

**DESALTER CONFIGURATION INTEGRATED WITH STEAM CRACKER****PRIORITY**

5 [0001] This application claims priority to and the benefit of U.S. Provisional Application No. 62/865,732, filed June 24, 2019, and European Patent Application No. 19206399.8 which was filed October 31, 2019, the disclosures of which are incorporated herein by reference in their entireties.

**FIELD**

10 [0002] The present disclosure relates to processes for upgrading hydrocarbons by removing salts; to apparatus, systems, and equipment useful for such upgrading; to the use of such upgraded hydrocarbons as feed for steam cracking, to the steam cracking of such feeds, and to the products of such steam cracking

**BACKGROUND**

15 [0003] Historically steam cracker feedstocks to produce olefins have come from refinery process streams and the refining process has removed many of the contaminants that were present in the feedstocks making them more compatible for steam cracking in a steam cracker furnace. However, growth in the demand for olefins has exceeded the growth in demand for refined fuels. Therefore, it has become increasingly desirable to utilize raw feedstocks (e.g. various crudes) as feed to steam crackers to produce olefins. The use of crude oil in steam  
20 cracking would remove dependency on the limited supply and relatively high costs of the various refinery fuel cuts.

[0004] Salts, metals, particulates and asphaltenes are contaminants found in or produced from the raw resid containing feeds such as crude should be managed in order to meet the stringent product specifications and operating requirements in a steam cracker. Processing  
25 hydrocarbons, e.g., crude oil or other raw feedstocks, with contaminants in a steam cracker involves management of: (i) furnace coking resulting from salts, metal, particulates and asphaltenes; (ii) corrosion associated with salts; (iii) product specification for by-product streams; and (iv) operational management due to the contaminants or their by-products in the steam cracker processing unit.

30 [0005] Although acceptable limits on salts and/or particulate matter concentrations in a steam cracker feed comprising hydrocarbons ("hydrocarbon feed") can vary with steam cracker furnace design and operating conditions, the salt removal may be desired when salt content (e.g., sodium chloride content) exceeds a fraction of a ppm or few ppm by weight ("wppm") of

the hydrocarbon feed. Desalting removes salts and particulates to reduce corrosion, erosion, fouling and catalyst poisoning. In certain conventional desalting processes, water is mixed with a hydrocarbon feed and subsequent separation of the oil and water phases, e.g., in one or more desalters. The separation of the phases may be improved at elevated temperatures where the viscosity of the crude oil is lessened. In order to avoid vaporization of the crude oil and/or water at the higher temperature, a desalter may also run at an elevated pressure. One conventional process for hydrocarbon feed desalting is disclosed in U.S. Patent No. 5,271,841. According to that process two desalters are operated in series, with the first desalter operated at a lesser temperature than the second deslater. A more recent conventional process for steam cracking hydrocarbon feeds containing salt is disclosed in U.S. Patent Application Publication No. 2006/0094918. According to that process, a hydrocarbon feed is heated in a convection section of a steam cracking furnace. Vapor and liquid streams are separated from the heated feed, with at least a portion of the salt contained the hydrocarbon feed being conducted away with the separated liquid phase. The separated vapor phase, which has a lesser salt content than the hydrocarbon feed, is steam cracked in a radiant section of the steam cracker. Sill more recently, U.S. Patent Application Publication No. 2007/0004952 discloses desalting hydrocarbon feed in a first desalter, heating the hydrocarbon feed in a convection section of a steam cracking furnace, and then carrying out a second desalting on the heated hydrocarbon feed. A vapor-liquid separator is then used to separate a vapor-phase stream (lean in salt) and a liquid-phase steam (rich in salt) from the desalted feed. The vapor-phase stream in steam cracked in a radiant section of the steam cracking furnace. Now, however, even more stringent limitations on hydrocarbon feed salt content are needed to achieve desired steam cracking product quality and run length goals. See, e.g., Sundaram, K.M. et al. in *(32D) How Much Is Too Much? –Feed Contaminants and Their Consequences* AIChE 2018 Spring Meeting and Global Congress on Process Safety April 23, 2018, Orlando, Florida for a discussion of limitations on feed contaminants.

**[0006]** Crude tanks (typically external floating-roof tanks) being large (e.g. 500,000 bbl) are not generally designed to store crude above ambient pressure or temperature. Therefore, before entering a desalter, the hydrocarbon feed may be pressurized with one or more pumps and pre-heated through one or more heat exchangers. The desalted hydrocarbon feed can be conducted to a steam cracking furnace, where a steam cracking process can be carried out to produce products such as light olefin.

[0007] Steam cracker furnaces are sensitive to disruption in feed because they are typically supply fired duty at elevated temperatures for an endothermic reaction (as opposed to simple distillation in a CDU/pipe still), meaning that loss of hydrocarbon feed includes a loss of an endothermic heat sink which can lead to a heat imbalance exceeding the design temperatures of the furnace. The sensitivity to feed disruption means that reliable desalter performance (e.g. controls, interface, removal-efficiency, etc.) may ensure hydrocarbon feed reaches the steam cracking furnace at uninterrupted acceptable rates. Therefore, for steam crackers, the level of contaminants and reliable feed flow should each be managed, even during fast rate changes as furnaces are brought online or offline. A reliable flow of hydrocarbon feed to the furnace prevents wear on furnace parts due to heat imbalances and thermal stress reducing or eliminating the frequency of plant shutdowns for furnace repair and refurbishment. Robust contaminant management (e.g. removal-efficiency of various salts) may allow for flexibility in hydrocarbon feed flow especially during start-up and shutdown of individual steam crackers, including during normal decoking procedures.

[0008] There is a need for improved processes to remove contaminants from unrefined steam cracker feedstocks despite anticipated and/or unexpected increases or decreases in flow to the steam cracker(s) (due to regular furnace decoke cycles) in order to produce high value light olefins.

#### **SUMMARY**

[0009] This disclosure provides processes for producing light hydrocarbons, including high value light olefin, from a hydrocarbon feed containing heavy hydrocarbons, where there may be fluctuations in the feed flow rate.

[0010] In at least one embodiment, a process includes pressurizing the hydrocarbon feed in one or more pumps to produce a pressurized hydrocarbon feed. The process includes heating the pressurized hydrocarbon feed in one or more heat exchangers to produce a heated hydrocarbon feed. The process also includes mixing the heated hydrocarbon feed with the water, and separating an inter-stage hydrocarbon feed from inter-stage water. The process further includes mixing the inter-stage hydrocarbon feed with water and separating a desalted hydrocarbon feed from outlet water. An upgraded hydrocarbon feed which comprises, consists essentially of, or even consists of the desalted hydrocarbon feed can be pyrolysed (e.g., in one or more steam cracking furnaces) more efficiently than can conventional hydrocarbon feeds.

[0011] In certain other aspects, this disclosure also provides apparatus, systems, and equipment useful for producing the upgraded hydrocarbon feed, for steam cracking the

upgraded hydrocarbon feeds to produce products such as light hydrocarbon including light olefin.

[0012] In at least one embodiment, an apparatus includes a storage tank in fluid connection with a first desalter, the first desalter in fluid connection with at least a second desalter, the second desalter being in fluid connection with a hydrocarbon recycle line, a surge drum, and/or a steam cracker. The hydrocarbon recycle line is in fluid connection with the storage tank. The surge drum is in fluid connection with the steam cracker. The steam cracker is in fluid connection with one or more recycle lines. The one or more recycle lines are in fluid connection with the first desalter.

#### 10 **BRIEF DESCRIPTION OF THE DRAWING**

[0013] So that the manner in which the above recited features of the disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to implementations, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical implementations of this disclosure and are therefore not to be considered limiting of scope, for the disclosure may admit to other equally effective implementations.

[0014] FIG. 1 is a flow diagram of an embodiment of an apparatus for removal of contaminants in a hydrocarbon feed while maintaining flow to one or more downstream steam cracking furnaces, as described in one or more embodiments.

