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(54) **STEAM CRACKING PROCESS**

(76) Inventors: **Viktor J. Cybulskis**, Pearland, TX
(US); **Kenneth M. Webber**,
Friendswood, TX (US)

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(57) **ABSTRACT**

A steam cracking process is disclosed. The process comprises contacting a liquid hydrocarbon feed with a solid adsorbent to produce a treated feed and cracking the treated feed in a steam cracker to produce olefins and other hydrocarbon products. The process reduces coking in the convection tubes and extends the run length of the cracker.

STEAM CRACKING PROCESS

FIELD OF THE INVENTION

[0001] This invention relates to the production of olefins by cracking a hydrocarbon feed. More particularly, this invention relates to contacting the feed with a solid adsorbent prior to cracking to reduce coke formation in a steam cracker.

BACKGROUND OF THE INVENTION

[0002] Steam cracking of hydrocarbons is a non-catalytic petrochemical process that is widely used to produce olefins such as ethylene, propylene, butenes, butadiene, and aromatics such as benzene, toluene, and xylenes ("Ethylene," in *Kirk-Othmer Encyclopedia of Chemical Technology*, online edition, 2009).

[0003] Basically, a hydrocarbon feed such as naphtha, gas oil, or other hydrocarbon is fractions is mixed with steam which serves as a diluent to keep the hydrocarbon molecules separated. The steam/hydrocarbon mixture is preheated to from about 900 to about 1,000 F, and then enters the reaction zone where it is very quickly heated to a severe hydrocarbon thermal cracking temperature in the range of from about 1,450 to about 1,550 F. Steam cracking is accomplished without the aid of any catalyst.

[0004] This process is carried out in a steam cracker (also called pyrolysis furnace, cracking furnace, cracker, or cracking heater) at pressures in the reaction zone ranging from about 10 to about 30 psig. A steam cracker has a convection section and a radiant section. Preheating is accomplished in the convection section, while severe cracking occurs in the radiant section.

[0005] After cracking in the radiant section, the effluent from the steam cracker contains gaseous hydrocarbons of great variety, e.g., from one to thirty-five carbon atoms per molecule. These gaseous hydrocarbons can be saturated, monounsaturated, and polyunsaturated, and can be aliphatic, alicyclics, and/or aromatic. The cracked gas also contains significant amounts of molecular hydrogen. The cracked product can contain, for example, about 1 weight percent (wt %) hydrogen, about 10 wt % methane, about 25 wt % ethylene, and about 17 wt % propylene, all wt % being based on the total weight of said product, with the remainder remainder consisting mostly of other hydrocarbon molecules having from 4 to 35 carbon atoms per molecule.

[0006] The cracked product is then further processed in a olefin production plant to produce, as products of the plant, various separate individual streams of high purity such as hydrogen, ethylene, propylene, mixed hydrocarbons having four carbon atoms per molecule, fuel oil, and pyrolysis gasoline.

[0007] Conventional steam cracking systems have been effective for cracking high-quality liquid feeds that contain mostly light volatile hydrocarbons, such as gas oil and naphtha. Hydrocarbon feed containing heavy components such as those containing crude oil or atmospheric resid can be cracked using a pyrolysis furnace as described. However, such feeds contain high molecular weight, non-volatile, heavy components that accumulate as coke in the convection section of the pyrolysis furnace, which reduces the run-length of the cracker.

[0008] During transport, it is not uncommon for the high-quality feedstocks (i.e., is naphthas and other light volatile hydrocarbons) to become contaminated with other materials containing non-volatile components such as crude oil. Such non-volatile components can cause problems for conventional pyrolysis furnaces.

[0009] Efforts have been directed to develop processes to use low-cost hydrocarbon feeds containing heavy components in steam crackers. For example, U.S. Pat. No. 3,617,493 discloses an external vaporization drum for crude oil feed and a first flash to remove naphtha as a vapor and a second flash to remove volatiles with a boiling point between 450 to 1100 F. The vapors are cracked in the pyrolysis furnace into olefins and the separated liquids from the two flash tanks are removed, stripped with steam, and used as fuel.

