

PROCESSES FOR CONVERTING
PLASTIC MATERIAL TO OLEFINS

CROSS REFERENCE TO RELATED APPLICATIONS

- 5 [0001] This application claims the benefit of and priority to US Provisional Application No. 63/480,646 filed January 19, 2023, the disclosure of which is incorporated herein by reference.

FIELD

- 10 [0002] This disclosure relates to processes and systems for converting one or more plastic materials to olefins. More particularly, this disclosure relates to processes and systems for processing a mixture that includes a plastic material and a carrier liquid by passing the mixture through at least one of a vis-breaker and a convection section of a stream cracking furnace to produce an effluent that includes pyrolysis oil and passing at least a portion of the effluent through a radiant section of the steam cracking furnace to produce a steam cracking effluent
15 that includes one or more olefins.

BACKGROUND

- [0003] Various techniques have been employed to recycle plastic materials, such as mechanical recycling and advanced recycling. In advanced recycling, the plastics are broken down to smaller hydrocarbon chains and monomers that can be processed to produce various
20 chemicals such as one or more light olefin monomers.

SUMMARY

- [0004] Processes and systems for converting hydrocarbons by pyrolysis are provided. In some embodiments, the process can include introducing a plastic material and a carrier liquid that can include a hydrocarbon into a vis-breaker. At least a portion of the plastic material can
25 be cracked in the vis-breaker under vis-breaking conditions to produce an effluent that can include a pyrolysis oil. At least a portion of the effluent can be heated within a convection section of a steam cracking furnace and the at least a portion of the effluent can be combined with an aqueous fluid to produce a heated mixture that can include hydrocarbons and steam. The heating can be carried out before, during, and/or after at least a portion of the effluent is
30 combined with the aqueous fluid. At least a portion of the heated mixture can be steam cracked within a radiant section of the steam cracking furnace to produce a steam cracker effluent that can include one or more olefins.

- [0005] In other embodiments, the process for converting hydrocarbons by pyrolysis can

include heating a mixture that can include a plastic material and a carrier liquid within a convection section of a steam cracking furnace and combining the mixture with an aqueous fluid to produce a heated mixture. The heating can be carried out before, during, and/or after the mixture is combined with the aqueous fluid. The carrier liquid can include a hydrocarbon.

- 5 At least a portion of the plastic material can be cracked to produce a pyrolysis oil. At least a portion of the heated mixture can be steam cracked within a radiant section of the steam cracking furnace to produce a steam cracker effluent that can include one or more olefins.

[0006] In other embodiments, the process for converting hydrocarbons by pyrolysis can include introducing a plastic material and a carrier liquid that can include a hydrocarbon into a
10 vis-breaker. At least a portion of the plastic material can be cracked in the vis-breaker under vis-breaking conditions to produce an effluent that can include a pyrolysis oil. A first fraction that can include H₂, one or more C₁-C₄ hydrocarbons, or a mixture thereof, a second fraction that can include one or more C₅-C₂₀ hydrocarbons, and, if present, a third fraction that can include one or more C₂₁₊ hydrocarbons can be separated from the effluent. A hydrocarbon feed
15 can be heated within a convection section of a steam cracking furnace and combined with an aqueous fluid to produce a heated mixture that can include hydrocarbons and steam. The heating can be carried out before, during, and/or after the hydrocarbon feed is combined with the aqueous fluid. At least a portion of the heated mixture and the second fraction separated from the effluent can be steam cracked within a radiant section of the steam cracking furnace
20 to produce a steam cracker effluent that can include one or more olefins.

[0007] In other embodiments, the process for converting hydrocarbons by pyrolysis can include heating a mixture that can include a plastic material and a carrier liquid within a convection section of a steam cracking furnace and combining the mixture with an aqueous fluid to produce a heated mixture. The heating can be carried out before, during, and/or after
25 the hydrocarbon feed is combined with the aqueous fluid. The carrier liquid can include a hydrocarbon. A portion of the plastic material can be cracked to produce a pyrolysis oil. A first fraction that can include H₂, one or more C₁-C₂₀ hydrocarbons, or a mixture thereof and a second fraction that can include one or more C₂₁₊ hydrocarbons can be separated from the heated mixture. The second fraction can include uncracked plastic material. The second
30 fraction can be introduced into a vis-breaker. At least a portion of the uncracked plastic material can be cracked in the vis-breaker under vis-breaking conditions to produce an effluent that can include an additional quantity of pyrolysis oil. A first fraction that can include H₂, one or more C₁-C₄ hydrocarbons, or a mixture thereof, a second fraction that can include one or

more C₅-C₂₀ hydrocarbons, and, if present, a third fraction that can include one or more C₂₁+ hydrocarbons can be separated from the effluent. At least a portion of the first fraction separated from the heated mixture and the second fraction separated from the effluent can be steam cracked within a radiant section of the steam cracking furnace to produce a steam cracker effluent that can include one or more olefins.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The subject disclosure is further described in the detailed description that follows in reference to the drawings by way of non-limiting embodiments.

[0009] FIGS. 1-6 each depict an illustrative process/system for processing a mixture that includes a plastic material and a carrier liquid in at least one of a vis-breaker and a convection section of a steam cracking furnace to produce an effluent that can include a pyrolysis oil and steam cracking at least a portion of the effluent in a radiant section of the steam cracking furnace to produce a steam cracker effluent that can include one or more olefins, according to one or more embodiments described.

DETAILED DESCRIPTION

[0010] Various specific embodiments, versions and examples of the invention will now be described, including preferred embodiments and definitions that are adopted herein for purposes of understanding the claimed invention. While the following detailed description gives specific preferred embodiments, those skilled in the art will appreciate that these embodiments are exemplary only, and that the invention may be practiced in other ways. For purposes of determining infringement, the scope of the invention will refer to any one or more of the appended claims, including their equivalents, and elements or limitations that are equivalent to those that are recited. Any reference to the “invention” may refer to one or more, but not necessarily all, of the inventions defined by the claims.

[0011] In this disclosure, a process is described as including at least one “step.” It should be understood that each step is an action or operation that may be carried out once or multiple times in the process, in a continuous or discontinuous fashion. Unless specified to the contrary or the context clearly indicates otherwise, multiple steps in a process may be conducted sequentially in the order as they are listed, with or without overlapping with one or more other steps, or in any other order, as the case may be. In addition, one or more or even all steps may be conducted simultaneously with regard to the same or different batch of material. For example, in a continuous process, while a first step in a process is being conducted with respect to a raw material just fed into the beginning of the process, a second step may be carried out

simultaneously with respect to an intermediate material resulting from treating the raw materials fed into the process at an earlier time in the first step. Preferably, the steps are conducted in the order described.

[0012] Unless otherwise indicated, all numbers indicating quantities in this disclosure are to be understood as being modified by the term “about” in all instances. It should also be understood that the precise numerical values used in the specification and claims constitute specific embodiments. Efforts have been made to ensure the accuracy of the data in the examples. However, it should be understood that any measured data inherently contains a certain level of error due to the limitation of the technique and/or equipment used for making the measurement.

[0013] Certain embodiments and features are described herein 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.

[0014] As used herein, the indefinite article “a” or “an” shall mean “at least one” unless specified to the contrary or the context clearly indicates otherwise. Thus, embodiments using “a steam cracking furnace” include embodiments where one, two, or more steam cracking furnaces are used, unless specified to the contrary or the context clearly indicates that only one steam cracking furnace is used.

[0015] The term “hydrocarbon” as used herein means (i) any compound consisting of hydrogen and carbon atoms or (ii) any mixture of two or more such compounds in (i). The term “C_n hydrocarbon,” where n is a positive integer, means (i) any hydrocarbon compound comprising carbon atom(s) in its molecule at the total number of n, or (ii) any mixture of two or more such hydrocarbon compounds in (i). Thus, a C₂ hydrocarbon can be ethane, ethylene, acetylene, or mixtures of at least two of these compounds at any proportion. A “C_m to C_n hydrocarbon” or “C_m-C_n hydrocarbon,” where m and n are positive integers and m < n, means any of C_m, C_{m+1}, C_{m+2}, ..., C_{n-1}, C_n hydrocarbons, or any mixtures of two or more thereof. Thus, a “C₂ to C₃ hydrocarbon” or “C₂-C₃ hydrocarbon” can be any of ethane, ethylene, acetylene, propane, propene, propyne, propadiene, cyclopropane, and any mixtures of two or more thereof at any proportion between and among the components. A “saturated C₂-C₃ hydrocarbon” can be ethane, propane, cyclopropane, or any mixture thereof of two or more thereof at any proportion. A “C_n+ hydrocarbon” means (i) any hydrocarbon compound

comprising carbon atom(s) in its molecule at the total number of at least n, or (ii) any mixture of two or more such hydrocarbon compounds in (i). A “C_n- hydrocarbon” means (i) any hydrocarbon compound comprising carbon atoms in its molecule at the total number of at most n, or (ii) any mixture of two or more such hydrocarbon compounds in (i). A “C_m hydrocarbon stream” means a hydrocarbon stream consisting essentially of C_m hydrocarbon(s). A “C_m-C_n hydrocarbon stream” means a hydrocarbon stream consisting essentially of C_m-C_n hydrocarbon(s).

[0016] The term “crude” means whole crude oil as it flows from a wellhead, a production field facility, a transportation facility, or other initial field processing facility, optionally including crude that has been processed by a step of desalting, treating, and/or other steps as may be necessary to render it acceptable for conventional distillation in a refinery. Crude is presumed to contain resid. The term “crude fraction” means a hydrocarbon fraction obtained via the fractionation of crude. Non-limiting examples of crudes can be or can include, but are not limited to, Tapis, Murban, Arab Light, Arab Medium, and/or Arab Heavy.

[0017] The term “resid” refers to a bottoms cut of a crude distillation process that contains non-volatile components. Resids are complex mixtures of heavy petroleum compounds otherwise known in the art as residuum or residual or pitch. Atmospheric resid is the bottoms product produced from atmospheric distillation of crude where a typical endpoint of the heaviest distilled product is nominally 343°C, and is referred to as 343°C resid. The term “nominally”, as used herein, means that reasonable experts may disagree on the exact cut point for these terms, but by no more than +/- 55.6°C preferably no more than +/- 27.8°C. Vacuum resid is the bottoms product from a distillation column operated under vacuum where the heaviest distilled product can be nominally 566°C, and is referred to as 566°C resid.