20 [0015] FIG. 2 is a graph illustrating salt and water content after a rate change of hydrocarbon feed to a first desalter and a second desalter, as described in one or more embodiments.

#### **DETAILED DESCRIPTION**

[0016] Certain aspects of the invention will now be described in more detail, which aspects relate to processes for producing an upgraded hydrocarbon feed. These aspects include (i) removing contaminants from a heavy hydrocarbon feed to produce an upgraded feed for a steam cracking process to produce light olefins, and (ii) managing fluctuations in the flow of the hydrocarbon feed. The invention is not limited to these aspects, and this description should not be interpreted as excluding other aspects within the broader scope of the invention, such as those which utilize other forms of hydrocarbon feed and/or other forms of pyrolysis.

[0017] At least part of the contaminant-removal can be carried out in one or more desalters, in which clean water is vigorously mixed with a hydrocarbon feed such as crude oil entering the bottom of the desalter. When used in this sense, the term “clean water” means

- water with relatively low salt content, e.g. one or more of high-purity, clarified fresh, deionized, and/ reverse osmosis water. The water has the form of small water droplets, these typically being in a size range selected to facilitate mass transfer. The water and crude oil are combined to facilitate a transfer of soluble contaminants such as various salts (e.g. NaCl) from the crude
- 5 oil to these small water droplets. Since the water has a greater density than does the crude oil, the water tends to settle towards a lower region (e.g., bottom) of the desalter vessel. An at least partially-desalted crude oil of lesser density accumulates in an upper region of the desalter vessel, by virtue of its lesser density. Since the settling of the water proceeds relatively slowly, particularly when the droplets are small, an emulsion layer is observed to form between the
- 10 water and the at least partially-desalted crude oil. As such, a water layer forms in the bottom of each vessel/stage, a crude layer at the top, and an emulsion layer in between. An oleaginous phase comprising the at least partially-desalted (e.g., “clean”) crude oil is taken off the top of the vessel. An aqueous phase comprising the contaminated water (e.g., a salt-laden water known to those skilled in the art as brine) is removed from the bottom of the desalter vessel.
- 15 **[0018]** Elevating temperature has been found to increase desalting efficiency, it is believed by decreasing the density and viscosity of the water and crude oil. This in turn aids both the initial formation of small droplets, and the subsequent separation of the aqueous (bottom) phase and the oleaginous (top) phase. Elevated pressure can be used to lessen or substantially avoid vaporizing the crude oil and/or water at the higher temperature.
- 20 **[0019]** Maintaining hydrocarbon feed flow rate and quality to steam cracker furnaces during conventional desalting may increase the cost of recycling and/or storage. Moreover, elevated temperatures in a floating roof tank might imbalance the floating roof, e.g., as a result of vapor pockets or increased fugitive emissions from tank seals. This in turn may lead to a need to cool and/or depressurize the desalted hydrocarbon feed prior to either recycling to the
- 25 feed tank or to another tank in between the desalter and steam cracker furnace.
- [0020]** It has been discovered that these obstacles can be at least partially overcome by utilizing the specified combination of one or more desalters, recycle lines, spare pumps, and/or surge drums. Doing so has been found to accommodate unexpected or anticipated feed flow fluctuations to the steam cracking furnace (e.g., as may occur when one or more of the steam
- 30 cracking furnaces in the facility are switched from pyrolysis mode to decoking mode or *vice versa*) without an appreciable decrease in contaminant-removal efficiency in comparison with conventional desalting processes, as would be detrimental to the performance of a steam cracker furnace.

Definitions

- [0021]** The term " $C_n$ " hydrocarbon means hydrocarbon having  $n$  carbon atom(s) per molecule, where  $n$  is a positive integer. The term " $C_{n+}$ " hydrocarbon means hydrocarbon having at least  $n$  carbon atom(s) per molecule, where  $n$  is a positive integer. The term " $C_n$ " hydrocarbon means hydrocarbon having no more than  $n$  number of carbon atom(s) per molecule, where  $n$  is a positive integer. The term "hydrocarbon" means a class of compounds containing hydrogen bound to carbon, and encompasses (i) saturated hydrocarbon, (ii) unsaturated hydrocarbon, and (iii) mixtures of hydrocarbons, including mixtures of hydrocarbon compounds (saturated and/or unsaturated), including mixtures of hydrocarbon compounds having different values of  $n$ . A mixture of  $C_n$  and  $C_m$  hydrocarbon, where  $m$  and  $n$  are integers and  $n < m$ , means a mixture containing at least  $C_n$  and  $C_m$  hydrocarbon and optionally one or more hydrocarbon compounds having a number of carbon atoms greater than  $n$  but less than  $m$ .
- [0022]** The term "unsaturate" or "unsaturated hydrocarbon" mean a  $C_{2+}$  hydrocarbon containing at least one carbon atom directly bound to another carbon atom by a double or triple bond. The term "olefin" means an unsaturated hydrocarbon containing at least one carbon atom directly bound to another carbon atom by a double bond. An olefin is a compound which contains at least one pair of carbon atoms, where the carbon atoms of the pair are directly linked by a double bond.
- [0023]** The term "non-volatile components" means the fraction of a hydrocarbon stream with a nominal boiling point above  $590^{\circ}\text{C}$  or greater, as measured by ASTM D-6352-98 or D-2887. Non-volatile components may be further limited to components with a boiling point of about  $760^{\circ}\text{C}$  or greater. The boiling point distribution of a hydrocarbon stream may be measured by gas chromatograph distillation according to the methods described in ASTM D-6352-98 or D2887, extended by extrapolation for materials above  $700^{\circ}\text{C}$ . Non-volatile components may include coke precursors, which are moderately heavy and/or reactive molecules, such as multi-ring aromatic compounds, which can condense from the vapor phase and then from coke under the operating conditions encountered in a process of the present disclosure.
- [0024]** The term "steam cracker" and "steam cracker furnace" are interchangeable with "thermal pyrolysis unit", "pyrolysis furnace", or just "furnace." Steam, although optional, may be added for a variety of reasons, such as to reduce hydrocarbon partial pressure, to control residence time, and/or to decrease coke formation. In at least one embodiment, the steam may

be superheated, such as in the convection section of the furnace, and/or the steam may be sour or treated process steam.

[0025] The addition of steam at various points in the process is not detailed in every embodiment described. It is further noted that the steam added may include sour or treated process steam and that the steam added, whether sour or not, may be superheated. Superheating is common when the steam comes from sour water.

#### Hydrocarbon Feed

[0026] The hydrocarbon feed may include relatively high molecular weight hydrocarbons (heavy hydrocarbon), such as those which produce a relatively large amount of steam cracker naphtha (SCN), steam cracker gas oil (SCGO), and steam cracker tar during steam cracking. The heavy hydrocarbon typically includes C5+ hydrocarbon, which may include one or more of residues, gas oils, heating oil, jet fuel, diesel, kerosene, coker naphtha, hydrocrackate, reformat, raffinate reformat, distillate, crude oil, atmospheric pipestill bottoms, vacuum pipestill streams including bottoms, condensates, heavy non-virgin hydrocarbon streams from refineries, vacuum gas oils, heavy gas oil, naphtha contaminated with crude, atmospheric residue, heavy residue, C4/residue admixture, naphtha residue admixture, gas oil residue admixture, low sulfur waxy residue, atmospheric residue, lubes extract steams, and heavy residue. It may be advantageous to use a heavy hydrocarbon feedstock including economically advantaged, minimally processed heavy hydrocarbon streams containing non-volatile components and coke precursors. The hydrocarbon feed can have a nominal final boiling point of about 315°C or greater, such as about 400°C or greater, about 450°C or greater, or about 500°C or greater.

