 220°C to 500°C for a time in the range of from 10 minutes to 100 minutes and (ii) $A_2 \leq 0.8 * A_1$.
- 5 7. The process of any of claims 1-6, wherein the second thermal treatment includes maintaining the first higher-density portion at a temperature in the range of from 250°C to 400°C for a time in the range of from 20 minutes to 90 minutes.
8. The process of any of claims 1-7, wherein A_2 is in the range of from 10% of A_1 to 40% of
- 10 A_1 .
9. The process of any of claims 1-8, wherein the tar is a pyrolysis tar comprising steam cracker tar.
- 15 10. The process of any of claims 1-9, wherein the tar is a steam cracker tar produced by steam cracking a steam cracker feed that includes ≥ 10 wt. % based on the weight of the steam cracker feed of material that is solid-phase or liquid-phase at 25°C and a pressure of 1 bar absolute.
11. The process of any of claims 1-10, wherein:
- 20 (i) the tar is a steam cracking tar produced by steam cracking a hydrocarbon feed comprising ≥ 1 wt. % of hydrocarbon having a normal boiling point $\geq 566^\circ\text{C}$ based on the weight of the steam cracker feed;
- (ii) the steam cracker includes a convection section and a radiant section;
- (iii) the hydrocarbon feed is preheated in the convection section and combined with
- 25 steam to produce a steam cracker feed;
- (iv) a primarily vapor-phase stream and a primarily non-vapor-phase stream are separated from at least a portion of the steam cracker feed, wherein ≥ 50 wt. % of any hydrocarbon having a normal boiling point $\geq 566^\circ\text{C}$ in the hydrocarbon-containing feed is transferred to the non-vapor-phase stream;
- 30 (v) at least a portion of the primarily vapor-phase stream is conducted into an inlet of at least one radiant coil located in the radiant section for cracking under steam cracking conditions, wherein the radiant coil includes the inlet and an outlet, and the steam cracking conditions include:

- a temperature at the radiant coil outlet in the range of from about 760°C to about 1200°C,
- a steam cracking pressure at the radiant coil outlet in the range of from about 1 bar(absolute) to about 10 bar(absolute), and
- 5 a steam cracking residence time in the radiant coil in the range of from about 0.1 seconds to about 2 seconds;
- (vi) a steam cracker effluent is conducted away from the radiant section; and
- (vii) separating at least the steam cracker tar from the steam cracker effluent.
- 10 12. The process of claim 11, wherein the primarily vapor-phase stream and the primarily non-vapor-phase stream are separated from the steam cracker feed in a separation stage integrated with the convection section, and wherein the separated primarily vapor-phase stream is exposed to additional heating in the convection section before the cracking.
- 15 13. The process of claim 11, wherein the temperature at the radiant coil outlet is in the range of from about 880°C to about 1,200°C.
14. The process of claim 11, wherein the temperature at the radiant coil outlet is in the range of from about 1,000°C to about 1,200°C, and the steam cracking pressure is in the range of
- 20 from about 6 bar(absolute) to about 10 bars(absolute).
15. The process of claim 11 wherein the steam cracking temperature is in the range of from about 760°C to about 880°C, and the steam cracking pressure is in the range of from about 1 bar(absolute) to about 5 bars(absolute).
- 25 16. The process of any of claims 1-11, wherein the tar composition further comprises material resulting from the first thermal treatment.
17. The process of claim 3, further comprising grinding the first higher-density portion before
- 30 and/or after adding the diluent.
18. A steam cracker tar upgrading process comprising:
- steam cracking a hydrocarbon feed comprising heavy oil to form a steam cracker effluent comprising steam cracker tar;

- separating at least a portion of the steam cracker tar from the steam cracker effluent;
thermally treating at least the separated steam cracker tar in a first thermal treatment to produce a steam cracker tar composition;
adding a first utility fluid and/or a first separation fluid to the steam cracker tar composition to produce a tar-fluid mixture;
5 separating from the tar-fluid mixture (i) a first lower-density portion comprising upgraded steam cracker tar and (ii) a first higher-density portion;
conducting away at least a portion of the first lower-density portion;
introducing a second utility fluid to the first higher-density portion to form a diluted first higher-density portion, wherein the diluted first higher density portion comprises solids in an amount A_1 wt. % based on the weight of the first higher density portion ;
10 thermally-treating the diluted first higher-density portion in a second thermal treatment to form a thermally-treated first higher-density portion, wherein (i) the thermally-treated first higher density portion comprises solids in an amount A_2 wt. % based on the weight of thermally-treated first higher density portion and (ii) $A_2 \leq 0.8 * A_1$;
15 separating in a second separation at least a second lower-density portion and a second higher-density portion from the thermally-treated first higher-density portion; and
adding at least a portion of the second lower-density portion to one or more of (i) the steam cracker effluent, (ii) the steam cracker tar before and/or during the first thermal treatment, (iii) the steam cracker tar composition, (iv) the tar-fluid mixture before and/or during the separation of the first higher-density portion and the first lower-density portion, (v) the first higher-density portion, and (vi) the first lower-density portion.
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19. The process of claim 18, wherein
- (i) steam cracking the heavy oil is performed at a temperature of from about 760°C to about 880°C, a pressure of from about 1 bar(absolute) to about 5 bars(absolute), and a residence time of from about 0.1 seconds to about 2 seconds;
(ii) the first thermal treatment includes maintaining the steam cracker tar at a temperature in the in the range of from 150°C to 300°C for a time in the range of from 15 minutes to 30 minutes; and
(iii) the second thermal treatment includes maintaining the diluted first higher-density portion at a temperature in the range of from 300°C to 400°C for a time in the range of from 30 minutes to 60 minutes.