[0018] The term “hydrocarbon feed” refers to a composition that includes one or more hydrocarbons. Illustrative hydrocarbon feeds can be or can include, but are not limited to, crude, gas oils, heating oil, jet fuel, diesel, kerosene, gasoline, coker naphtha, steam cracked naphtha, catalytically cracked naphtha, hydrocrackate, reformate, raffinate reformate, Fischer-Tropsch liquids and/or gases, natural gasoline, distillate, virgin naphtha, atmospheric pipestill bottoms, vacuum pipestill streams such as vacuum pipestill bottoms and wide boiling range vacuum pipestill naphtha to gas oil condensates, non-virgin hydrocarbons from refineries, vacuum gas oils, heavy gas oil, naphtha contaminated with crude, atmospheric residue, heavy residue, a C₄/residue admixture, naphtha/residue admixture, hydrocarbon gases/residue admixture, hydrogen/residue admixtures, waxy residues, gas oil/residue admixture, relatively

light alkanes, *e.g.*, ethane, propane, butane, and/or pentane, recycle streams that can include ethane, propane, ethylene, propylene, butadiene, or a mixture thereof, one or more condensates, fractions thereof, or any mixture thereof.

[0019] The term “non-volatile components” as used herein refers to the fraction of a hydrocarbon-containing feed, *e.g.*, a petroleum feed, having a nominal boiling point of at least 590°C, as measured by ASTM D6352-15 or D-2887-18. Non-volatile components include coke precursors, which are large, condensable molecules that condense in the vapor and then form coke during steam cracking of the hydrocarbon feed.

[0020] The term “coke” refers to the solid or semi-solid product that can be produced during the steam cracking of hydrocarbons that includes carbon and high carbon-content organic molecules, whether produced within the convection section, radiant section, transfer lines therebetween, or within transfer lines and other equipment, *e.g.*, a transfer line heat exchanger, downstream of the radiant section.

[0021] The term “asphaltene” refers to a material obtainable from crude oil or other sources and having an initial boiling point above 650°C and which is insoluble in a paraffinic solvent.

[0022] A “polymer” has two or more of the same or different repeating units/mer units or simply units. A “homopolymer” is a polymer having repeating units that are the same. A “copolymer” is a polymer having two or more repeating units that are different from each other. As such, the term “copolymer” includes terpolymers (a polymer having three units that are different from each other), tetrapolymers (a polymer having four units that are different from each other), and so on. The term “different” as used to refer to units indicates that the units differ from each other by at least one atom and/or are different isomerically.

[0023] In some embodiments, the polymer can be or can include, but is not limited to, a nitrogen-containing polymer, a chlorine-containing polymer, a bromine-containing polymer, a fluorine-containing polymer, an oxygen-containing polymer, a polyethylene polymer, a polypropylene polymer, a polystyrene polymer, a butadiene polymer, an isoprene polymer, an isobutylene polymer, or any mixture thereof. In some embodiments, the oxygen-containing polymer can be or can include a polyterephthalate polymer, an ethylene vinyl acetate polymer, a polycarbonate polymer, a polylactic acid polymer, an acrylate polymer, a polyoxymethylene polymer, a polyester polymer, a polyoxybenzylmethyleneglycolanhydride polymer, a polyepoxide polymer, or any mixture thereof. In some embodiments, the nitrogen-containing polymer can be or can include one or more polyamide polymers, *e.g.*, nylon; one or more polynitrile polymers, *e.g.*, poly(acrylonitrile) and/or poly(methacrylonitrile); one or more

aramids, one or more polyurethane polymers, or any mixture thereof. It is noted that polyamides, among other nitrogen-containing polymers, also contain oxygen as part of the polymer structure. In this disclosure, a polymer that includes both oxygen and nitrogen as part of the repeat unit for forming the polymer is defined as a nitrogen-containing polymer for purposes of characterizing the plastic feedstock. In some embodiments, the chlorine-containing polymers can be or can include, but are not limited to, polyvinyl chloride (PVC) and/or polyvinylidene chloride (PVDC). A polymer can be naturally occurring, modified naturally occurring, and/or synthetic.

[0024] The term “plastic material” refers to a composition that includes one or more polymers. Preferably, the plastic material comprises, consists essentially of, or consists of a synthetic polymer. Preferably, the plastic material comprises, consists essentially of, or consists of a used polymer. Preferably, the plastic material comprises, consists essentially of, or consists of one or more polymers derived from one or more olefin monomers (*e.g.*, polyethylene, polypropylene, polyethylenepropylene, polystyrene, and the like).

[0025] It is noted that some types of plastic material can also include bio-derived components. For example, some types of plastic labels can include biogenic waste in the form of paper compounds. In some embodiments, 1 wt% to 25 wt% of the plastic material can correspond to bio-derived material. Such bio-derived material can also potentially contribute to the nitrogen content of a plastic material. The plastic material, in addition to the one or more polymers, can also include any additives, modifiers, packaging dyes, and/or other components typically added to a polymer during and/or after formulation. The plastic material can also further include any components typically found in polymer waste.

[0026] The plastic material alone or the plastic material mixed, blended, or otherwise combined with an optional carrier liquid is also referred to as a “heavy feed.” Although the heavy feed may have a similar or identical composition as the hydrocarbon feed, preferably the heavy feed differs from the hydrocarbon feed. Although the hydrocarbon feed may contain a plastic material, *e.g.*, the same or different plastic material contained in the heavy feed, preferably the hydrocarbon feed is substantially free, or completely free of a plastic material. Preferably, the hydrocarbon feed is derived from a petroleum source substantially free or completely free of a plastic material.

[0027] The optional “carrier liquid” disclosed herein that can be contacted with the plastic material and/or a liquid phase effluent at least partially derived from the plastic material can be or can include, but is not limited to, a wide range of petroleum or petrochemical products or

streams (*e.g.*, hydrocarbon products and/or intermediate streams produced from petroleum processing such as distillation, steam cracking, catalytic cracking, refining, and the like). For example, some suitable carrier liquids can correspond to, include, comprise, consist essentially of, or consist of:

- 5 (i) naphtha, kerosene, diesel, light or heavy cycle oils, catalytic slurry oil, gas-oils, white oils, derived from sources including but not limited to petroleum sources, *e.g.*, from a refinery, a steam cracker, and/or a coker;
- (ii) isoparaffins;
- (iii) metallocene-derived hydrocarbons;
- 10 (iv) hydrocarbons produced from biologically derived raw materials;
- (v) hydrocarbons derived from coal processing;
- (vi) biologically derived raw materials for producing hydrocarbons;
- (vii) ethylene-propylene copolymers; polybutenes;
- (viii) polyalphaolefins ("PAOs"), including but not limited those described in or
- 15 obtainable by using the processes described in U.S. Patent Nos. 9,365,788, 9,409,834, 4,827,064, and 5,264,642;
- (ix) alkylated benzenes;
- (x) alkylated naphthalenes ("ANs");
- (xi) esters such as adipate esters, phthalate esters, trimellitate esters, polyol esters
- 20 (*e.g.*, trimethylolpropane ("TMP") esters, pentaerythritol ("PE") esters, and blends thereof; and esters suitable for jet oils);
- (xii) polyethers/polyalkylene glycols;
- (xiii) thermally stable liquids, *e.g.*, DOWTHERM® A available from Dow Chemical Company;
- 25 (xiv) naphthenic and/or aromatic solvents, such as toluene, benzene, methylnaphthalene, cyclohexane, methylcyclohexane, mineral oil, or any mixture thereof;
- (xv) Group I, II, III, IV, or V lubricant basestocks, description of which can be found in EP2828367A1, which are incorporate herein by reference, including re-refined basestocks;
- (xvi) lubricant formulations comprising any Group I, II, III, IV, or V lubricant
- 30 basestock;
- (xvii) crudes, condensates, or any mixture thereof;
- (xviii) any formulation comprising one or more of the foregoing in one or more of groups (i) to (xvii); and

(xix) any mixture comprising two or more of the foregoing in one or more of groups (i) to (xvii), *e.g.*, PAO/AN blends.

[0028] In some embodiments, the carrier liquid can be, can include, or can comprise a heat-soaked and/or hydrotreated hydrocarbon stream having an initial boiling point of at least 300°C.

- 5 Boiling point distributions (the distribution at atmospheric pressure) can be determined, *e.g.*, by conventional methods such as ASTM D7500 – 15(2019) or ASTM-D86-20b. A suitable heat-soaked hydrocarbon stream having an initial boiling point of at least 300°C can be produced according to the processes disclosed in WO Publication No. WO2018/111577A1. A suitable hydrotreated hydrocarbon stream having an initial boiling point of at least 300°C can be produced according to the processes disclosed in WO Publication No. WO2018/111577A1.
- 10 A suitable heat-soaked and hydrotreated hydrocarbon stream having an initial boiling point of 300°C can be produced according to the processes disclosed in WO Publication No. WO2018/111577A1. In some embodiments, when the heavy feed includes the plastic material combined with the carrier liquid, the heavy feed can be in the form of a solution, slurry,
- 15 suspension, dispersion, or other fluid-type phase. As such, in some embodiments, the carrier liquid can act as a solvent.

[0029] The term “aqueous fluid” refers to a composition that includes water in the liquid phase, water in the vapor phase, or a mixture of water in the liquid phase and water in the vapor phase.

- 20 [0030] The terms “char” and “ash” interchangeably refer to the solid or solid/liquid mixture produced during the pyrolysis of an optionally contaminated plastic material and deposited on the inner surface of a conduit or vessel, which can include organic molecules having long carbon chains and/or high boiling points such as asphaltenes, coke, organometallic compounds, inorganic materials such as metals, metallic oxides, and salts, and mixtures thereof. Char and
- 25 ash can be produced from the chemical reactions of the various components of a plastic material and/or introduced directly from the plastic feed material.

[0031] The term “pyrolysis oil” refers to a composition that includes hydrocarbons produced by at least partially cracking a plastic material.

- [0032] The terms “equivalent residence time” and “ERT”, as used herein, are determined
- 30 according to the following equation: $ERT = \tau \exp[A \cdot T - B]$, where τ is equal to the actual residence time in minutes, T is equal to the temperature in degrees Celsius, A is equal to 0.04745, and B is equal to 18.120. The equivalent residence time or ERT is in seconds.

[0033] An "olefin" is a linear, branched, or cyclic compound of carbon and hydrogen having at least one double bond. The term "olefin product" as used herein means a product that includes an olefin, preferably a product consisting essentially of or consisting of an olefin. An olefin product in the meaning of this disclosure can be, *e.g.*, an ethylene stream, a propylene stream, a butylene stream, an ethylene/propylene mixture stream, and the like.

[0034] The term "consisting essentially of" as used herein means the composition, feed, effluent, product, or other stream comprises a given component at a concentration of at least 60 wt%, preferably at least 70 wt%, more preferably at least 80 wt%, more preferably at least 90 wt%, still more preferably at least 95 wt%, based on the total weight of the composition, feed, effluent, product, or other stream in question.

[0035] The term "aromatic" as used herein is to be understood in accordance with its art-recognized scope which includes alkyl substituted and unsubstituted mono- and poly-nuclear compounds.

[0036] The term "rich" when used in phrases such as "X-rich" or "rich in X" means, with respect to an outgoing stream obtained from a device, that the stream comprises material X at a concentration higher than in the feed material fed to the same device from which the stream is derived.