[0027] Certain aspects of the invention will now be described which related to feeds comprising heavy hydrocarbon, e.g., one or more crude oils, crude oil fractions, or other residue-containing streams. The invention is not limited to these feeds, and this description is not meant to foreclose other feeds within the broader scope of the invention, such as feeds containing one or more relatively low molecular weight hydrocarbon (light hydrocarbon), such as C5-hydrocarbon. The use of such heavy hydrocarbon is of increasing interest due to lower costs and higher availability. The hydrocarbon feed can include about 10 wt. % or more of heavy hydrocarbon, based on the weight of the hydrocarbon feed, such as about 25 wt. % or more, about 50 wt. % or more, about 75 wt. % or more, about 90 wt. % or more, or about 99 wt. % or more.

#### Desalters (First Desalter and Optional Second Desalter)

[0028] Because of the desirably low concentration of sodium in the radiant section of steam crackers, one or more desalters may be included to remove salts and particulate matter from the hydrocarbon feed prior to steam cracking. Certain forms of desalter will now be described in more detail. The invention is not limited to these, and this description should not  
5 be interpreted as excluding other desalter forms within the broader scope of the invention.

[0029] The desalting can be carried out in one or more conventional desalter vessels such as a plurality of vessels in semi-continuous operation, such as with one drum in use and the other under maintenance, but the invention is not limited thereto. The vessels and related equipment in the apparatus and system can be configured in series, parallel, and/or series  
10 parallel. Optionally, at least one of the vessels can include a mud-wash functionality and/or a tri-line sampling functionality, and can further include auxiliary equipment such as one or more brine tanks. While acceptable salt and/or particulate matter concentration vary with furnace design, the addition of a desalter may be advantageous when sodium chloride is greater than a predetermined amount (in wppm) of the hydrocarbon feed, and can further depend on the  
15 operating conditions of a particular feed. Typically, desalting is carried out when the hydrocarbon feed comprises salt in an amount  $\geq 0.5$  wppm, e.g.,  $\geq 1$  wppm, such as  $\geq 2$  wppm, or  $\geq 3$  wppm, or  $\geq 4$  wppm, or in a range of from 1 wppm to 100 wppm.

[0030] As disclosed in U.S. Patent Application Publication No. 2006-0094918 (incorporated by reference herein), a partial desalting of a hydrocarbon feed can be achieved  
20 using a vapor-liquid separator that is fluidically and thermally integrated with the steam cracking furnace's convection section. U.S. Patent Application Publication No. 2007-0004952 (also incorporated by reference herein) improves upon this by using a pair of cyclonic separators operating in tandem. A partially desalted hydrocarbon feed is conducted away from the cyclonic separators to the vapor-liquid separator for additional desalting before cracking  
25 the hydrocarbon feed in the steam cracking furnace's radiant section. In aspects of the invention which utilize such a vapor-liquid separator, the hydrocarbon feed can have an even greater salt content, e.g.,  $\geq 100$  wppm, such as  $\geq 500$  wppm, or  $\geq 1000$  wppm, or  $\geq 5000$  wppm, or  $\geq 10,000$  wppm or in a range of from 100 wppm to 50,000 wppm, or 200 wppm to 10,000 wppm. In these aspects, the first and second desalters (e.g., the first and second desalters as  
30 shown in Fig. 1) produce a desalted hydrocarbon feed having a salt content  $\leq 1$  wppm, e.g.,  $\leq 0.5$  wppm, with the vapor separated from the vapor-liquid separator having a salt content  $\leq 0.125$  wppm, such as  $\leq 0.0625$  wppm.

[0031] Typically, wash water (or fresh water, or deionized water) is mixed with a heated hydrocarbon feed to produce a water-in-oil emulsion, which in turn extracts salt, brine and particulates from the oil. The wash water used to treat the hydrocarbon feed may be derived from various sources. For example, the water may be recycled and/or recirculated water from other units in the facility, e.g., sour water stripper bottoms, overhead condensate, boiler feed water, with and/or without clarification, purification, etc. Alternately, or in addition, water may be obtained from other sources, e.g., from surface water sources such as from a river, and/or or from geological water sources, such as from one or more wells. The concentration of various salts in water can be expressed in parts per thousand by weight (ppt), and typically salt concentration is in the range of from that of fresh water (less than 0.5 ppt of sodium chloride), brackish water (0.5-30 ppt of sodium chloride), or saline water (30-50 ppt of sodium chloride) to that of brine (more than 50 ppt of sodium chloride). Although deionized water may be used to favor exchange of salt from the crude into the aqueous solution, de-ionized water is not normally required to desalt crude oil feedstocks. In certain aspects, however, deionized water may be mixed with recirculated water from the desalter to achieve a specific ionic content in either the water before emulsification or to achieve a specific ionic strength in the final emulsified product. Wash water rates are typically in a range of from about 5% to about 7% by volume of the total crude oil to be desalted, but may be higher or lower dependent upon the crude oil source and quality. A variety of water sources may be combined as determined by cost requirements, supply, salt content of the water, salt content of the hydrocarbon feed, and other factors specific to the desalting conditions such as the size of the separator and the degree of desalting required.

[0032] During the separation phase of a desalting process, an emulsion phase of varying composition and thickness may form at the interface of the oil and aqueous layers. If unresolved, these emulsions may carry-over with the desalted crude oil or carry-under into the aqueous layer. If carried-over, the emulsions may lead to coking or fouling of downstream equipment and disruption of the downstream fractionation process. If carried-under, they can disrupt the downstream water treatment process. Consequently, refiners typically desire to either control the formation/growth of these emulsions or remove the emulsions from desalter units and, using an additional processing step, to resolve the emulsion into its constituent parts (i.e., to break the emulsion, resulting in separate oil, water and solid phases) to allow for reuse and/or disposal of the oil, water, and solids.

[0033] Methods for separating the oil and water phases may include gravitational or centrifugal methods. In a gravity method, the emulsion is allowed to stand in the separator and the density difference between the oil and the water causes the water to settle through and out of the oil by gravity. In the centrifugation method, the stable emulsion is moved from the desalter unit to a centrifuge (not shown) which separates the emulsion into separate water, oil and solids. The gravity method generally requires the use of time-intensive, and thus inefficient, settling tanks as well as costly methods for disposing of the partially resolved emulsion, while the centrifugation method may require large centrifuges that are costly to build and operate.

[0034] Typically, an electric field is established in a region within the desalter to enhance water droplet coalescence. This in turn breaks the emulsion to form an oleaginous continuous phase and an aqueous continuous phase. Even when a relatively strong electric field is established in the desalter, an emulsion layer (called a “rag layer”) may form, typically below the region in which the electric field is established. This emulsion layer is observed to be stable, even when adjacent to the strong electric field. The strength of this emulsion layer (sometimes called a “persistent emulsion”, indicating its resistance to emulsion-breaking) typically depends on factors such as feed hydrocarbon gravity (e.g., the gravity of crude oil in the hydrocarbon feed), the presence and amount of solids and semi-solids, such as particles, etc.). Such a rag layer typically contains a high concentration of oil, residual water, suspended solids and salts which, in a typical example, might be about 70% v/v water, 30% v/v oil, with 5000-8000 pounds per thousand barrels (PTB) (about 14 to 23 g/l.) solids, and 200-400 PTB (about 570 to 1100 mg/l.) salts. The aqueous phase contains salts transferred from the hydrocarbon feed. Conventional methods for managing the rag layer can be used, but the invention is not limited thereto. For example, introducing into the desalter one or more de-emulsifier compositions and/or separating and conducting away at least a portion of the emulsion.

[0035] Certain hydrocarbon feed contaminants have been identified as being especially effective in establishing a persistent emulsion layer. In hydrocarbon feeds comprising crude oil and/or compositions derived from crude oil, such contaminants include natural surfactants (asphaltenes and resins) and finely divided solid particles. Since a persistent emulsion is typically observed when desalting a hydrocarbon feed comprising crude oil, hydrocarbon feeds having a high solids contents are typically not preferred. While not wishing to be bound by any theory or model, it is believed that the presence of such solids, often with particle sizes

under 5 microns, stabilizes the rag layer and the oil/bulk-resolved-water interface, leading to a progressive increase in the depth of the rag layer.