20. The process of claims 18 or 19, the tar-fluid mixture comprises the steam cracker tar composition in an amount in the range of about 40 wt. % to about 80 wt. % of, based on the weight of the tar-fluid mixture.

5 21. The process of any of claims 18- 20, further comprising grinding the first higher-density portion before and/or after introducing the second utility fluid.

22. The process of any of claims 18-21, further comprising (i) hydroprocessing at least a portion of the first lower-density portion and (ii) conducting away at least a portion of the
10 second higher-density portion.

23. The process of any of claims 18-22, wherein (i) the first and/or second thermal treatments include heat soaking in at least one soaker drum, and/or (ii) the first and/or second separations include centrifuging and/or filtration.

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24. A steam cracker tar upgrading process comprising:

steam cracking a hydrocarbon feed comprising heavy oil at a temperature of from about 760°C to about 880°C, a pressure of from about 1 bar(absolute) to about 5 bars(absolute), and a residence time of from about 0.1 seconds to about 2 seconds to form a steam cracker effluent
20 comprising a steam cracker tar;

separating at least a portion of the steam cracker tar from the steam cracker effluent;

thermally treating at least the separated steam cracker tar in a first thermal treatment by maintaining the steam cracker tar at a temperature of from 150°C to 300°C for a time of from 15 minutes to 30 minutes to produce a steam cracker tar composition comprising polymeric
25 particulates formed during or as a result of the first thermal treatment;

adding a first utility fluid and/or a first separation fluid to the steam cracker tar composition to produce a tar-fluid mixture;

separating from the tar-fluid mixture (i) a first lower-density portion comprising upgraded steam cracker tar and (ii) a first higher-density portion comprising the polymeric
30 particulates, wherein the first higher density portion comprises the polymeric particulates in an amount A₁ wt. % based on the weight of the first higher density portion;

conducting away at least a portion of the first lower-density portion;

introducing a second utility fluid to the first higher-density portion to form a diluted first higher-density portion;

thermally-treating the diluted first higher-density portion in a second thermal treatment by maintaining the diluted first higher-density portion at a temperature in the range of from 300°C to 400°C for a time in the range of from 30 minutes to 60 minutes to form a thermally-treated first higher density portion wherein (i) the thermally-treated first higher density portion
5 comprises conversion products of lesser density as compared to the polymeric particulates, (ii) the thermally-treated first higher density portion comprises polymeric particulates in an amount A_2 wt. % based on the weight of thermally-treated first higher density portion and (iii) $A_2 \leq 0.8 * A_1$;

separating in a second separation at least a second lower-density portion and a second
10 higher-density portion from the thermally-treated first higher-density portion, the second lower-density portion comprising the conversion products of lesser density; and

adding at least a portion of the second lower-density portion to one or more of (i) the steam cracker effluent, (ii) the steam cracker tar before and/or during the first thermal treatment, (iii) the steam cracker tar composition, (iv) the tar-fluid mixture before and/or during
15 the separation of the first higher-density portion and the first lower-density portion, (v) the first higher-density portion, and (vi) the first lower-density portion.

25. An apparatus for upgrading steam cracker tar, comprising:

a thermal treatment stage coupled at a first end to a first end of a primary fractionator
20 and coupled at a second end via an SCT composition line to a first end of a first separation stage;

a hydroprocessing stage coupled at a first end to a second end of the first separation stage;

a particle size reduction stage coupled at a first end via a second line to a third end of
25 the separation stage and at a second end via a third line to a first end of a second thermal treatment stage; and

a second separation stage coupled at a first end to a second end of the second thermal treatment stage and coupled at a second end to the SCT composition line.

30 26. The apparatus of claim 25, further comprising:

a utility fluid source coupled to the SCT composition line; and

a diluent source coupled to the second line or the third line.

27. An apparatus for upgrading steam cracker tar, comprising:

a thermal treatment stage coupled at a first end to a first end of a primary fractionator and coupled at a second end via an SCT composition line to a first end of a first separation stage;

5 a hydroprocessing stage coupled at a first end to a second end of the first separation stage; and

a second thermal treatment stage coupled at a first end via a second line to a third end of the first separation stage and at a second end to a second separation stage,

10 wherein the second separation stage is coupled at a second end to the SCT composition line.

28. The apparatus of claim 27, further comprising:

a utility fluid source coupled to the SCT composition line; and

a diluent source coupled to the second line.

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29. A steam cracker tar upgrading process, comprising:

separating solids from steam cracker tar;

converting at least a portion of the solids to a liquid;

conducting away from the conversion an effluent comprising the liquid;

20 separating at least a portion of the liquid from the effluent; and

hydroprocessing at least a portion of the separated liquid.

30. The process of claim 29, wherein the steam cracker tar includes thermally-treated steam cracker tar, the conversion includes heat soaking, and at least one of the separations includes

25 centrifuging.