[0037] The term "lean" when used in phrases such as "X-lean" or "lean in X" means, with respect to an outgoing stream obtained from a device, that the stream comprises material X at a concentration lower than in the feed material fed to the same device from which the stream is derived.

[0038] The terms "channel" and "line" are used interchangeably and mean any conduit configured or adapted for feeding, flowing, and/or discharging a vapor, a liquid, and/or a solid into the conduit, through the conduit, and/or out of the conduit, respectively. For example, a composition can be fed into the conduit, flow through the conduit, and can be discharged from the conduit to move the composition from a first location to a second location. Suitable conduits can be or can include, but are not limited to, pipes, hoses, ducts, tubes, and the like.

[0039] As used herein, "wt%" means percentage by weight, "vol%" means percentage by volume, "mol%" means percentage by mole, "ppm" means parts per million, and "ppm wt" and "wppm" are used interchangeably to mean parts per million on a weight basis. All concentrations herein are expressed on the basis of the total amount of the composition in question, unless specified otherwise. All ranges expressed herein should include both end points as two specific embodiments unless specified or indicated to the contrary.

Processes/Systems for Converting Hydrocarbons by Pyrolysis

[0040] A description of the processes/systems of this disclosure will now be made by referencing the non-limiting drawings showing various preferred embodiments. In the drawings, like reference numerals represent similar parts, feeds, or products throughout the several embodiments shown in the drawings. It should be understood that the composition of a given feed and/or the composition of a given product recovered from a given apparatus can substantially vary across the various embodiments shown in FIGS. 1-6. For example, a particular type of plastic material in line **102** shown in FIG. 1 can be the same or different from a particular type of plastic material in line **102** shown in any one of FIGS. 2-6. In another example, a composition of a heated mixture in line **134** recovered from a convection section **132** of a steam cracking furnace **138** can be the same or different from a composition of a heated mixture in line **134** recovered from the convection section **132** of the steam cracking furnace **138** shown in any one of FIGS. 2-6.

[0041] FIG. 1 depicts an illustrative process/system **100** for processing a plastic material in line **102** in a vis-breaker **110** to produce an effluent in line **112** that can include a pyrolysis oil and processing at least a portion of the effluent in line **112** in a convection section **132** and a radiant section **136** of a steam cracking furnace **138** to produce a steam cracker effluent in line **140** that can include one or more olefins, according to one or more embodiments. In some embodiments, the process/system **100** can also include an optional mixing, blending, or other “contact” vessel **106** and/or an optional separator **114**.

[0042] In some embodiments, the plastic material in line **102** can have been treated to remove at least a portion of any contaminants therefrom. In other embodiments, the plastic material in line **102** can be used as received. If the plastic material is treated to remove at least a portion of any contaminants therefrom, such treatment can include, but is not limited to, sortation, filtration, water washing, solvent extraction, contact with super-critical water, contact with supercritical carbon dioxide, or any combination thereof. In some embodiments, the plastic material in line **102** can have been subjected to one or more physical processes such as chopping, grinding, shredding, or other suitable process that can reduce the size of the plastic material. In some embodiments, the plastic material can have a median particle size of 10 cm or less, 3 cm or less, 2.5 cm or less, 2 cm or less, 1 cm or less, 0.1 cm or less, or 0.01 cm or less.

[0043] In some embodiments, the plastic material in line **102** and a carrier liquid in line **104** can be introduced into the optional contact vessel **106** that can be configured to contact the

plastic material with the carrier liquid. In some embodiments, the plastic material and the carrier liquid can be actively mixed or blended via one or more agitators such as a rotating mixer inside the contact vessel **106** (not shown). In other embodiments, the contact vessel **106** can be a mixing conduit that can include one or more static mixing elements such as one or more helical fins extending from an inner surface of the conduit that can cause the plastic material to be mixed with the carrier liquid. In still other embodiments, the plastic material via line **102** and the carrier liquid via line **104** can be separately introduced into the vis-breaker **110** and contacted therein. In some embodiments, the plastic material via line **102** and the carrier liquid via **104** that can be separately introduced into the vis-breaker **110** and/or a mixture of the plastic material and the carrier liquid via line **108** is introduced into the vis-breaker **110**, the plastic material and the carrier liquid and/or the mixture thereof can be actively mixed or blended via one or more agitators such as a rotating mixer disposed within the vessel **106** (not shown).

[0044] In some embodiments, the contact vessel **106**, if used, can be heated via one or more indirect heat exchanges that can be internal and/or external to the contact vessel **106**. In other embodiments, the plastic material in line **102** and/or the carrier liquid in line **104** can be pre-heated prior to introduction into the contact vessel **106**. In other embodiments, the carrier liquid in line **104** can be heated to a sufficient temperature such that heat can be transferred to the plastic material. In still other embodiments, the plastic material in line **102** and the carrier liquid in line **104** can be introduced into the contact vessel **106** at room temperature or a relatively low temperature, *e.g.*, less than 50°C.

[0045] In some embodiments, the contact vessel **106**, if used, can be configured to heat the plastic material and the carrier liquid to a temperature in a range from 50°C, 75°C, 100°C, or 150°C to 200°C, 275°C, or 350°C. In other embodiments, the plastic material in line **102** and/or the carrier liquid in line **104** can be pre-heated and at a temperature in a range from 50°C, 75°C, 100°C, or 150°C to 200°C, 275°C, or 350°C when introduced into the contact vessel **106**.

[0046] In some embodiments, when the plastic material in line **102** and the carrier liquid in line **104** are introduced directly into the vis-breaker **110**, the vis-breaker **110** can be heated via one or more indirect heat exchangers that can be internal and/or external to the vis-breaker **110**. In some embodiments, the vis-breaker **110** can be heated by a combustion gas produced by combusting a hydrocarbon fuel that can transfer heat into the vis-breaker **110** via indirect heat transfer. In some embodiments, the carrier liquid in line **104** can be heated to a sufficient temperature such that heat can be transferred to the plastic material within the vis-breaker **110**.

In still other embodiments, when the contact vessel **106** is used both the contact vessel **106** and the vis-breaker **110** can be configured to heat the mixture of the plastic material and the carrier liquid therein.

[0047] In some embodiments, contacting the plastic material in line **102** with the carrier liquid in line **104**, whether within the contact vessel **106** and/or the vis-breaker **110** can help facilitate the flow of the plastic material by forming a mixture having a reduced viscosity or otherwise improving flow through dilution as compared to the plastic material in line **102** before combining with the carrier liquid. The amount of the plastic material within the vis-breaker **110** can be in a range from 0.1 wt%, 1 wt%, 3 wt%, 5, wt%, or 10 wt% to 15 wt%, 17 wt%, 20 wt%, 23 wt%, or 25 wt%, based on the combined weight of the plastic material and the carrier liquid introduced into the contact vessel **106** or the vis-breaker **110**.

[0048] In some embodiments, at least a portion of the plastic material can be suspended in the carrier liquid once contacted therewith such that the mixture can be in the form of a slurry. In some embodiments, at least a portion of the plastic material in the vis-breaker **110** can be at least partially melted and/or solubilized in the carrier liquid therein. In some embodiments, at least a portion of the plastic material can be subjected to vis-breaking conditions within the vis-breaker **110** that can at least partially crack the plastic material such that at least a portion of the plastic material can be converted to a pyrolysis oil. In some embodiments, depending on the particular composition of the carrier liquid in line **104**, at least a portion of the hydrocarbons in the carrier liquid can also be cracked to produce additional pyrolysis oil. As such, the pyrolysis oil in the effluent recovered via line **112** can be derived from the plastic material alone or from both the plastic material and the carrier liquid.

[0049] In some embodiments, the vis-breaking conditions within the vis-breaker **110** can include heating the mixture of the plastic material and the carrier liquid at a temperature in a range from 300°C, 350°C, 375°C, or 400°C to 425°C, 450°C, 475°C, 525°C, 550°C, or 600°C. In some embodiments, the vis-breaking conditions in the vis-breaker **110** can include a pressure in a range from 1,000 kPa-gauge, 1,500 kPa-gauge, 2,000 kPa-gauge, 3,000 kPa-gauge, or 3,500 kPa-gauge to 4,500 kPa-gauge, 5,500 kPa-gauge, 6,500 kPa-gauge, 7,500 kPa-gauge, or 8,500 kPa-gauge.

[0050] In some embodiments, the equivalent residence time for the plastic material in the process/system **100** can be in a range from 0.5 minutes, 1 minute, 2 minutes, or 3 minutes to 5 minutes, 10 minutes, 30 minutes, 60 minutes or greater. The equivalent residence time can depend, at least in part, on the particular type of plastic material(s) and how fast the particular

plastic material(s) can be pyrolyzed. Depending, at least in part, on the composition and amount of the plastic material introduced into the vis-breaker **110**, the temperature within the vis-breaker **110** and/or the amount of time required to crack a desired amount of the plastic material can widely vary. Typically, increasing the temperature can reduce the actual residence
5 time, while the equivalent residence time required for a given quantity of a given plastic material to be cracked under the vis-breaking conditions to produce the effluent via line **112** can remain the same. In some embodiments, sufficient vis-breaking of the mixture of the plastic material and possibly the carrier liquid within the vis-breaker **110** can be determined by any suitable criteria or combination of criteria such as the equivalent residence time, a viscosity
10 measurement of the effluent in line **112**, and/or a final boiling point of the effluent in line **112**. In some embodiments, suitable vis-breaking conditions and suitable vis-breakers **110** can include those described in WO Publication No. WO 1997/008266.

[0051] In some embodiments, the effluent via line **112** can be introduced into the optional separator **114**. In some embodiments, the separator **114**, if present, can provide a first fraction
15 via line **116**, a second fraction via line **123**, and, optionally, a third fraction via line **118** and/or **122**. The first fraction in line **116** can be or can include H₂, one or more C₁-C₄ hydrocarbons, or a mixture thereof. The second fraction in line **123** can be or can include one or more C₅-C₂₀ hydrocarbons. The third fraction in lines **118** and/or **122** can be or can include one or more C₂₁₊ hydrocarbons. In other embodiments, the separator **114**, if present, can provide a vapor
20 phase fraction via line **123**, and a liquid phase fraction via line **118** and/or **122**, with the first fraction in line **116** making up a portion of the vapor phase fraction in line **123**.

[0052] In some embodiments, if the third fraction is recovered from the separator **114**, at least a portion of the third fraction can be recycled via lines **118/120** to, if present, the contact vessel **106** and/or via lines **118/121** to the vis-breaker **110**. In other embodiments, if the third
25 fraction is recovered from the separator **114**, at least a portion of the third fraction can be removed via line **122** from the process/system **100** and further processed in one or more other refinery, chemical, or other petrochemical operations and/or separated out into two or more products. In some embodiments, if the third fraction is recovered from the separator **114**, at least a portion of the third fraction can be recycled via lines **118/120** to the contact vessel **106**
30 and/or via lines **118/121** to the vis-breaker **110** and at least a portion of the third fraction via line **122** can be removed from the process/system **100**.