[0010] U.S. Pat. No. 7,374,664 discloses a method for utilizing whole crude oil as a feedstock for the pyrolysis furnace of an olefin production plant. The feedstock is subjected to vaporization conditions until substantially vaporized with minimal mild cracking but leaving some remaining liquid from the feedstock, the vapors thus formed being subjected to severe cracking in the radiant section of the furnace, and the remaining liquid from the feedstock being mixed with at least one quenching oil to lower the temperature of the remaining liquid.

[0011] U.S. Pat. No. 7,404,889 discloses a method for thermally cracking a hydrocarbon feed wherein the feed is first processed in an atmospheric thermal distillation step to form a light gasoline and atmospheric residuum mixture. The light gasoline/residuum combination is gasified at least in part in a vaporization step, and the gasified product of the vaporization step is thermally cracked.

[0012] U.S. Pat. No. 7,550,642 discloses a method for processing a liquid crude and/or natural gas condensate feed comprising subjecting the feed to a vaporization step to form a vaporous product and a liquid product, subjecting the vaporous product to thermal cracking, and subjecting the liquid product to crude oil refinery processing.

[0013] U.S. Pat. No. 7,138,047 teaches a process for cracking a heavy hydrocarbon feedstock containing non-volatile hydrocarbons, comprising: heating the heavy hydrocarbon feedstock, mixing the heavy hydrocarbon feedstock with a fluid and/or a primary dilution steam stream to form a mixture, flashing the mixture to form a vapor phase and a liquid phase, and varying the amount of the fluid and/or the primary dilution steam stream mixed with the heavy hydrocarbon feedstock in accordance is with at least one selected operating parameter of the process, such as the temperature of the flash stream before entering the flash drum.

[0014] U.S. Pat. No. 6,632,351 teaches a process for pyrolyzing a feedstock comprising crude oil and/or crude oil fractions containing pitch in an olefins pyrolysis furnace, comprising feeding said feedstock to a first stage preheater provided in a convection zone of said olefins pyrolysis furnace, heating said feedstock within said first stage preheater to a first temperature of at least 375° C. to produce a preheated gas-liquid mixture, withdrawing said preheated gas-liquid mixture from said first stage preheater to a vapor-liquid separator, separating and removing a gas fraction from a liquid fraction in said vapor-liquid separator, and feeding said gas fraction to a second stage preheater provided in said convection zone, further heating said gas fraction to a second temperature above said first temperature producing a preheated gas fraction, introducing said preheated gas fraction into a radiant zone of the pyrolysis furnace, and pyrolyzing the gas to a product comprising olefins.

[0015] U.S. Pat. Appl. Pub. No. 2008/0135451 discloses a process for thermally cracking a hydrocarbon feed in an installation comprising a radiant section and a convection section, the process comprising: feeding a hydrocarbon feedstock to a feed preheater present in the convection section, wherein the feed preheater has a heat pick-up; controlling the heat pick-up of the feed preheater by regulating the heat exchange capacity of an economizer, wherein the economizer is located in the convection section between the feed preheater and the radiant section; and thereafter cracking the feed that had been heated in the preheater, by cracking the preheated feed in the radiant section.

[0016] WO 2008/131336 discloses a process for processing a hydrocarbon feed to produce one or more olefins, comprising: preheating the hydrocarbon feed to a temperature sufficient to selectively separate the hydrocarbon feed into a heavy cut stream and a light cut stream, wherein at least a portion of the preheating is provided by heat from either the heavy cut stream or the light cut stream; heating the heavy cut to stream at conditions sufficient to provide a heated heavy cut stream having a vapor phase and a liquid phase; separating the vapor phase from the liquid phase to provide a vapor phase stream and a liquid phase stream; and thermally cracking the vapor phase stream to provide a first product stream comprising one or more olefins.