[0036] The invention is compatible with the use of de-emulsifiers (“demulsifiers”) to decrease rag layer size (e.g., height, when the plane of the rag layer is substantially parallel to the surface of the earth) and persistence. Conventional demulsifiers, such as those described in US. Patent Publication 2016/0208176 (incorporated by reference herein) can be used, but the invention is not limited thereto. Suitable demulsifiers may be one or more of: polyethyleneimines, polyamines, succinated polyamines, polyols, ethoxylated alcohol sulfates, long chain alcohol ethoxylates, long-chain alkyl sulfate salts, e.g. sodium salts of lauryl sulfates, epoxies, and di-epoxides (which may be ethoxylated and/or propoxylated). The addition of demulsifiers may be useful in the desalting of hydrocarbon feeds containing high levels of particulates or asphaltenes, which tend to stabilize the rag layer.

[0037] FIG. 1 is a flow diagram an apparatus **100** for removal of contaminants in a hydrocarbon feed while maintaining flow to one or more downstream steam crackers. As shown in FIG. 1, the hydrocarbon feed may be transferred from storage tank **101** through line **103** to pump **105**. Pump **105** may be supplemented by hydrocarbon transferred from storage tank **101** through line **104** to spare auto-starting pump **106** in order to allow for consistent pressure and flow in the system. The pressure and flow rate of the hydrocarbon feed is determined by the salt content of the hydrocarbon feed and the size and number of desalters and furnaces, but the pressure should be sufficiently high as to avoid vaporization of the water and hydrocarbon at the temperatures used in the desalting process. The pressurized hydrocarbon feed is pumped through line **107** to heat exchanger **109** to provide a heated hydrocarbon feed. Where a stand-by auto-starting pump **106** is used, pressurized hydrocarbon feed may flow through line **108** to join line **107** or flow directly to heat exchanger **109**. The heated hydrocarbon feed of line **111** (downstream of heat exchanger **109**) may undergo further heating. The additional heating can be carried out in one or more additional heat exchangers (not shown), which can be located before and/or after heat exchanger **109**. The additional transfer of heat results in an increased temperature of the heated hydrocarbon feed beyond what can be achieved by heat exchanger **109** alone. Doing so decreases the viscosity of the feed, and promote mixing with water, as described below. Suitable heat transfer fluids for the additional heat exchangers include, e.g., (i) steam such as low pressure, medium pressure, high pressure, or super high pressure steam (generally the lowest pressure steam that is effective for carrying out the heat transfer is used, typically medium pressure steam (15 bar – 30 bar) or low

pressure steam (< 15 bar) steam is sufficient), (ii) an oleaginous heat transfer fluid from purification system **151**, e.g., a bottoms pump around oil from a primary fractionator, and (iii) an aqueous quench fluid, e.g., one obtained from a quench tower included in purification system **151**. For example, in certain aspects heat exchanger **109** is located upstream of a first additional heat exchanger utilizing low pressure steam as a heat transfer fluid. The first additional heat exchanger is located upstream of a second additional heat exchanger utilizing a primary fractionator bottoms pump around oil as a heat transfer fluid. Optionally, in these aspects, an emulsion recovered (not shown in the figure) from purification system **151** is introduced into the hydrocarbon feed or heated hydrocarbon feed at a location upstream of heat exchanger **109** via line **167**. The heated hydrocarbon feed may be at a temperature of about 30°C or greater, e.g., about 100°C or greater, such as about 120°C or greater, about 140°C or greater, or about 150°C or greater. For example, the heated hydrocarbon feed may have a temperatures of from about 100°C to about 200°C, from about 120°C to about 180°C, from about 140°C to about 180°C, or from about 150°C to about 200°C.

**[0038]** The heated hydrocarbon feed passes through line **111** where it is mixed with water from fresh water line **113** to form an emulsion. The emulsion formed from the combination of fresh water in line **113** and heated hydrocarbon feed in line **111** may be passed through valve **115** and line **117** to first desalter **119** for optional additional mixing followed by separation. In first desalter **119** the hydrocarbon and salt water are separated producing (i) an aqueous by-product (brine) sent away via line **121**, and (ii) inter-stage hydrocarbon feed removed from first desalter **119** via line **123**. The desalted oleaginous phase forms a top layer which is continuously removed as inter-stage hydrocarbon feed via line **123** and the resolved aqueous phase accumulates in the bottom of the desalter and is continuously removed as a brine stream via line **121**. The brine stream may be sent for deionization and recycling or used with or without further processing in other processes. In some embodiments, a single desalter provides sufficient contaminant removal that no additional desalting is necessary. The use of a single desalter (with a recycle line to the desalter inlet and/or a surge drum) may be sufficient if fluctuations in flow rate, such as those caused by steam crackers being brought online or offline, are managed to allow steady flow of the hydrocarbon feed through the desalter.

**[0039]** One method of managing flow rate to steam crackers without sacrificing removal of contaminants is to add an additional desalter in series with the first desalter. In some embodiments, the addition of a second desalter allows for sufficient removal of contaminants even through rapid flow rate fluctuations. The (optional) addition of a second desalter is shown

in FIG. 1, where the inter-stage hydrocarbon feed is passed through line **123** and mixed with water from clean water line **125**. The emulsion formed from the combination of the inter-stage hydrocarbon feed and the water is passed through valve **127** and line **129** into second desalter **131**. In second desalter **131** the hydrocarbon and water are separated producing (i) a clean water product stream sent away via line **133**, and (ii) desalted hydrocarbon feed removed at the hydrocarbon outlet (not shown) from second desalter **131** via line **135**. Line **135** is coupled with heat exchanger **109** to allow heat exchange between the desalted hydrocarbon feed and the pressurized hydrocarbon feed. The desalted hydrocarbon feed (after heat exchange) transferred via line **136** is lower in temperature than the desalted hydrocarbon feed in line **135**, e.g., to meet furnace requirements that depend on specific furnace design. The clean water product stream from the second desalter may contain a sufficiently low sodium content (e.g. about 10 wppm or less) and may be recycled via line **133** to line **113** for reuse in first desalter **119**. Alternatively, the clean water product may be used with or without further processing in other processes at the facility (line not shown).

**[0040]** Typically the desalted hydrocarbon feed comprises  $\leq 1$  wppm of salt, e.g.,  $\leq 0.5$  wppm, such as  $\leq 0.25$  wppm, or  $\leq 0.125$  wppm, or  $\leq 0.0625$  wppm, or in a range of from 0.01 wppm to 0.125 wppm.

#### Surge Drum

**[0041]** The invention is compatible with the use of one or more surge drums as an aid in providing a substantially-uninterrupted flow rate of desalted hydrocarbon feed to steam cracker furnaces. The surge drum can be filled with desalted hydrocarbon feed during use. The desalted hydrocarbon feed in the filled surge drum could be transferred into a steam cracker furnace's feed line. Doing so can provide a short-term flow of desalted hydrocarbon feed during a decrease in flow, as might occur when a pump fails or must be taken offline for servicing while spare pumps are being started. The volume of desalted hydrocarbon feed in the surge drum could be transferred into the feed line at a similar pressure in a variety of ways, e.g. using  $N_2$  as a motive force, along with automatic valving. In certain aspects, e.g., where such a surge drum is not used and/or where the surge drum's inventory of desalted hydrocarbon feed is depleted, one or more of the desalters can be by-passed to maintain a sufficient flow of feed to the stream cracker furnaces.

**[0042]** The addition of a surge drum is shown in FIG. 1 where desalted hydrocarbon feed in line **136** may be diverted through line **137** and valve **139** to surge drum **141** in order to fill the drum with desalted hydrocarbon feed for use in the case of a loss in pressure or of flow

rate. If a drop in pressure or flow rate were to occur, the desalted hydrocarbon feed stored in surge drum **141** could be released through valve **143** and line **145** to rejoin line **136**, thus stabilizing the pressure and flow rate at levels acceptable to the steam cracker(s).