[0053] Illustrative separators **114** can include, but are not limited to, fractionation or distillation column(s), centrifuge(s), filter(s), settling drum(s), flash drum(s) ballistic

separation, cyclone(s) or any combination thereof. Suitable separators **114** can include those described in U.S. Patent Nos.: 6,376,732; 7,311,746; 7,427,381; 7,767,008; and 7,481,871.

[0054] In some embodiments, the plastic material in line **102** and/or the carrier liquid in line **104** can include one or more contaminants and/or include one or more compounds from which one or more contaminants can be produced or derived from when subjected to the vis-breaking conditions within the vis-breaker **110**. In such embodiments, an optional contaminant removal unit **124** can be used to remove at least a portion of the contaminant to produce a contaminant-lean second fraction or a contaminant-lean vapor phase that can be recovered via line **128**.

[0055] In some embodiments, the plastic material and/or the carrier liquid can include one or more compounds that include one or more halogen atoms, *e.g.*, chlorine, fluorine, bromine, or a mixture thereof. For example, the plastic material can be or can include one or more halide-containing polymers and/or the plastic material can include one or more halide containing compounds disposed thereon. In such embodiment, the second fraction or the vapor phase fraction in line **123** can include one or more halide-containing compounds, *e.g.*, HCl. In some embodiments, the second fraction or the vapor phase fraction in line **123** can be introduced into the contaminant removal unit **124** and contacted with one or more guard beds **126** disposed therein to remove at least a portion of the halide-containing compound(s) to produce a halide-lean second fraction or halide-lean vapor fraction via line **128**. Examples of suitable materials that can be used to make-up the guard bed **126** can be or can include, but are not limited to, alkaline or basic oxides such as calcium oxide, magnesium oxide, zinc oxide, or any mixture thereof. In some embodiments, suitable processes/systems for removing contaminants can include those disclosed in U.S. Provisional Patent Application No. 63/301,079. The halide-lean second fraction or the halide-lean vapor phase fraction in line **128** can be introduced into the convection section **132** of the steam cracking furnace **134** and heated therein by flowing the second fraction through one or more conduits disposed therein.

[0056] In other embodiments, the second fraction or the vapor phase fraction in line **123** can include ammonia. In addition to nitrogen-containing polymers such as polyamines, various types of polymer additives can also include nitrogen. In some embodiments, in the plastic vis-breaking conditions within the vis-breaker **110**, at least a portion of the nitrogen can be converted to ammonia. As such, in other embodiments, another type of guard bed **126** can be a guard bed configured to remove at least a portion of any ammonia that may be present in the

second fraction or the vapor phase fraction in line **123**. Various types of adsorbents are available for the removal of ammonia, such as molecular sieve-based adsorbents.

[0057] In still other embodiments, the second fraction or the vapor phase fraction can include mercury. In some embodiments, the vis-breaking conditions within the vis-breaker

5 **110** can convert at least a portion of any mercury present in the plastic material in line **102** and/or the carrier liquid in line **104** into elemental mercury. As such, in other embodiments, another type of guard bed **126** can be a guard bed configured to remove at least a portion of any mercury that may be present in the second fraction or the vapor phase fraction in line **123**. Such elemental mercury can be removed using a mercury removal guard bed. It is noted that

10 some guard beds suitable for mercury removal can also be suitable for silicon removal. Examples of such guard beds can include, but are not limited to, refractory oxides with transition metals optionally supported on the surface, such as the oxides and metals used in demetallization catalysts or a spent hydrotreating catalysts. Additionally, separate guard beds can be used for silicon and mercury removal, or separate adsorbents for silicon removal and

15 mercury removal can be included in a single guard bed. Examples of suitable mercury adsorbents and silicon adsorbents can be or can include, but are not limited to, molecular sieves that are suitable for adsorption of mercury and/or silicon. In some embodiments, two or more separate guard beds **126** can be used for halide, ammonia, mercury, and/or silicon removal or separate materials configured to remove one or more of a halide, ammonia, mercury, and/or

20 silicon can be included in a single guard bed **126**. While the guard bed **126** has been described with reference to solid adsorbents, it should be understood that one or more guard beds **126** can be or can include one or more non-solid guard beds such as a wash drum/vessel that can be configured for amine treating, caustic treating, and/or other treating. In some embodiments, one or more guard beds **126** can be incorporated into one or more of the processes/systems **200**,

25 **300**, **400**, **500**, and/or **600** described below.

[0058] At least a portion of the second fraction or vapor phase fraction in line **123** or the contaminant-lean second fraction or contaminant-lean vapor phase fraction in line **128** can be introduced into the convection section **132** of the steam cracking furnace **138**. In some

embodiments, an aqueous fluid via line **130** can also be introduced into the convection section

30 **132** and can be combined with the second fraction, the vapor phase fraction, the contaminant-lean second fraction, or the contaminant-lean vapor fraction in line **123** to produce a heated mixture.

[0059] In some embodiments, at least a portion the aqueous fluid in line **130** can be combined with the second fraction, the vapor phase fraction, the contaminant-lean second fraction, or the contaminant-lean vapor fraction prior to introduction into the convection section **132**. In other embodiments, the second fraction, the vapor phase fraction, the contaminant-lean second fraction, or the contaminant-lean vapor fraction can be partially heated within the convection section **132** by flowing through one or more conduits disposed within the convection section **132** and can then be combined with the aqueous fluid in line **130** to produce a mixture that can be further heated by flowing through one or more additional conduits disposed within the convection section **132**. In still other embodiments, the second fraction, the vapor phase fraction, the contaminant-lean second fraction, or the contaminant-lean vapor fraction can be heated within the convection section **132** and can be combined with the aqueous fluid after exiting the convection section **132**, *e.g.*, in line **134** to produce the heated mixture. As such, heating of the second fraction, the vapor phase fraction, the contaminant-lean second fraction, or the contaminant-lean vapor fraction that is introduced into the convection section **132** can be carried out before, during, and/or after the at least a portion of the second fraction, the vapor phase fraction, the contaminant-lean second fraction, or the contaminant-lean vapor fraction is combined with the aqueous fluid in line **130**.

[0060] The heated mixture in line **134** can be at a temperature in a range 300°C, 350°C, 375°C, or 400°C to 425°C, 450°C, 475°C, 525°C, 550°C, or 600°C. The heated mixture in line **134** can be in the gas phase or can primarily be in the gas phase with a minor amount in the liquid phase. When a minor amount of the heated mixture in line **134** is in the liquid phase, such minor amount can be up to about 5 wt%, 4 wt%, 3 wt%, 2 wt%, 1 wt%, 0.5 wt%, 0.1 wt%, or 0.01 wt%, based on the total weight of the heated mixture.

[0061] In some embodiments, at least a portion of the heated mixture in line **134** can be introduced into the radiant section **136** of the steam cracking furnace **138** and steam cracked therein to produce a stream cracker effluent that can be recovered via line **140**. The steam cracker effluent in line **140** can include, among other products, one or more olefins, steam cracker naphtha, steam cracker gas oil, steam cracker quench oil, steam cracker tar, or any mixture thereof.

[0062] The steam cracking conditions within the radiant section **136** of the steam cracking furnace **138** can include, but are not limited to, one or more of: exposing the heated mixture to a temperature (as measured at a radiant outlet of the steam cracker) of $\geq 400^{\circ}\text{C}$, *e.g.*, a temperature of about 700°C, about 800°C, or about 900°C to about 950°C, about 1,000°C, or

about 1,050°C, a pressure of about 100 kPa-absolute to about 600 kPa-absolute, and/or a steam cracking residence time of about 0.01 seconds to about 5 seconds. In some embodiments, the heated mixture can be steam cracked according to the processes and systems disclosed in U.S. Patent Nos. 6,419,885; 7,993,435; 9,637,694; and 9,777,227; U.S. Patent Application
5 Publication No. 2018/0170832; and International Patent Application Publication No. WO 2018/111574. The steam cracker effluent in line **140**, at an outlet of the radiant section **136**, can be at a temperature of $\geq 400^{\circ}\text{C}$, *e.g.*, a temperature of 700°C, 800°C, or 900°C to 950°C, 1,000°C, or 1,050°C.

[0063] In the embodiment shown in FIG. 1 and the embodiments of other drawings
10 described below, the vis-breaker **110** is shown to be connected with a single steam cracking furnace **138**. It is further contemplated that, in certain preferred embodiments, the vis-breaker **110** may be connected with multiple steam cracking furnaces. For example, in one embodiment (not shown), a split stream of the effluent in line **112**, the second fraction or vapor phase fraction in line **123**, or the contaminant-lean second fraction or the contaminant-lean vapor phase
15 fraction in line **128** may be sent to a heat exchanger located in the convection section of a second steam cracking furnace (not shown), where it is combined with another aqueous fluid and heated and sent to a radiant section of the second steam cracking furnace. Such multiple steam cracking furnace arrangement can ensure continued plastic pyrolysis and steam cracking operation even if one steam cracking furnace stopped operation due to, *e.g.*, decoking or other
20 needs.

[0064] In the embodiment shown in FIG. 1 and the embodiments of other drawings described below, a single vis-breaker **110** is shown to be connected with a single steam cracking furnace **138**. It is further contemplated that, in certain preferred embodiments, multiple vis-breakers **110**, of the same, similar, or differing sizes and/or designs, may be connected with
25 one or multiple steam cracking furnaces. For example, in one embodiment (not shown), one vis-breaker can be designed and configured to accept a first type of plastic material, and a second vis-breaker can be designed to accept a second type of plastic material, which may be the same or different from the first plastic material. Where the first and second plastic materials differ, the two vis-breakers can be operated under differing vis-breaking conditions to suit the
30 needs of the differing plastic materials. The second fraction exiting the two vis-breakers can be combined and then fed into the convection section(s) of one or more steam cracking furnaces optionally together with an additional hydrocarbon stream. The second fraction exiting the two vis-breakers, if differing substantially in terms of temperature and/or composition, may be

separately introduced into separate heat exchangers disposed within the convection section(s) of one or more steam cracking furnaces, and then introduced to the same or different radiant section of one or more steam cracking furnaces. Such embodiments including multiple vis-breakers can have the advantage of being capable of handling multiple differing plastic materials requiring differing pyrolysis conditions.

[0065] It should be understood that the steam cracking furnace **138** can be operated on all hydrocarbon feeds that can be processed in a steam cracking furnace. For example, the steam cracking furnace **138** can be operated exclusively on one or more feeds thereto that are gaseous at room temperature, *e.g.*, ethane, propane, and/or butane, one or more feeds that are liquid at room temperature, *e.g.*, naphtha, one or more feeds that are solid at room temperature, *e.g.*, heavy fractions obtained from a crude oil, or any combination or mixture thereof. It should also be understood that the steam cracking furnace may be operated to combust any fuel suitable for a steam cracking furnace to generate the thermal energy required for the pyrolysis of hydrocarbon molecules in the radiant section of the furnace. Such fuel can include, *e.g.*, methane, natural gas, hydrogen, and mixtures thereof at any proportion.