SUMMARY OF THE INVENTION

[0017] This invention is a steam cracking process. The process comprises contacting a hydrocarbon feed with a solid adsorbent to produce a treated feed and cracking the treated feed in a steam cracker to produce olefins and other products. The process reduces coking in the convection tubes.

DETAILED DESCRIPTION OF THE INVENTION

[0018] The process comprises contacting a liquid hydrocarbon feed with a solid adsorbent to produce a treated feed.

[0019] Any liquid hydrocarbon feed may be used. For example, the feed may comprise steam cracked gas oil and residue, gas oil, heating oil, jet fuel, diesel, kerosene, gasoline, coker naphtha, steam cracked naphtha, catalytically cracked naphtha, hydrocrackate, reformate, raffinate reformate, Fischer-Tropsch liquids, natural gasoline, distillate, virgin naphtha, crude oil, natural gas condensate, atmospheric pipestill bottoms, vacuum pipestill streams including bottoms, wide boiling range naphtha to gas oil condensates, heavy non-virgin hydrocarbon streams from refineries, vacuum gas oils, heavy gas oil, naphtha contaminated with crude, atmospheric resid, heavy residuum, C_4's/residue admixture, naphtha residue admixture, derivatives thereof, and any combinations thereof.

[0020] The hydrocarbon feed comprises heavy components. By "heavy components" we mean those species present in a hydrocarbon feed that do not vaporize in a convection section of a cracker. Generally, the heavy components are non-volatile large organic molecules including asphaltene fractions.

[0021] There are many suitable ways to determine the presence and the amount of heavy components. One such method is to evaporate the feed at 1 atmospheric pressure under inert gas (e.g., nitrogen, argon, helium) to a temperature generally from about 900 to about 1100 F and to determine the amount of residue left from a given amount of feed. In another method, a given amount of feed is fed to a small tubular

reactor controlled at a temperature of from about 900 to about 1100 F, optionally along with inert gas and/or steam. The amount of deposit is measured at the end of test (see Example 2). Other standard methods, such as ASTM D4530-07 can be used. ASTM D4530-07 is a method for determining the carbon residue value of the various petroleum materials, which serves as an approximation of the tendency of the material to form carbonaceous type deposits under degradation conditions similar to those used in the test method.

[0022] One preferred feed for the present invention comprises natural gas condensate. Natural gas and crude oil are formed naturally in a number of subterranean geologic formations of widely varying porosities. Many of these formations are capped by impervious layers of rock. Natural gas and crude oil also accumulate in various stratigraphic traps below the earth's surface. Vast amounts of both natural gas and/or crude oil are thus collected to form hydrocarbon bearing formations at varying depths below the earth's surface. Much of this natural gas is in close physical contact with crude oil, and, therefore, absorbed a number of lighter molecules from the crude oil.

[0023] When a well bore is drilled into the earth and pierces one or more of such hydrocarbon bearing formations, natural gas and/or crude oil can be recovered through that well bore to the earth's surface.

[0024] Natural gas, like crude oil, can vary widely in its composition as produced to the earth's surface, but generally contains a significant amount, most often a major amount, i.e., greater than about 50 wt %, methane. Natural gas often also carries minor amounts (less than about 50 wt %), often less than about 20 wt %, of one or more of ethane, propane, butane, nitrogen, carbon dioxide, hydrogen sulfide, and the like. Many, but not all, natural gas streams as produced from the earth can contain minor amounts (less than about 50 wt %), often less than about 20 wt %, of hydrocarbons having from 5 to 20, inclusive, carbon atoms per molecule (C_5 to C_{20}) that are not normally gaseous at generally prevailing ambient atmospheric conditions of temperature and pressure at the earth's surface, and that can condense out of the natural gas once it is produced to the earth's surface. All wt % are based on the total weight of the natural gas stream in question.