#### Steam Cracker

5   **[0043]**       Steam cracking can be carried out in at least one steam cracker (also referred to as a steam cracker furnace or furnace). Typically, a plurality of steam crackers in parallel may be used at a facility to improve efficiency in production of light hydrocarbons. Steam crackers are typically taken offline for periodic maintenance and decoking, and having a plurality of furnaces in parallel allows for continuous operation of the remainder of the steam cracking and  
10 light hydrocarbon purification process without undue downtime. Generally, a steam cracker furnace includes a convection section where the desalted hydrocarbon feed is pre-heated and steam is added before entering the steam cracker's radiant section where the heat is sufficient for cracking to occur. A steam cracker may have a vapor-liquid separator, e.g., a flash separation vessel, integrated by fluid connection between the convection section and the radiant  
15 section. The radiant section may include fired heaters, and flue gas from combustion carried out with the fired heaters travels upward from the radiant section through the convection section and then away as flue gas.

**[0044]**       The heating of the desalted hydrocarbon feed in the convection section of a steam cracker may include indirect contact (e.g. within a line or tube within the furnace) with hot flue  
20 gases from the radiant section of the furnace. The heating of the hydrocarbon feed can be accomplished, for example, by passing the desalted hydrocarbon feed through a bank of heat exchange tubes located within the convection section of the steam cracker. The heated desalted hydrocarbon feed may have a temperature from about 315°C to about 560°C, such as about 370°C to about 510°C, or about 430°C to about 480°C.

25   **[0045]**       The heated desalted hydrocarbon feed may be combined with steam and subjected to additional heating in the convection section. The heated desalted hydrocarbon feed can include steam in an amount from about 10 wt. % to about 90 wt. %, based on the weight of the hydrocarbon and steam mixture, with the remainder including the hydrocarbon feed. In certain embodiments, the weight ratio of steam to hydrocarbon feed can be from about 0.1 to about 1,  
30 such as about 0.2 to about 0.6.

**[0046]**       A steam cracker may be integrated with a vapor-liquid separator, e.g., one or more flash separation vessels. Such vessels, sometimes referred to as flash pot or flash drum, can provide upgrading of the preheated desalted hydrocarbon feed. Such flash separation

vessels are suitable when the preheated hydrocarbon feed includes about 0.1 wt. % or more of asphaltenes based on the weight of the hydrocarbon components of the convection product stream, e.g., about 5 wt. % or more. Upgrading the preheated hydrocarbon feed through vapor/liquid separation may be accomplished through flash separation vessels or other suitable means. Examples of suitable flash separation vessels include those disclosed in U.S. Pat. Nos. 6,632,351; 7,138,047; 7,090,765; 7,097,758; 7,820,035; 7,311,746; 7,220,887; 7,244,871; 7,235,705; 7,247,765; 7,351,872; 7,297,833; 7,488,459; 7,312,371; and 7,578,929; and, which are incorporated by reference herein.

**[0047]** One advantage of having a flash separation vessel downstream of the convection section and upstream of the radiant section is an increased breadth of hydrocarbon types available to be used directly, without pretreatment, as hydrocarbon feed. For example, the addition of a flash separation vessel allows for utilization of a hydrocarbon feed that contains crude oil or heavy hydrocarbon in about 50 wt. % or greater, such as about 75 wt. % or greater, or about 90 wt. % or greater. The flash separation vessel may operate at a temperature from about 315°C to about 560°C and/or a pressure from about 275 kPa to about 1400 kPa, such as, a temperature from about 430°C to about 480°C, and/or a pressure from about 700 kPa to about 760 kPa. Typically, only the vapor phase within the flash separation vessel is conducted on to the radiant section of a steam cracker, while the liquid phase can be conducted away from the flash separation vessel, e.g., for storage and/or further processing. The portion conducted to the radiant section is typically in the vapor phase at the inlet of the radiant coils, e.g., about 90 wt. % or greater is in the vapor phase, such as about 95 wt. % or greater, or about 99 wt. % or greater.

**[0048]** The vapor portion of the heated desalted hydrocarbon feed may be pyrolysed in the radiant section of a steam cracker, where the hydrocarbon is indirectly exposed to the combustion carried out by the burners. Steam cracking conditions (pyrolysis conditions) may include exposing the vapor portion of the heated desalted hydrocarbon feed in the radiant section (within a radiant line) to a temperature (measured at the outlet of the steam cracker) of about 400°C or greater, such as, from about 400°C to about 1100°C, a pressure of about 10 kPa or greater, and/or a steam cracking residence time from about 0.01 second to 5 seconds. For example, the steam cracking conditions can include one or more of (i) a temperature of about 760°C or greater, such as from about 760°C to about 1100°C, or from about 790°C to about 880°C, or for hydrocarbon feeds containing light hydrocarbon from about 760°C to about 950°C; (ii) a pressure of about 50 kPa or greater, such from about 60 kPa to about 500 kPa, or

from about 90 kPa to about 240 kPa; and/or (iii) a residence time from about 0.1 seconds to about 2 seconds. The steam cracking conditions may be sufficient to convert at least a portion of the steam cracking feed's hydrocarbon molecules to C<sub>2+</sub> olefins by pyrolysis.

[0049] The steam cracked effluent generally includes C<sub>2+</sub> olefin, molecular hydrogen, acetylene, aromatic hydrocarbon, saturated hydrocarbon, C<sub>3+</sub> diolefin, and one or more of aldehyde, acidic gases such as H<sub>2</sub>S and/or CO<sub>2</sub>, and mercaptans. The steam cracked effluent may be categorized as (i) vapor-phase products such as one or more of acetylene, ethylene, propylene, butenes, and (ii) liquid-phase products including, e.g., one or more of C<sub>5+</sub> molecules and mixtures thereof.

10 [0050] As shown in FIG. 1, desalted hydrocarbon feed passed through line 136 may enter steam cracker 147. Within steam cracker 147, the desalted hydrocarbon feed may be heated via indirect exposure to flue gases in the convection section (not shown), semi-purified in a flash separation vessel (not shown) and pyrolysed within the radiant section (not shown) producing steam cracker effluent which is transferred via line 149 to undergo further purification in  
15 purification system 151. Purification system 151 may contain a number of fractionators, separation columns, purification and/or catalyst beds, cooling and/or quench towers, and/or other devices for the production of purified light hydrocarbons transferred via line 153.

#### Hydrocarbon Recycle Line

[0051] Another method of managing variations in flow of hydrocarbon feeds used in an  
20 apparatus, such as apparatus 100, is using one or more desalters large enough to maintain flow to the maximum number of steam cracker furnaces that could be online and use of a hydrocarbon recycle line downstream of one or both of the desalters (and optionally one or more of the steam crackers) to allow recycling of desalted hydrocarbon feed to the original storage tank or another storage tank. Large storage tanks are typically external floating roof  
25 tanks and are not suitable to store hydrocarbon (with a flash point < 60°C) above ambient pressure or temperature. The desalted hydrocarbon feed sent to a large storage tank (e.g. crude oil storage tanks) may be cooled and/or depressurized so as not to cause fugitive emissions from tank seals or imbalances in the floating roof due to vapor pockets.

[0052] A hydrocarbon recycle line for managing greater-than-needed flow can be sized  
30 to offset the flow of one or more steam crackers being taken offline, as is frequently done due to the need to accommodate variations in the need for desalted hydrocarbon feed flow to the furnaces, e.g., during periodic maintenance and decoking. The hydrocarbon recycle line may have an automatic valve that determines the necessity to divert a portion of the desalted

hydrocarbon feed to storage. For example, if ten steam crackers are online and a single furnace comes offline, e.g., is switched from pyrolysis mode to decoking mode, the valve in the hydrocarbon recycle line will open to send the excess flow from the offline furnace back a storage tank. In doing so the flow rate through the desalter(s) will stay the same despite the  
5 change in the number of furnaces online. Similarly when nine steam cracker furnaces are online and a tenth is to be brought online, the valve in the hydrocarbon recycle line can close to send the flow forward rather than be recycled back to a storage tank.