[0066] FIG. 2 depict an illustrative process/system **200** for processing a plastic material in line **102** in a vis-breaker **110** to produce an effluent in line **112** that can include a pyrolysis oil and processing at least a portion of the effluent in line **112** in a convection section **132** and a radiant section **136** of a steam cracking furnace **138** to produce a steam cracker effluent in line **140** that can include one or more olefins, according to one or more embodiments. In some embodiments, the process/system **200** can also include an optional contact vessel **106** and/or an optional separator **114**.

[0067] The process/system **200** is similar to the process/system **100**, with the main difference being that the process/system **200** further includes a separation drum **202** configured to separate a vapor phase fraction and a liquid phase fraction from the heated mixture in line **134**. The vapor phase fraction can be recovered via line **204** from the separation drum **202**. At least a portion of the vapor phase fraction via line **204** can be introduced into the radiant section **136** of the steam cracking furnace **138** to produce a steam cracker effluent via line **140** that can include one or more olefins, as described above with reference to FIG. 1.

[0068] The liquid phase fraction can be recovered via line **206** and/or line **208**. In some embodiments, at least a portion of the liquid phase fraction can be recycled to the optional contact vessel **106** and/or to the vis-breaker **110** (not shown). In some embodiments, at least a portion of the liquid phase fraction can be removed via line **208** from the process/system **200**

and further processed in one or more other refinery, chemical, or other petrochemical operations and/or separated out into two or more products. In still other embodiments, a first portion of the liquid phase fraction can be recycled via line **206** to the optional contact vessel **106** and/or the vis-breaker **110** and a second portion can be removed via line **208** from the process **200**.

[0069] The separation drum **202** can also be referred to as a vapor-liquid separator, vaporization drum, or flash drum. In some embodiments, the liquid phase fraction in line **206** and/or **208** can have a cutoff point of from 300°C to 700°C, *e.g.*, 310°C to 550°C, as measured according to ASTM D1160-18, ASTM D-86-20b, or ASTM D2887-19ae2. Conventional separation drums can be utilized to do this, though the invention is not limited thereto. Examples of such conventional separation drums can include those disclosed in U.S. Patent Nos. 7,097,758; 7,138,047; 7,220,887; 7,235,705; 7,244,871; 7,247,765; 7,297,833; 7,311,746; 7,312,371; 7,351,872; 7,427,381; 7,488,459; 7,578,929; 7,674,366; 7,767,008; 7,820,035; 7,993,435; 8,105,479; and 9,777,227. In some embodiments, the equivalent residence time for the plastic material in the process/system **200** can be in a range from 0.5 minutes, 1 minute, 2 minutes, or 3 minutes to 5 minutes, 10 minutes, 30 minutes, 60 minutes or greater.

[0070] In some embodiments, the system **200** can also include one or more contaminant removal units **124** as described above with reference to FIG. 1. In such embodiment, the second fraction or the vapor phase fraction via line **123** can be processed within one or more contaminant removal units to produce a contaminant-lean second fraction or a contaminant-lean vapor phase fraction that can be introduced into the convection section **132** of the steam cracking furnace **138**.

[0071] FIG. 3 depicts an illustrative process/system **300** for processing a plastic material in line **102** and a carrier liquid in line **104** in a convection section **132** of a steam cracking furnace **138** to produce a heated mixture in line **134** that can include a pyrolysis oil and processing at least a portion of the heated mixture in line **134** in a radiant section **136** of the steam cracking furnace **138** to produce a steam cracker effluent in line **140** that can include one or more olefins, according to one or more embodiments. In some embodiments, the process/system **300** can also include an optional mixing, blending, or other contact vessel **106** and/or an optional a separation drum **202**.

[0072] In some embodiments, the plastic material in line **102** and a carrier liquid in line **104** can be directly introduced into the convection section **132** of the steam cracking furnace **138** and contacted therein to produce a mixture or can be combined within the optional contact

vessel **106** and a mixture that includes the plastic material and the carrier liquid via line **108** can be introduced into the convection section **132** of the steam cracking furnace **138**. The amount of the plastic material in the mixture can be in a range from 0.1 wt%, 1 wt%, 3 wt%, 5, wt%, or 10 wt% to 15 wt%, 17 wt%, 20 wt%, 23 wt%, or 25 wt%, based on the combined weight of the plastic material and the carrier liquid introduced into the contact vessel **106** or the convection section **132**. In some embodiments, an aqueous fluid via line **130** can also be introduced into the convection section **132** and can be combined with the mixture that includes the plastic material and the carrier liquid before, during, or after the mixture is heated within the convection section **132** to produce a heated mixture via line **134**. In other embodiments, the plastic material in line **102** and/or the carrier liquid in line **104** can include a sufficient amount of aqueous fluid that the addition of the aqueous fluid via line **130** can be reduced or avoided. In other embodiments, an aqueous fluid can be introduced into the contact vessel **106** such that the addition of the aqueous fluid via line **130** can be reduced or avoided. At least a portion of the plastic material can be cracked within the convection section **132** of the steam cracking furnace **138** to produce the pyrolysis oil.

[0073] The heated mixture in line **134** can be at a temperature in a range 300°C, 350°C, 375°C, or 400°C to 425°C, 450°C, 475°C, 525°C, 550°C, or 600°C. In some embodiments, the heated mixture in line **134** can be a vapor/liquid mixture. In such embodiment, the heated mixture in line **134** can be introduced into the separation drum **202** to produce a vapor phase fraction via line **204** and a liquid phase fraction via line **206** and/or **208**. In some embodiments, at least a portion of the liquid phase fraction can be recycled to the contact vessel **106** (if present) and/or to the convection section **132** of the steam cracking furnace. In some embodiments, at least a portion of the vapor phase fraction via line **204** can be introduced into and steam cracked within the radiant section **136** of the steam cracking furnace **138** to produce the steam cracker effluent via line **140** that can include one or more olefins.

[0074] In other embodiments, the heated mixture in line **134** can be in the gas phase or can primarily be in the gas phase with a minor amount in the liquid phase. When a minor amount of the heated mixture in line **134** is in the liquid phase, such minor amount can be up to about 5 wt%, 4 wt%, 3 wt%, 2 wt%, 1 wt%, 0.5 wt%, 0.1 wt%, or 0.01 wt%, based on the total weight of the heated mixture. In such embodiment, the heated mixture via line **134** can be introduced directly into the radiant section **136** of the steam cracking furnace **138** to produce the steam cracker effluent via line **140** that can include one or more olefins.

- [0075] In the embodiments shown in FIG. 3, a vis-breaker is not needed to crack the plastic material. Rather heat from the convection section **132** of the steam cracking furnace **138** can be sufficient to convert a desired amount of the plastic material in line **102** into pyrolysis oil that can be steam cracked within the radiant section **136** of the steam cracking furnace **138**.
- 5 When the heated mixture in line **134** is in the gas phase or primarily in the gas phase the plastic material in line **102** can include primarily light polymers that can more readily be cracked under the conditions present within the convection section **132** and/or the amount of plastic material combined with the carrier liquid in line **104** can be relatively low such that essentially all the plastic material can be cracked within the convection section **132** of the steam cracking
- 10 furnace **138**.
- [0076] When the heated mixture in line **134** includes the liquid phase fraction, recycling at least a portion of the liquid phase fraction can increase the equivalent residence time of the plastic material subjected to the heat within the convection section **132** to crack a sufficient amount of the plastic material. In some embodiments, the convection section process
- 15 conditions in the convection section **132** can include an equivalent residence time in the convection section **132** sufficient to crack at least a portion of the plastic material to produce the pyrolysis oil. In some embodiments, the equivalent residence time for the plastic material in the process/system **300** can be in a range from 0.5 minutes, 1 minute, 2 minutes, or 3 minutes to 5 minutes, 10 minutes, 30 minutes, 60 minutes or greater.
- 20 [0077] In some embodiments, the system **300** can also include one or more contaminant removal units **124** as described above with reference to FIG. 1. In such embodiment, the heated mixture (when in the gas phase or primarily in the gas phase) via line **134** or the vapor phase fraction via line **204** can be processed within the one or more contaminant removal units to produce a contaminant-lean heated mixture or a contaminant-lean vapor phase fraction that can
- 25 be introduced into the radiant section **136** of the steam cracking furnace **138** and steam cracked therein to produce the steam cracker effluent via line **140**.
- [0078] FIG. 4 depicts an illustrative process/system **400** for processing a plastic material in line **102** and a carrier liquid in line **104** in a convection section **132** of a steam cracking furnace **138**, a vis-breaker **110**, and a radiant section **136** of the steam cracking furnace **138** to
- 30 produce a steam cracker effluent via line **140** that can include one or more olefins, according to one or more embodiments. In some embodiments, the process/system **400** can also include an optional contact vessel **106** and/or an optional separator **114**.

[0079] In some embodiments, the plastic material in line **102** and a carrier liquid in line **104** can be directly introduced into the convection section **132** of the steam cracking furnace **138** and contacted therein to produce a mixture or can be combined within the optional contact vessel **106** and a mixture that includes the plastic material and the carrier liquid via line **108** can be introduced into the convection section **132** of the steam cracking furnace **138**. The amount of the plastic material in the mixture can be in a range from 0.1 wt%, 1 wt%, 3 wt%, 5, wt%, or 10 wt% to 15 wt%, 17 wt%, 20 wt%, 23 wt%, or 25 wt%, based on the combined weight of the plastic material and the carrier liquid introduced into the contact vessel **106** or the convection section **132**. In some embodiments, an aqueous fluid via line **130** can also be introduced into the convection section **132** and can be combined with the mixture that includes the plastic material and the carrier liquid before, during, or after the mixture is heated within the convection section **132** to produce a heated mixture via line **134**. In other embodiments, the plastic material in line **102** and/or the carrier liquid in line **104** can include a sufficient amount of aqueous fluid that the addition of the aqueous fluid via line **130** can be reduced or avoided. In other embodiments, an aqueous fluid can be introduced into the contact vessel **106** such that the addition of the aqueous fluid via line **130** can be reduced or avoided.

[0080] The mixture of the plastic material, carrier liquid, and aqueous fluid can be heated within the convection section **132** of the steam cracking furnace **138** to produce a heated mixture via line **134**. At least a portion of the plastic material can be cracked within the convection section **132** to produce a pyrolysis oil. As such, the heated mixture in line **134** can include pyrolysis oil. The heated mixture in line **134** can be at a temperature in a range 300°C, 350°C, 375°C, or 400°C to 425°C, 450°C, 475°C, 525°C, 550°C, or 600°C.