[0025] When various natural gas streams are produced to the earth's surface, a hydrocarbon composition often naturally condenses out of the thus produced natural gas stream under the then prevailing conditions of temperature and pressure at the earth's surface where that stream is collected. There is thus produced a normally liquid hydrocarbon condensate separate from the normally gaseous natural gas under the same prevailing conditions. The normally gaseous natural gas can contain methane, ethane, propane, and butane. The normally liquid hydrocarbon fraction that condenses from the produced natural gas stream is generally referred to as "condensate," and generally contains molecules heavier than butane (C_5 to about C_{20} or higher). After separation from the produced natural gas, this liquid condensate fraction is processed separately from the remaining gaseous fraction that is normally referred to as natural gas.

[0026] Condensate, unlike crude oil, can be characterized by way of its boiling point range. Condensates normally boil in the range of from about 100 to about 650 F. With this boiling range, condensates contain a wide variety of hydrocarbon materials. These materials can include compounds that make up fractions that are commonly referred to as naphtha, kerosene, diesel fuel(s), and gas oil (fuel oil, furnace oil,

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heating oil, and the like). Naphtha and associated lighter boiling materials (naphtha) are in the C_5 to C_{10}, inclusive, range, and are the lightest boiling range fractions in condensate, boiling in the range of from about 100 to about 400 F. Petroleum distillates (kerosene, diesel, gas oil) are generally in the C_{10} to about C_{20} or slightly higher range, and generally boil, in their majority, in the range of from about 350 to about 650 F. They are, individually and collectively, referred to herein as "distillate" or "distillates."

[0027] The present invention comprises contacting the hydrocarbon feed with an adsorbent. Any solid material that can preferably adsorb heavy hydrocarbon components from the feed may be used. Examples of suitable adsorbents include carbon, silica, alumina, zeolites, clay (including pillared clays), polymeric resin, and mixtures thereof. Preferred adsorbents include carbon, clay, polymeric resin, and mixtures thereof.

[0028] One preferred class of adsorbents is carbon. Carbon adsorbents include activated carbon, activated coke, and carbon molecular sieves (see "Adsorption," in Ullmann's Encyclopedia of Industrial Chemistry, online edition, 2009). They are highly porous solids which, because of their surface properties, preferentially accumulate heavy hydrocarbon molecules. Their amorphous skeleton consists of microcrystallites with a graphite lattice.

[0029] Activated carbons are produced from organic materials such as wood, peat, coal, and petroleum coke. During manufacture, the particles are first formed, then carbonized at low temperature, and finally activated. The activated carbon can be in a variety of forms, most commonly as powdered, granular or pelleted products. The activated carbon used in the present invention preferably has a surface area of at least 50 m^2/g, more preferably, a surface area of at least 100 m^2/g.

[0030] Polymeric resins are synthetic porous polymers with a large internal surface. For example, AMBERLITE™ XAD™ polymeric adsorbents, available from Dow Chemical Company, are porous spherical polymers based on highly cross-linked, macroreticular polystyrene, aliphatic, or phenol-formaldehyde condensate polymers.

[0031] A treated feed is produced by contacting the hydrocarbon feed with the adsorbent. The hydrocarbon feed may be contacted with the adsorbent in a number of ways, including batch mode and fixed bed mode. Generally, the adsorption is conducted at 40 to 200 F and under a pressure of 0 to 500 psig. In a batch mode, the treated feed is obtained by separating the adsorbent from the liquid hydrocarbon, for example, by filtration. If the adsorption is performed in a fixed-bed mode, it may be conducted either in down flow or up flow. The space velocity is generally in the range of 1 to 100 h^{-1}, preferably 5 to 20 h^{-1}.