**[0053]** Use of a hydrocarbon recycle line has also been found to be beneficial when operating a desalter in “turndown”, e.g., with a reduced flow of hydrocarbon feed to the  
10 desalter. Various factors influence the desalter turndown rate including the distributor within the vessel that maintains emulsion uniformity, and mixing valves intended to intimately mix the water and hydrocarbon feed. At low flow rates, both the distributor and mixing valves operate outside of their effective operating range, and may cause contaminant removal to suffer. The use of a hydrocarbon recycle line allows increased flow through the desalter even  
15 if flow to the steam crackers is reduced. As steam crackers are brought offline, it is common to turndown flow to maintain regular flow to the remaining steam crackers, the turndown of flow is not typically found in refinery processes. The addition of a recycle line can improve desalting by allowing for greater flow through the desalter, while accommodating the fluctuations in flow as steam crackers are brought online or offline.

**[0054]** One embodiment of the hydrocarbon recycle line is shown according to apparatus  
20 **100** in FIG. 1. Line **155** leads to valve **157**, which according to one embodiment is an automatic valve that maintains the pressure and/or flow rate for one or more steam crackers downstream and may divert a portion of the desalted hydrocarbon feed. The valve is fluidly connected with heat exchanger **159**, which is configured to cool the portion of the desalted hydrocarbon feed  
25 to a temperature suitable for entry into a storage tank producing a cooled desalted hydrocarbon feed. In at least one embodiment, the cooled desalted hydrocarbon feed is recycled through line **161** to storage tank **101**. In another embodiment the cooled desalted hydrocarbon feed is sent for storage in a separate tank (not shown) before use in a steam cracker.

**[0055]** The hydrocarbon recycle line may include a variety of configurations with the  
30 result of maintaining desired flow and pressure to downstream steam crackers. For example the recycle line could be installed after a single desalter, or in some embodiments, after the surge drum. The hydrocarbon recycle line could lead to floating-roof storage tanks (typically after cooling) or to storage vessels designed to contain the heated hydrocarbon, like the surge

drum discussed above. In other aspects, the hydrocarbon recycle line is in fluidic communication with a desalter, e.g., via a connection (not shown) to line 111. In these aspects, heat exchange duty in heat exchanges **109** and/or **159** may be beneficially lessened, which increases process efficiency.

5 Other Recycle Lines

[0056] The purification process of pyrolysis products may produce difficult to manage small volumes of emulsified by-product streams that can be recycled upstream of a desalter. It may be more economical and efficient to recycle emulsified by-product streams than conduct them away for further treatment and/or upgrading. One example of a small volume emulsified  
10 by-product stream is disulfide oil produced when spent caustic is treated by an oxidation process (e.g. Merox) as described in U.S. Patent Nos. 5,320,742; and 6,579,444, which are incorporated by reference herein in their entireties. The disulfides may be separated from the caustic using a light solvent and a separation vessel, producing a stream that is mainly hydrocarbon with sulfur incorporated, but cannot be sent to a steam cracker because the  
15 disulfide oil may contain traces of caustic including sodium. By-product streams of similar types can be recycled upstream of a desalter which can remove contaminants of the hydrocarbon feeds down to an acceptable level for steam cracking.

[0057] Example recycle lines from the post steam cracking purification process are shown in FIG. 1. Recycle line **163** provides recycling of certain process streams directly into  
20 hydrocarbon recycle line **161** and from there return to storage tank **101**. Additionally or alternatively, process streams can be recycled directly to storage tank **101** through recycle line **165**. Where purification process **151** produces emulsions at elevated temperatures and/or pressures, and the emulsions may be recycled in line **167** to line **111** to join the heated hydrocarbon feed (and/or the hydrocarbon feed upstream of exchanger **109**, not shown) sent to  
25 desalter **119**. Other recycle stream configurations may be suitable for use with a hydrocarbon feed to one or more steam crackers that is cleaned by passing through one or more desalters.

Other embodiments of the present disclosure can include:

[0058] Paragraph 1. A process for producing light hydrocarbons from a hydrocarbon feed containing heavy hydrocarbons, the process including pressurizing the hydrocarbon feed in one  
30 or more pumps producing a pressurized hydrocarbon feed; heating the pressurized hydrocarbon feed in one or more heat exchangers producing a heated hydrocarbon feed; mixing the heated hydrocarbon feed with water and separating an inter-stage hydrocarbon feed from inter-stage water; mixing the inter-stage hydrocarbon feed with water and separating a desalted

hydrocarbon feed from outlet water; and pyrolysing the desalted hydrocarbon feed in a steam cracker.

5    **[0059]**       Paragraph 2. The process of paragraph 1, where pressurizing includes pressurizing the hydrocarbon feed to a pressure of from about 101 kPa (abs) to about 2000 kPa (abs) or higher.

**[0060]**       Paragraph 3. The process of any of paragraphs 1 to 2, where heating includes heating the pressurized hydrocarbon feed to a temperature from about 100°C to about 150°C.

**[0061]**       Paragraph 4. The process of any of paragraphs 1 to 3, further including storing at least a portion of the desalted hydrocarbon feed in a surge drum.

10   **[0062]**       Paragraph 5. The process of any of paragraphs 1 to 4, further including recycling at least a portion of the desalted hydrocarbon feed to a storage tank.

**[0063]**       Paragraph 6. The process of any of paragraphs 1 to 5, where pyrolysing is performed at a temperature from about 760°C to about 1100°C

15   **[0064]**       Paragraph 7. The process of any of paragraphs 1 to 6, further including a pyrolysis pressure from about 60 kPa (gauge) to about 500 kPa (gauge).

**[0065]**       Paragraph 8. An apparatus for removing contaminants from a hydrocarbon feed containing heavy hydrocarbons, the apparatus including: a first desalter; a second desalter in fluid connection with the first desalter; and a steam cracker in fluid connection with the second desalter.

20   **[0066]**       Paragraph 9. The apparatus of paragraph 8, further including a storage tank in fluid connection with the first desalter.

**[0067]**       Paragraph 10. The apparatus of any of paragraphs 8 to 9, further including a surge drum in fluid connection with the second desalter and the steam cracker.

25   **[0068]**       Paragraph 11. The apparatus of any of paragraphs 9 to 10, further including a hydrocarbon recycle line in fluid connection with the second desalter and the storage tank.

**[0069]**       Paragraph 12. The apparatus of any of paragraphs 8 to 11, further including a recycle line in fluid connection with the steam cracker and the first desalter.

**[0070]**       Paragraph 13. The apparatus of any of paragraphs 9 to 12, further including a recycle line in fluid connection with the steam cracker and the storage tank.

30   **[0071]**       Paragraph 14. The apparatus of any of paragraphs 11 to 13, further including a recycle line in fluid connection with the steam cracker and the hydrocarbon recycle line.

**[0072]**       Paragraph 15. An apparatus for removing contaminants from a hydrocarbon feed containing heavy hydrocarbons, the apparatus including: a desalter; a storage tank in fluid

connection with the desalter; a hydrocarbon recycle line in fluid connection with the desalter and the storage tank; and a steam cracker in fluid connection with the desalter.

**[0073]** Paragraph 16. The apparatus of paragraph 15, further including a surge drum in fluid connection with the desalter and the steam cracker.

5 **[0074]** Paragraph 17. The apparatus of any of paragraphs 15 to 16, further including a recycle line in fluid connection with the steam cracker and the storage tank.

**[0075]** Paragraph 18. The apparatus of any of paragraphs 15 to 17, further including a recycle line in fluid connection with the steam cracker and the desalter.

**[0076]** Paragraph 19. The apparatus of any of paragraphs 15 to 18, further including a  
10 recycle line in fluid connection with the steam cracker and the hydrocarbon recycle line.