[0081] The heated mixture via line **134** can be introduced into the vis-breaker **110**. At least a portion of any remaining plastic material present in the heated mixture in line **134** can be cracked under vis-breaking conditions within the vis-breaker **110** to produce an effluent in line **112** that can include additional pyrolysis oil. In some embodiments, an additional carrier liquid via line **404** can be introduced into the vis-breaker **110**. If the additional carrier liquid via line **404** is introduced into the vis-breaker **110**, the additional carrier liquid can be the same or different from the carrier liquid introduced via line **104** into the convection section **132** of the steam cracking furnace **138**.

[0082] In some embodiments, the effluent via line **112** can be introduced into the optional separator **114**. In such embodiment, the separator **114** can separate a first fraction that can include H₂, one or more C₁-C₄ hydrocarbons, or a mixture thereof, a second fraction that can

include one or more C₅-C₂₀ hydrocarbons, and, if present, a third fraction that can include one or more C₂₁+ hydrocarbons from the effluent. The first fraction can be recovered via line **116**, the second fraction can be recovered via line **123**, and, if present, the third fraction via line **118** and/or **122** can be recovered from the separator **114**.

5 **[0083]** In some embodiments, if the third fraction is separated from the effluent, at least a portion of the third fraction can be recycled to the contact vessel **106** via lines **118/120**, at least a portion of the third fraction can be recycled to the vis-breaker via lines **118/121**, and/or at least a portion of the third fraction can be removed via line **122** from the process/system **400** and further processed in one or more other refinery, chemical, or other petrochemical
10 operations and/or separated out into two or more products. In other embodiments, the separator **114**, if present, can provide a vapor phase fraction via line **123**, and a liquid phase fraction via line **118** and/or **122**, with the first fraction in line **116** making up a portion of the vapor phase fraction in line **123**.

15 **[0084]** At least a portion of the second fraction or the vapor phase fraction via line **123** can be introduced into the radiant section **136** of the steam cracker furnace **138** and can be steam cracked therein to produce the steam cracker effluent via line **140** that can include one or more olefins. In some embodiments, the equivalent residence time for the plastic material in the process/system **400** can be in a range from 0.5 minutes, 1 minute, 2 minutes, or 3 minutes to 5 minutes, 10 minutes, 30 minutes, 60 minutes or greater.

20 **[0085]** In some embodiments, the system **400** can also include one or more contaminant removal units **124** as described above with reference to FIG. 1. In such embodiment, the second fraction or the vapor phase fraction via line **123** can be processed within one or more contaminant removal units to produce a contaminant-lean second fraction or a contaminant-lean vapor phase fraction that can be introduced into the radiant section **136** of the steam
25 cracking furnace **138** and steam cracked therein to produce the steam cracker effluent via line **140**.

30 **[0086]** FIG. 5 depicts an illustrative process/system **500** for processing a plastic material in line **102** in a vis-breaker **110** to produce an effluent via line **112**, processing a hydrocarbon feed in line **502** and an aqueous fluid in line **130** within a convection section **132** of a steam cracking furnace **138** to produce a heated mixture via line **134**, and processing at least a portion of the effluent in line **112** and at least a portion of the heated mixture in line **134** within a radiant section **136** of the steam cracking furnace **138** to produce a steam cracker effluent via line **140** that can include one or more olefins, according to one or more embodiments. In some

embodiments, the process/system **500** can also include an optional contact vessel **106**, an optional separator **114**, and/or an optional separation drum **202**.

[0087] In some embodiments, the plastic material via line **102** and a carrier liquid via line **104** can be introduced into the vis-breaker **110** or can be combined within the optional contact vessel **106** and a mixture that includes the plastic material and the carrier liquid via line **108** can be introduced into the vis-breaker **110**. The amount of the plastic material in the mixture can be in a range from 0.1 wt%, 1 wt%, 3 wt%, 5 wt%, or 10 wt% to 15 wt%, 17 wt%, 20 wt%, 23 wt%, or 25 wt%, based on the combined weight of the plastic material and the carrier liquid introduced into the contact vessel **106** or the vis-breaker **110**. The mixture of the plastic material and the carrier liquid can be subjected to vis-breaking conditions within the vis-breaker **110** sufficient to crack at least a portion of the plastic material to produce an effluent via line **112** that can include pyrolysis oil.

[0088] In some embodiments, the effluent via line **112** can be introduced into the optional separator **114**. In some embodiments, the separator **114** can separate a first fraction that can include H₂, one or more C₁-C₄ hydrocarbons, or a mixture thereof, a second fraction that can include one or more C₅-C₂₀ hydrocarbons, and, if present, a third fraction that can include one or more C₂₁₊ hydrocarbons from the effluent. The first fraction can be recovered via line **116**, the second fraction can be recovered via line **123**, and, if present, the third fraction via line **118** and/or **122** can be recovered from the separator **114**.

[0089] In some embodiments, if the third fraction is separated from the effluent, at least a portion of the third fraction can be recycled to the contact vessel **106** via lines **118/120**, at least a portion of the third fraction can be recycled to the vis-breaker via lines **118/121**, and/or at least a portion of the third fraction can be removed via line **122** from the process/system **500** and further processed in one or more other refinery, chemical, or other petrochemical operations and/or separated out into two or more products. In other embodiments, the separator **114**, if present, can provide a vapor phase fraction via line **123**, and a liquid phase fraction via line **118** and/or **122**, with the first fraction in line **116** making up a portion of the vapor phase fraction in line **123**.

[0090] At least a portion of the second fraction or the vapor phase fraction via line **123** can be introduced into the radiant section **136** of the steam cracking furnace **138** and can be steam cracked therein to produce a first portion of the steam cracker effluent via line **140** that can include one or more olefins.

[0091] The hydrocarbon feed via line **502** and the aqueous fluid via line **130** can be introduced into the convection section **132** of the steam cracking furnace **138** and heated therein to produce the heated mixture in line **134** that can include hydrocarbons and steam. In some embodiments, the aqueous fluid in line **130** can be combined with the hydrocarbon feed before, during, or after the hydrocarbon feed is heated within the convection section **132** to produce the heated mixture via line **134**.

[0092] The heated mixture in line **134** can be at a temperature in a range 300°C, 350°C, 375°C, or 400°C to 425°C, 450°C, 475°C, 525°C, 550°C, or 600°C. In some embodiments, the heated mixture in line **134** can be in the gas phase or can primarily be in the gas phase with a minor amount in the liquid phase. When a minor amount of the heated mixture in line **134** is in the liquid phase, such minor amount can be up to about 5 wt%, 4 wt%, 3 wt%, 2 wt%, 1 wt%, 0.5 wt%, 0.1 wt%, or 0.01 wt%, based on the total weight of the heated mixture. In some embodiments, at least a portion of the heated mixture in line **134** can be introduced into the radiant section **136** of the steam cracking furnace **138** and cracked therein to produce a second portion of the steam cracker effluent via line **140** that includes one or more olefins.

[0093] In other embodiments, the heated mixture in line **134** can be a vapor/liquid mixture. In such embodiment, the heated mixture in line **134** can be introduced into the separation drum **202** to produce a vapor phase fraction via line **204** and a liquid phase fraction via line **206** and/or line **208**. At least a portion of the vapor phase fraction via line **204** can be introduced into and steam cracked within the radiant section **136** of the steam cracking furnace to produce the second portion of the steam cracker effluent via line **140** that can include one or more olefins.

[0094] In some embodiments, at least a portion of the liquid phase fraction via line **206** can be introduced to the contact vessel (when present) **106**, as shown, and/or the vis-breaker **110** (not shown), and/or recycled to the convection section **132** of the steam cracking furnace **138** (not shown). In some embodiments, at least a portion of the liquid phase fraction can be removed via line **208** from the process/system **500** and further processed in one or more other refinery, chemical, or other petrochemical operations and/or separated out into two or more products. In still other embodiments, a first portion of the liquid phase fraction can be introduced via line **206** to the optional contact vessel **106** and/or the vis-breaker **110** and/or recycled to the convection section **132** and a second portion can be removed via line **208** from the process/system **500**. In some embodiments, the equivalent residence time for the plastic

material in the process/system **500** can be in a range from 0.5 minutes, 1 minute, 2 minutes, or 3 minutes to 5 minutes, 10 minutes, 30 minutes, 60 minutes or greater.

[0095] The second fraction or the vapor phase fraction in line **123** and the heated mixture in line **134** or the vapor phase fraction in line **204** steam cracked within the radiant section **136** to produce the first portion and the second portion of the steam cracker effluent can be recovered as a mixture via line **140**. In some embodiments, the second fraction or the vapor phase fraction in line **123** and the heated mixture in line **134** or the vapor phase fraction in line **204** can be combined with one another to produce a mixture that can be steam cracked within the radiant section **136** of the steam cracking furnace to produce the steam cracker effluent in line **140**. In other embodiments, the second fraction or the vapor phase fraction in line **123** and the heated mixture in line **134** or the vapor phase fraction in line **204** can be steam cracked within separate tubes disposed within the radiant section **136** of the steam cracking furnace **138**. In such embodiment, the steam cracker effluents recovered from the separate tubes can be combined with one another to produce the steam cracker effluent in line **140**. In another such embodiment, the steam cracker effluents recovered from the separate tubes can be maintained as separate steam cracker effluents rather than combining the two.

[0096] In some embodiments, the system **500** can also include one or more contaminant removal units **124** as described above with reference to FIG. 1. In such embodiment, the second fraction or the vapor phase fraction via line **123** can be processed within one or more contaminant removal units to produce a contaminant-lean second fraction or a contaminant-lean vapor phase fraction that can be introduced into the radiant section **136** of the steam cracking furnace **138** and steam cracked therein to produce the steam cracker effluent via line **140**.

[0097] FIG. 6 depicts an illustrative process/system **600** for processing a plastic material in line **102** and a carrier liquid in line **104** in a convection section **132** of a steam cracking furnace **138** to produce a heated mixture in line **134**, introducing a first portion of the heated mixture via line **204** into a radiant section **136** of the steam cracking furnace **138** to produce a first portion of a steam cracker effluent in line **140**, introducing a second portion of the heated mixture via line **206** into a vis-breaker **110** to produce an effluent in line **112**, and introducing at least a portion of the effluent via line **123** into the radiant section **136** of the steam cracking furnace **138** to produce a second portion of the steam cracker effluent in line **140**. In some embodiments, the process/system **300** can also include an optional contact vessel **106** and/or an optional separation drum **202**.