**[0077]** Paragraph 20. An apparatus for removing contaminants from a hydrocarbon feed containing heavy hydrocarbons, the apparatus including: a surge drum; a desalter in fluid connection with the surge drum; and a steam cracker in fluid connection with the surge drum.

**[0078]** Paragraph 21. The apparatus of paragraph 20, further including a storage tank in  
15 fluid connection with the desalter.

**[0079]** Paragraph 22. The apparatus of any of paragraphs 20 to 21, further including a recycle line in fluid connection with the steam cracker and the storage tank.

**[0080]** Paragraph 23. The apparatus of any of paragraphs 20 to 22, further including a recycle line in fluid connection with the steam cracker and the desalter.

20 **[0081]** Paragraph 24. An apparatus for removing contaminants from a hydrocarbon feed containing heavy hydrocarbons, the apparatus including: a storage tank in fluid connection with a first desalter; a second desalter in fluid connection with the first desalter; a first hydrocarbon recycle line in fluid connection with the second desalter and the storage tank; a steam cracker in fluid connection with the second desalter; a surge drum in fluid connection with the second  
25 desalter and the steam cracker; and a purification system in fluid connection with the steam cracker.

**[0082]** Paragraph 25. The apparatus of paragraph 25, where the apparatus further includes a recycle line in fluid connection with the purification system and the first desalter.

**[0083]** Paragraph 26. A process for producing light hydrocarbons from a hydrocarbon  
30 feed containing heavy hydrocarbons, the process comprising: mixing a hydrocarbon feed with water and separating an inter-stage hydrocarbon feed from inter-stage water; mixing the inter-stage hydrocarbon feed with water and separating a desalted hydrocarbon feed from outlet water; and pyrolysing the desalted hydrocarbon feed in a steam cracker.

[0084] Paragraph 27. The process of paragraph 26, where pressurizing includes pressurizing the hydrocarbon feed to a pressure of from about 101 kPa (abs) to about 2000 kPa (abs) or higher.

5 [0085] Paragraph 28. The process of any of paragraphs 26 to 27, where heating includes heating the pressurized hydrocarbon feed to a temperature from about 100°C to about 150°C.

[0086] Paragraph 29. The process of any of paragraphs 26 to 28, further including storing at least a portion of the desalted hydrocarbon feed in a surge drum.

[0087] Paragraph 30. The process of any of paragraphs 26 to 29, further including recycling at least a portion of the desalted hydrocarbon feed to a storage tank.

10 [0088] Paragraph 31. The process of any of paragraphs 26 to 30, where pyrolysing is performed at a temperature from about 760°C to about 1100°C

[0089] Paragraph 32. The process of any of paragraphs 26 to 31, further including a pyrolysis pressure from about 60 kPa (gauge) to about 500 kPa (gauge).

15 [0090] Paragraph 33. A process for producing light hydrocarbons from a hydrocarbon feed containing heavy hydrocarbons, the process comprising: mixing a hydrocarbon feed with water and separating an inter-stage hydrocarbon feed from inter-stage water; mixing the inter-stage hydrocarbon feed with water and separating a desalted hydrocarbon feed from outlet water; recycling at least a portion of the desalted hydrocarbon feed to a storage tank and pyrolysing the remaining desalted hydrocarbon feed in a steam cracker.

20 [0091] Paragraph 34. The process of paragraph 33, further including storing at least a portion of the desalted hydrocarbon feed in a surge drum.

[0092] Paragraph 35. The process of any of paragraphs 33 to 34, where pyrolysing is performed at a temperature from about 760°C to about 1100°C.

25 [0093] Paragraph 36. The process of any of paragraphs 33 to 35, further including a pyrolysis pressure from about 60 kPa (gauge) to about 500 kPa (gauge).

[0094] Paragraph 37. A process for producing light hydrocarbons from a hydrocarbon feed containing heavy hydrocarbons, the process comprising: mixing a hydrocarbon feed with water and separating an inter-stage hydrocarbon feed from inter-stage water; mixing the inter-stage hydrocarbon feed with water and separating a first desalted hydrocarbon feed from outlet water; introducing a second desalted hydrocarbon feed from a surge drum to the first desalted hydrocarbon feed and pyrolysing the combined first desalted hydrocarbon feed and second desalted hydrocarbon feed in a steam cracker.

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[0095] Paragraph 38. The process of paragraph 37, further including introducing a portion of the first hydrocarbon feed and/or a third desalted hydrocarbon feed to the surge drum.

[0096] Paragraph 39. The process of any of paragraphs 37 to 38, further including  
5 recycling at least a portion of the first desalted hydrocarbon feed to a storage tank.

### **EXAMPLES**

[0097] FIG. 2 shows a plant test evaluating the performance of two desalters in series during a rapid rate change in the flow of hydrocarbon feed. In the test, pressure was maintained at 1800 kPa, and temperature at 130°C, the rate of crude oil with 16 wppm of sodium was  
10 decreased from 60 kBD to 39 kBD (350 T/hr to 230 T/hr), and the rate change occurred at vertical line **201**. Time is shown on the x-axis, the sodium content of the oil is shown on one y-axis, and the percent water (by volume) in the oil is shown on the other y-axis. The salt content of the inter-stage hydrocarbon feed (line **203**) and hydrocarbon outlet (line **205**) demonstrates that the salt content of only the inter-stage hydrocarbon feed (**203**) increases  
15 above the furnace limit (line **207**), while the salt content of the hydrocarbon outlet (**205**) remains under the furnace limit (**207**). Therefore, a second desalting stage allows for consistent flow to the furnace while providing a desalted hydrocarbon feed to the furnace with a salt content below the furnace limit. It is noted that the last sample of line **203** was retested showing a salt content of 3.4 wppm instead of the 4.5 wppm originally measured. By way of an  
20 additional comparison, the desalting of crude oil in accordance with the process of U.S. Patent Application Publication No. 2007/0004952 (at paragraph [0016]) discloses a salt content of 0.01 wt. % or more in its partially desalted hydrocarbon feed. Accordingly, stream **205** achieves a much greater degree of desalting than does the conventional process. The desalted hydrocarbon feed (line **205**) is conducted to a vapor-liquid separator integrated with the  
25 convection section of the steam cracker. Vapor transferred from the vapor-liquid separator to the radiant section of the steam cracking furnace typically has a salt content  $\leq 0.125$  wppm, e.g.,  $\leq 0.10$  wppm, such as  $\leq 0.050$  wppm, based on the weight of the transferred vapor.

[0098] Also, as shown by FIG. 2, the water content of the hydrocarbon feed is kept within the furnace limit (line **209**) with a second desalting stage. The inter-stage water content (line  
30 **211**) crosses furnace limit **209**, while the outlet water content (line **213**) remains below furnace limit **209**. The second sample of the inter-stage water content was retested showing water content of 0.6% by volume, instead of the original 2% by volume, demonstrating the accuracy of the high result.

[0099] Overall, it has been found that management of contaminants in a hydrocarbon feed for steam cracking with limited to no feed disruptions can be accomplished by (i) the combination of two or more desalters, (ii) the combination of one or more desalters and a surge drum, and/or (iii) the combination of one or more desalters and a hydrocarbon recycle line. Additionally, it has been discovered that the above management systems can allow for recycling of emulsified by-product streams produced by the purification of light hydrocarbons produced in the steam cracker.

[0100] The phrases, unless otherwise specified, "consists essentially of" and "consisting essentially of" do not exclude the presence of other steps, elements, or materials, whether or not, specifically mentioned in this specification, so long as such steps, elements, or materials, do not affect the basic and novel characteristics of this disclosure, additionally, they do not exclude impurities and variances normally associated with the elements and materials used.

[0101] For the sake of brevity, only certain ranges are explicitly disclosed herein. However, ranges from any lower limit may be combined with any upper limit to recite a range not explicitly recited, as well as, ranges from any lower limit may be combined with any other lower limit to recite a range not explicitly recited, in the same way, ranges from any upper limit may be combined with any other upper limit to recite a range not explicitly recited. Additionally, within a range includes every point or individual value between its end points even though not explicitly recited. Thus, every point or individual value may serve as its own lower or upper limit combined with any other point or individual value or any other lower or upper limit, to recite a range not explicitly recited.