- [0098] In some embodiments, the plastic material in line **102** and a carrier liquid in line **104** can be directly introduced into the convection section **132** of the steam cracking furnace **138** and contacted therein to produce a mixture or can be combined within the optional contact vessel **106** and a mixture that includes the plastic material and the carrier liquid via line **108** can be introduced into the convection section **132** of the steam cracking furnace **138**. The amount of the plastic material in the mixture can be in a range from 0.1 wt%, 1 wt%, 3 wt%, 5, wt%, or 10 wt% to 15 wt%, 17 wt%, 20 wt%, 23 wt%, or 25 wt%, based on the combined weight of the plastic material and the carrier liquid introduced into the contact vessel **106** or the convection section **132**. In some embodiments, an aqueous fluid via line **130** can also be introduced into the convection section **132** and can be combined with the mixture that includes the plastic material and the carrier liquid before, during, or after the mixture is heated within the convection section **132** to produce the heated mixture via line **134**. In other embodiments, the plastic material in line **102** and/or the carrier liquid in line **104** can include a sufficient amount of aqueous fluid that the addition of the aqueous fluid via line **130** can be reduced or avoided. In other embodiments, an aqueous fluid can be introduced into the contact vessel **106** such that the addition of the aqueous fluid via line **130** can be reduced or avoided. At least a portion of the plastic material can be cracked within the convection section **132** of the steam cracking furnace **138** to produce a pyrolysis oil. As such, the heated mixture in line **134** can include pyrolysis oil.
- [0099] The heated mixture in line **134** can be at a temperature in a range 300°C, 350°C, 375°C, or 400°C to 425°C, 450°C, 475°C, 525°C, 550°C, or 600°C. In some embodiments, the heated mixture in line **134** can be a vapor/liquid mixture. In such embodiment, the heated mixture in line **134** can be introduced into the separation drum **202** to produce a vapor phase fraction or first fraction via line **204** and a liquid phase fraction or second fraction via line **206** and/or **208**. The vapor phase or first fraction in line **204** can include H₂, one or more C₁-C₂₀ hydrocarbons, or a mixture thereof. The liquid phase or second fraction in line **206** and/or **208** can include one or more C₂₁₊ hydrocarbons, where the second fraction includes uncracked plastic material.
- [0100] At least a portion of the vapor phase or first fraction via line **204** can be introduced into the radiant section **136** of the steam cracking furnace **138** to produce a first portion of the steam cracker effluent in line **140** that can include one or more olefins. In some embodiments, at least a portion of the liquid phase or second fraction via line **206** can be introduced into the vis-breaker **110**. At least a portion of the uncracked plastic material can be cracked in the vis-

breaker under vis-breaking conditions to produce an effluent via line **112** that can include an additional quantity of pyrolysis oil. In some embodiments, an additional carrier liquid via line **404** can be introduced into the vis-breaker **110**. If the additional carrier liquid via line **404** is introduced into the vis-breaker **110**, the additional carrier liquid can be the same or different
5 from the carrier liquid introduced via line **104** into the convection section **132** of the steam cracking furnace **138**. In some embodiments, at least a portion of the liquid phase or second fraction via line **206** can be recycled to the contact vessel **106** and/or the convection section **132**. If at least a portion of the liquid phase or second fraction via line **206** is recycled to the contact vessel and/or the convection section **132**, at least a portion of the uncracked plastic
10 material can be cracked within the convection section **132** to produce another additional quantity of pyrolysis oil.

[0101] In some embodiments, the effluent via line **112** can be introduced into the optional separator **114**. In some embodiments, the separator **114** can separate a first fraction that can include H₂, one or more C₁-C₄ hydrocarbons, or a mixture thereof, a second fraction that can
15 include one or more C₅-C₂₀ hydrocarbons, and, if present, a third fraction that can include one or more C₂₁+ hydrocarbons from the effluent. The first fraction can be recovered via line **116**, the second fraction can be recovered via line **123**, and, if present, the third fraction via line **118** and/or **122** can be recovered from the separator **114**.

[0102] In some embodiments, if the third fraction is separated from the effluent, at least a
20 portion of the third fraction can be recycled to the contact vessel **106** via lines **118/120**, the convection section **132** (not shown), at least a portion of the third fraction can be recycled to the vis-breaker via lines **118/121**, and/or at least a portion of the third fraction can be removed via line **122** from the process/system **500** and further processed in one or more other refinery, chemical, or other petrochemical operations and/or separated out into two or more products.
25 In other embodiments, the separator **114**, if present, can provide a vapor phase fraction via line **123**, and a liquid phase fraction via line **118** and/or **122**, with the first fraction in line **116** making up a portion of the vapor phase fraction in line **123**. In some embodiments, the equivalent residence time for the plastic material in the process/system **600** can be in a range from 0.5 minutes, 1 minute, 2 minutes, or 3 minutes to 5 minutes, 10 minutes, 30 minutes, 60
30 minutes or greater.

[0103] At least a portion of the second fraction or the vapor phase fraction via line **123** can be introduced into the radiant section **136** of the steam cracking furnace **138** and can be steam cracked therein to produce a second portion of the steam cracker effluent via line **140** that can

include one or more olefins. In some embodiments, the second fraction or the vapor phase fraction in line **123** and the vapor phase fraction in line **204** can be combined with one another to produce a mixture that can be steam cracked within the radiant section **136** of the steam cracking furnace **138** to produce the steam cracker effluent in line **140**. In other embodiments, the second fraction or the vapor phase fraction in line **123** and the vapor phase fraction in line **204** can be steam cracked within separate tubes disposed within the radiant section **136** of the steam cracking furnace **138**. In such embodiment, the steam cracker effluents recovered from the separate tubes can be combined with one another to produce the steam cracker effluent in line **140**. In another such embodiment, the steam cracker effluents recovered from the separate tubes can be maintained as separate steam cracker effluents rather than combining the two.

[0104] In some embodiments, the system **600** can also include one or more contaminant removal units **124** as described above with reference to FIG. 1. In such embodiment, the second fraction or the vapor phase fraction via line **123** can be processed within one or more contaminant removal units to produce a contaminant-lean second fraction or a contaminant-lean vapor phase fraction that can be introduced into the radiant section **136** of the steam cracking furnace **138** and steam cracked therein to produce the steam cracker effluent via line.

Prophetic Example

[0105] A simulation was carried out to determine how much equivalent residence time is sufficient to ensure the waste plastic is converted enough for effective processing in the steam cracker radiant section. Hydrocarbons that boil at about 510°C (about 950°F) and below are preferred as feedstocks for a steam cracker radiant section. The Table below shows the thermal conversion of high-density polyethylene (HDPE) to products boiling below about 510°C (about 950°F) as a function of residence time (in seconds) at a temperature of about 427°C (about 800°F). At low conversion, there is insufficient thermal severity to convert the high-density polyethylene to products vaporizable in the radiant section of the steam cracking furnace. Higher conversion indicates sufficient thermal severity for the plastic decomposition products to be suitable for steam cracking in the radiant section of the steam cracking furnace. This guideline can be used to identify the equivalent severity preferred for any combination of vis-breaker and convection sections as pre-processors to convert waste plastic into pyrolysis products and then ultimately produce olefins by feeding those products to the radiant section of the steam cracking furnace. For example, an equivalent residence time of about 600 seconds at a temperature of about 427°C (about 800°F) is sufficient to convert about 90% of the high-

density polyethylene to a feed suitable for introducing into the radiant section of the steam cracking furnace.

ERT (sec)	%Conversion
50	19.7
100	41.9
150	54.8
200	64.3
250	71.5
300	76.7
350	80.7
400	83.2
450	85.9
500	87.5
550	89.5
600	90.2

- [0106] Various terms have been defined above. To the extent a term used in a claim is not defined above, it should be given the broadest definition persons in the pertinent art have given that term as reflected in at least one printed publication or issued patent. Furthermore, all patents, test procedures, and other documents cited in this application are fully incorporated by reference to the extent such disclosure is not inconsistent with this application and for all jurisdictions in which such incorporation is permitted.
- 5
- 10 [0107] While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

CLAIMS:

What is claimed is:

1. A process for converting hydrocarbons by pyrolysis, comprising:
5 introducing a plastic material and a carrier liquid comprising a hydrocarbon into a vis-breaker;
cracking at least a portion of the plastic material in the vis-breaker under vis-breaking conditions to produce an effluent comprising a pyrolysis oil;
heating at least a portion of the effluent within a convection section of a steam cracking
10 furnace and combining the at least a portion of the effluent with an aqueous fluid to produce a heated mixture comprising hydrocarbons and steam, wherein the heating is carried out before, during, and/or after the at least a portion of the effluent is combined with the aqueous fluid;
and
steam cracking at least a portion of the heated mixture within a radiant section of the
15 steam cracking furnace to produce a steam cracker effluent comprising one or more olefins.
2. The process of claim 1, further comprising separating a first fraction comprising H₂, one or more C₁-C₄ hydrocarbons, or a mixture thereof, a second fraction comprising one or more C₅-C₂₀ hydrocarbons, and, if present, a third fraction comprising one or more C₂₁+
20 hydrocarbons from the effluent, wherein the second fraction is heated within the convection section of the steam cracking furnace and combined with the aqueous fluid to produce the heated mixture.
3. The process of claim 2, wherein the third fraction is separated from the effluent, the
25 process further comprising recycling at least a portion of the third fraction to the vis-breaker.
4. The process of claim 2 or claim 3, wherein the plastic material comprises a contaminant-containing polymer and/or a compound comprising a contaminant disposed thereon, and wherein the second fraction is in a vapor phase and further comprises one or more
30 contaminant-containing compounds, the process further comprising:
contacting the second fraction with a guard bed to remove at least a portion of the one or more contaminant-containing compounds to produce a contaminant-lean second fraction, wherein the contaminant-lean second fraction is heated within the convection section of the steam cracking furnace and combined with the aqueous fluid to produce the heated mixture.

35

5. The process of claim 4, wherein the plastic material comprises the contaminant-containing polymer, and wherein the contaminant-containing polymer comprises polyvinyl chloride, polyvinylidene chloride, chlorinated polyvinyl chloride, or a mixture thereof.
- 5 6. The process of claim 4 or claim 5, wherein the compound comprising the contaminant is disposed on the plastic material, and wherein the compound comprising the contaminant comprises calcium hypochlorite, sodium hypochlorite, sodium chloride, calcium chloride, magnesium chloride, iron chloride, or a mixture thereof.
- 10 7. The process of any one of claims 1 to 6, further comprising separating a vapor phase fraction and a liquid phase fraction from the heated mixture, wherein the vapor phase fraction is steam cracked within the radiant section of the steam cracking furnace to produce the steam cracker effluent.
- 15 8. The process of claim 7, further comprising recycling at least a portion of the liquid phase fraction to the vis-breaker.
9. The process of any one of claims 1 to 8, wherein the plastic material and the carrier liquid are separately introduced into the vis-breaker.
- 20 10. The process of any one of claims 1 to 9, wherein the plastic material and the carrier liquid are introduced as a mixture into the vis-breaker.
11. The process of claim 10, wherein at least a portion of the plastic material is solubilized in the mixture.
- 25 12. The process of claim 10, wherein the plastic material is slurried in the carrier liquid.
13. The process of any one of claims 1 to 12, wherein the vis-breaking conditions comprise a temperature of from 350°C to 550°C and an equivalent residence time of from 5 minutes to 30 minutes.
- 30 14. The process of any one of claims 1 to 13, wherein the carrier liquid comprises a heat-soaked and/or hydrotreated hydrocarbon stream having an initial boiling point of at least 300°C, as measured according to ASTM D2887-19aee.
- 35 15. The process of any one of claims 1 to 14, wherein the plastic material comprises a

nitrogen-containing polymer, a chlorine-containing polymer, an oxygen-containing polymer, a polyethylene polymer, a polypropylene polymer, a polystyrene polymer, a butadiene polymer, an isoprene polymer, an isobutylene polymer, or any mixture thereof.