[0102] All documents described herein are incorporated by reference herein, including any priority documents and/or testing procedures to the extent they are not inconsistent with this text. As is apparent from the foregoing general description and the specific embodiments, while forms of this disclosure have been illustrated and described, various modifications can be made without departing from the spirit and scope of this disclosure. Accordingly, it is not intended that this disclosure be limited thereby. Likewise, the term "comprising" is considered synonymous with the term "including" for purposes of United States law. Likewise whenever a composition, an element or a group of elements is preceded with the transitional phrase "comprising," it is understood that we also contemplate the same composition or group of elements with transitional phrases "consisting essentially of," "consisting of," "selected from the group of consisting of," or "is" preceding the recitation of the composition, element, or elements and vice versa.

**[0103]** While this disclosure has been described with respect to a number of embodiments and examples, those skilled in the art, having benefit of this disclosure, will appreciate that other embodiments can be devised which do not depart from the scope and spirit of this disclosure.

**CLAIMS:**

1. A desalting process, the process comprising:
  - providing a hydrocarbon feed comprising heavy hydrocarbon;
  - pressurizing the hydrocarbon feed to produce a pressurized hydrocarbon feed;
  - 5 heating the pressurized hydrocarbon feed in one or more heat exchangers producing a heated hydrocarbon feed;
  - mixing the heated hydrocarbon feed with water and separating an inter-stage hydrocarbon feed from inter-stage water;
  - mixing the inter-stage hydrocarbon feed with water and separating a desalted
  - 10 hydrocarbon feed from outlet water; dividing the desalted hydrocarbon stream into at least first and second portions, at least one hydrocarbon-recycle stream away from the desalted hydrocarbon feed;
  - pyrolysing at least part of the first portion of the desalted hydrocarbon feed in a steam cracker; and
  - 15 combining at least part of the second portion of the desalted hydrocarbon feed with at least a portion of the hydrocarbon feed.
2. The process of claim 1, wherein the pressurization includes pressurizing the hydrocarbon feed in at least one pump to a pressure of from about 101 kPa (abs) to about 2000
- 20 kPa (abs).
3. The process of any of claims 1 to 2, wherein heating comprises heating the pressurized hydrocarbon feed to a temperature from about 100°C to about 150°C.
- 25 4. The process of any of claims 1 to 3, further comprising storing at least a portion of the desalted hydrocarbon feed in a surge drum.
5. The process of any of claims 1 to 4, wherein 1 wt. % to 50 wt. % of the desalted hydrocarbon feed resides in the second portion, and wherein the second portion is combined
- 30 with the hydrocarbon feed in at least one storage tank.
6. The process of any of claims 1 to 5, wherein the pyrolysis is performed at a temperature from about 760°C to about 1100°C, and wherein the first portion contains  $\leq 4$  wppm of salt.

7. The process of any of claims 1 to 6, further comprising a pyrolysis pressure from about 60 kPa (gauge) to about 500 kPa (gauge).

5 8. An apparatus for removing contaminants from a hydrocarbon feed containing heavy hydrocarbons, the apparatus comprising:

a first desalter;

a second desalter in fluid connection with the first desalter;

a steam cracker in fluid connection with the second desalter,

10 a storage tank in fluid connection with the first desalter, and

a hydrocarbon recycle line in fluid connection with the second desalter and the storage tank.

9. The apparatus of claim 8, further comprising, a vapor-liquid separator fluidically and  
15 thermally integrated with the steam cracker, and wherein the first and/or second desalters utilize water injection for the desalting.

10. The apparatus of any of claims 8 to 9, further comprising a surge drum in fluid  
20 connection with the second desalter and the steam cracker.

11. The apparatus of any of claims 9 to 10, further comprising a third desalter situated  
between the second desalter and the steam cracker and in fluidic communication with the  
second desalter and the steam cracker.

25 12. The apparatus of any of claims 8 to 11, further comprising a recycle line in fluid connection with the steam cracker and the first desalter.

13. The apparatus claim 12, further comprising a recycle line in fluid connection with the  
steam cracker and the storage tank.

30 14. The apparatus of any of claims 11 to 13, further comprising a recycle line in fluid connection with the steam cracker and the hydrocarbon recycle line.

15. An apparatus for removing contaminants from a hydrocarbon feed containing heavy hydrocarbons, the apparatus comprising:

a desalter having an established electric field;

a storage tank in fluid connection with the desalter;

5 a hydrocarbon recycle line in fluid connection with the desalter and the storage tank;  
and

a steam cracker in fluid connection with the desalter.

16. The apparatus of claim 15, further comprising a surge drum in fluid connection with  
10 the desalter and the steam cracker.

17. The apparatus of any of claims 15 to 16, further comprising a recycle line in fluid connection with the steam cracker and the storage tank.

18. The apparatus of any of claims 15 to 17, further comprising a recycle line in fluid connection with the steam cracker and the desalter.

19. The apparatus of any of claims 15 to 18, further comprising a recycle line in fluid connection with the steam cracker and the hydrocarbon recycle line.

20

20. An apparatus for removing contaminants from a hydrocarbon feed containing heavy hydrocarbons, the apparatus comprising:

a surge drum;

25 a desalter in fluid having an established electric field, the desalter being in fluidic connection with the surge drum; and

a steam cracker in fluidic connection with the surge drum.

21. The apparatus of claim 20, further comprising a storage tank in fluid connection with the desalter.

30

22. The apparatus of claim 21, further comprising a first pump in fluid connection with the storage tank and the desalter, and a stand-by auto-starting pump in fluid connection with the storage tank and the desalter.

23. The apparatus of any of claims 20 to 22, further comprising a recycle line in fluid connection with the steam cracker and the storage tank.

5 24. The apparatus of any of claims 20 to 23, further comprising a recycle line in fluid connection with the steam cracker and the desalter.

25. An apparatus for removing contaminants from a hydrocarbon feed containing heavy hydrocarbons, the apparatus comprising:

- 10 a storage tank in fluid connection with a first desalter;  
a second desalter in fluid connection with the first desalter;  
a first hydrocarbon recycle line in fluid connection with the second desalter and the storage tank;  
a steam cracker in fluid connection with the second desalter;  
15 a surge drum in fluid connection with the second desalter and the steam cracker; and  
a purification system in fluid connection with the steam cracker.

26. The apparatus of claim 25, wherein the apparatus further comprises a recycle line in fluid connection with the purification system and the first desalter.

20

27. A process for producing light hydrocarbons from a hydrocarbon feed containing heavy hydrocarbons, the process comprising:

- pressurizing the hydrocarbon feed to produce a pressurized hydrocarbon feed;  
heating the pressurized hydrocarbon feed in one or more heat exchangers producing a heated  
25 hydrocarbon feed;  
mixing the heated hydrocarbon feed with water to produce an emulsion,  
separating from the emulsion at least a desalted hydrocarbon feed;  
storing at least a portion of the desalted hydrocarbon feed in one or more surge drums, and  
pyrolysing in at least one steam cracking furnace at least a portion of the desalted hydrocarbon  
30 feed and/or at least a portion of the stored desalted hydrocarbon feed.

28. A process for producing light hydrocarbons from a hydrocarbon feed containing heavy hydrocarbons, the process comprising:

- pressurizing the hydrocarbon feed to produce a pressurized hydrocarbon feed;  
heating the pressurized hydrocarbon feed in one or more heat exchangers producing a heated hydrocarbon feed;  
mixing the heated hydrocarbon feed with water to produce an emulsion,  
5 separating from the emulsion at least a desalted hydrocarbon feed;
- recycling at least a portion of the desalted hydrocarbon feed to a location upstream of the mixing, and  
pyrolysing in at least one steam cracking furnace at least a portion of the desalted hydrocarbon  
10 feed.