5 16. The process of any one of claims 1 to 15, wherein the amount of plastic material introduced into the vis-breaker is in a range from 0.1 wt% to 25 wt%, based on the combined weight of the plastic material and the carrier liquid introduced into the vis-breaker.

17. A process for converting hydrocarbons by pyrolysis, comprising:
10 heating a mixture comprising a plastic material and a carrier liquid within a convection section of a steam cracking furnace and combining the mixture with an aqueous fluid to produce a heated mixture, wherein:

the heating is carried out before, during, and/or after the mixture is combined with the aqueous fluid,

15 the carrier liquid comprises a hydrocarbon, and
at least a portion of the plastic material is cracked to produce a pyrolysis oil;
and

steam cracking at least a portion of the heated mixture within a radiant section of the steam cracking furnace to produce a steam cracker effluent comprising one or more olefins.

20 18. The process of claim 17, further comprising separating a vapor phase fraction and a liquid phase fraction from the heated mixture, wherein the vapor phase fraction is steam cracked within the radiant section of the steam cracking furnace to produce the steam cracker effluent.

25 19. The process of claim 18, further comprising recycling at least a portion of the liquid phase fraction to the convection section of the steam cracking furnace.

30 20. The process of claim 18 or claim 19, wherein the plastic material comprises a contaminant-containing polymer and/or a compound comprising a contaminant disposed thereon, and wherein the vapor phase fraction comprises one or more contaminant-containing compounds, the process further comprising:

contacting the vapor phase fraction with a guard bed to remove at least a portion of the one or more contaminant-containing compounds to produce a contaminant-lean vapor phase
35 fraction, wherein the contaminant-lean vapor phase fraction is steam cracked within the radiant

section of the steam cracking furnace to produce the steam cracker effluent.

21. The process of claim 17, further comprising:

introducing the heated mixture into a vis-breaker;

5 cracking at least a portion of any remaining plastic material in the vis-breaker under vis-breaking conditions to produce an effluent comprising additional pyrolysis oil; and

separating a first fraction comprising H₂, one or more C₁-C₄ hydrocarbons, or a mixture thereof, a second fraction comprising one or more C₅-C₂₀ hydrocarbons, and, if present, a third fraction comprising one or more C₂₁+ hydrocarbons from the effluent, wherein the second
10 fraction is steam cracked within the radiant section of the steam cracking furnace to produce the steam cracker effluent.

22. The process of claim 21, wherein the third fraction is separated, the process further comprising recycling at least a portion of the third fraction to the vis-breaker.

15 23. The process of any claim 21 or claim 22, wherein the plastic material comprises a contaminant-containing polymer, a compound comprising a contaminant disposed thereon, or a mixture thereof, and wherein the second fraction is in a vapor phase and further comprises one or more contaminant-containing compounds, the process further comprising:

20 contacting the second fraction with a guard bed to remove at least a portion of the one or more contaminant-containing compounds to produce a contaminant-lean second fraction, wherein the contaminant-lean second fraction is steam cracked within the radiant section of the steam cracking furnace to produce the steam cracker effluent.

25 24. The process of any one of claims 21 to 23, further comprising introducing an additional quantity of the carrier liquid into the vis-breaker, wherein a composition of the additional quantity of the carrier liquid is the same as or different from a composition of the carrier liquid in the mixture heated within the convection section of the steam cracking furnace.

30 25. The process of any one of claims 17 to 24, wherein the plastic material and the carrier liquid are introduced as a mixture into the convection section of the steam cracking furnace.

26. The process of claim 25, wherein at least a portion of the plastic material is solubilized in the mixture.

35 27. The process of claim 25, wherein the plastic material is slurried in the carrier liquid.

28. The process of any one of claims 17 to 27, wherein the mixture comprises from 0.1 wt% to 25 wt% of the plastic material, based on the combined weight of the plastic material and the carrier liquid in the mixture.
- 5 29. A process for converting hydrocarbons by pyrolysis, comprising:
introducing a plastic material and a carrier liquid comprising a hydrocarbon into a vis-breaker;
cracking at least a portion of the plastic material in the vis-breaker under vis-breaking
10 conditions to produce an effluent comprising a pyrolysis oil;
separating from the effluent a first fraction comprising H₂, one or more C₁-C₄ hydrocarbons, or a mixture thereof, a second fraction comprising one or more C₅-C₂₀ hydrocarbons, and, if present, a third fraction comprising one or more C₂₁+ hydrocarbons;
heating a hydrocarbon feed within a convection section of a steam cracking furnace and
15 combining the hydrocarbon feed with an aqueous fluid to produce a heated mixture comprising hydrocarbons and steam, wherein the heating is carried out before, during, and/or after the hydrocarbon feed is combined with the aqueous fluid; and
steam cracking at least a portion of the heated mixture and the second fraction separated from the effluent within a radiant section of the steam cracking furnace to produce a steam
20 cracker effluent comprising one or more olefins.
30. The process of claim 29, further comprising separating a vapor phase fraction and a liquid phase fraction from the heated mixture, wherein the vapor phase fraction is steam cracked within the radiant section of the steam cracking furnace.
- 25 31. The process of claim 30, further comprising introducing at least a portion of the liquid phase fraction into the vis-breaker.
32. The process of any one of claims 29 to 31, wherein the third fraction is separated from
30 the effluent, the process further comprising recycling at least a portion of the third fraction to the vis-breaker.
33. The process of any one of claims 29 to 32, wherein the at least a portion of the heated mixture and the second fraction are steam cracked within separate tubes disposed within the
35 radiant section of the steam cracking furnace, and wherein effluents recovered from the

separate tubes are combined to produce the steam cracker effluent.

34. The process of any one of claims 29 to 32, wherein the at least a portion of the heated mixture and the second fraction are combined with one another to produce a mixture that is
5 steam cracked within the radiant section of the steam cracking furnace to produce the steam cracker effluent.

35. The process of any one of claims 29 to 34, wherein the amount of plastic material introduced into the vis-breaker is in a range from 0.1 wt% to 25 wt%, based on the combined
10 weight of the plastic material and the carrier liquid introduced into the vis-breaker.

36. The process of any one of claims 29 to 35, wherein the plastic material comprises a contaminant-containing polymer, a compound comprising a contaminant disposed thereon, or a mixture thereof, and wherein the second fraction is in a vapor phase and further comprises
15 one or more contaminant-containing compounds, the process further comprising:

contacting the second fraction with a guard bed to remove at least a portion of the one or more contaminant-containing compounds to produce a contaminant-lean second fraction, wherein the contaminant-lean second fraction is steam cracked within the radiant section of the steam cracking furnace to produce the steam cracker effluent.

20 37. A process for converting hydrocarbons by pyrolysis, comprising:
heating a mixture comprising a plastic material and a carrier liquid within a convection section of a steam cracking furnace and combining the mixture with an aqueous fluid to produce a heated mixture, wherein:

25 the heating is carried out before, during, and/or after the hydrocarbon feed is combined with the aqueous fluid,

the carrier liquid comprises a hydrocarbon, and

a portion of the plastic material is cracked to produce a pyrolysis oil;

30 separating from the heated mixture a first fraction comprising H_2 , one or more C_1 - C_{20} hydrocarbons, or a mixture thereof and a second fraction comprising one or more C_{21+} hydrocarbons, wherein the second fraction comprises uncracked plastic material;

introducing the second fraction into a vis-breaker;

cracking at least a portion of the uncracked plastic material in the vis-breaker under vis-breaking conditions to produce an effluent comprising an additional quantity of pyrolysis oil;

separating from the effluent a first fraction comprising H₂, one or more C₁-C₄ hydrocarbons, or a mixture thereof, a second fraction comprising one or more C₅-C₂₀ hydrocarbons, and, if present, a third fraction comprising one or more C₂₁+ hydrocarbons; and
5 steam cracking at least a portion of the first fraction separated from the heated mixture and the second fraction separated from the effluent within a radiant section of the steam cracking furnace to produce a steam cracker effluent comprising one or more olefins.

38. The process of claim 37, wherein the third fraction is separated from the effluent, the process further comprising recycling at least a portion of the third fraction separated from the
10 effluent to the vis-breaker.

39. The process of claim 37 or claim 38, further comprising introducing an additional quantity of the carrier liquid into the vis-breaker, wherein a composition of the additional quantity of the carrier liquid is the same as or different from a composition of the carrier liquid
15 in the mixture heated within the convection section of the steam cracking furnace.

40. The process of any one of claims 37 to 39, wherein the plastic material comprises a contaminant-containing polymer, a compound comprising a contaminant disposed thereon, or a mixture thereof, and wherein the second fraction separated from the effluent is in a vapor
20 phase and further comprises one or more contaminant-containing compounds, the process further comprising:

contacting the second fraction separated from the effluent with a guard bed to remove at least a portion of the one or more contaminant-containing compounds to produce a contaminant-lean second fraction, wherein the contaminant-lean second fraction is steam
25 cracked within the radiant section of the steam cracking furnace to produce the steam cracker effluent.

41. The process of any one of claims 37 to 40, wherein the second fraction separated from the heated mixture and the second fraction separated from the effluent are steam cracked within
30 separate tubes disposed within the radiant section of the steam cracking furnace, and wherein effluents recovered from the separate tubes are combined to produce the steam cracker effluent.

42. The process of any one of claims 37 to 40, wherein the second fraction separated from the heated mixture and the second fraction separated from the effluent are combined with one

another to produce a mixture that is steam cracked within the radiant section of the steam cracking furnace to produce the steam cracker effluent.

43. The process of any one of claims 37 to 42, wherein the mixture comprises from 0.1 wt%
5 to 25 wt% of the plastic material, based on the combined weight of the plastic material and the carrier liquid in the mixture.

44. The process of any one of claims 37 to 43, further comprising separating from the first
fraction separated from the heated mixture a light fraction comprising H₂, one or more C₁-C₄
10 hydrocarbons, or a mixture thereof and a heavy fraction comprising one or more C₅-C₂₀
hydrocarbons, wherein the heavy fraction is steam cracked within the radiant section of the
steam cracking furnace.