[0032] The treated feed has reduced level of heavy components. This can be determined by the measurement methods described in the previous sections of this specification. Generally, the treated feed has reduced color, as measured by, for example, ASTM D1500 method (see Example 1). It is believed that the color of a hydrocarbon feed is due to the presence of polyaromatic compounds, which can cause coking.

[0033] The treated feed is cracked in a steam cracker to produce a reaction mixture comprising hydrogen, ethylene, propylene, butenes, butadiene, and aromatics such as benzene, toluene, and xylenes. A steam cracker includes a pyrolysis furnace for receiving and cracking the feed. Pyrolysis furnaces for steam cracking of hydrocarbons heat by

means of convection and radiation, and comprise a series of preheating, circulation, and cracking tubes, usually bundles of such tubes, for preheating, transporting, and cracking the hydrocarbon feed. The high cracking heat is supplied by burners disposed in the radiant section (sometimes called "radiation section") of the furnace. The waste gas from these burners is circulated through the convection section of the furnace to provide the heat necessary for preheating the incoming hydrocarbon feed. The convection and radiant sections of the furnace are joined at the "cross-over," and the tubes referred to hereinabove carry the hydrocarbon feed from the interior of one section to the interior of the next.

[0034] Pyrolysis furnaces are designed for rapid heating in the radiant section starting at the radiant tube (coil) inlet where reaction rate constants are low because of low temperature. Most of the heat transferred simply raises the hydrocarbons from the inlet temperature to the reaction temperature. In the middle of the coil, the rate of temperature rise is lower but the cracking rates are appreciable. At the coil outlet, the rate of temperature rise increases somewhat but not as rapidly as at the inlet. The rate of disappearance of the reactant is the product of its reaction rate constant times its localized concentration. At the end of the coil, reactant concentration is low and additional cracking can be obtained by increasing the process gas temperature.

[0035] Steam dilution of the feed hydrocarbon lowers the hydrocarbon partial pressure, enhances olefin formation, and reduces any tendency toward coke formation in the radiant tubes.

[0036] Cracking furnaces typically have rectangular fireboxes with upright tubes centrally located between radiant refractory walls. The tubes are supported from their top:

[0037] Firing of the radiant section is accomplished with wall or floor mounted burners or a combination of both using gaseous or combined gaseous/liquid fuels. Fireboxes are typically under slight negative pressure, most often with upward flow of flue gas. Flue gas flow into the convection section is established by at least one of natural draft or induced draft fans.

[0038] Radiant coils are usually hung in a single plane down the center of the fire box. They can be nested in a single plane or placed parallel in a staggered, double-row tube arrangement. Heat transfer from the burners to the radiant tubes occurs largely by radiation where the hydrocarbons are heated to from about 1,450 to about 1,550 F and thereby subjected to severe cracking.

[0039] The initially empty radiant coil is, therefore, a fired tubular chemical reactor. Hydrocarbon feed to the furnace is preheated to from about 900 to about 1,000 F in the convection section by convectional heating from the flue gas from the radiant section, steam dilution of the feed in the convection section, or the like. After is preheating, in a conventional commercial furnace, the feed is ready for entry into the radiant section.

[0040] In a typical furnace, the convection section can contain multiple zones. For example, the feed can be initially preheated in a first upper zone, boiler feed water heated in a second zone, mixed feed and steam heated in a third zone, steam superheated in a fourth zone, and the final feed/steam mixture preheated to completion in the bottom, fifth zone. The number of zones and their functions can vary considerably. Thus, pyrolysis furnaces can be complex and have variable structures.

[0041] The hydrocarbons formed in the radiant section are rapidly reduced in temperature to prevent destruction of the product distribution. Cooling of the cracked gases before further processing of same downstream in the olefin production plant recovers a large amount of energy as high pressure steam for re-use in the furnace and/or the olefin plant. This is often accomplished with the use of transfer-line exchangers (TLE) that are well known in the art.

[0042] Radiant coil designers strive for short residence time, high temperature and low hydrocarbon partial pressure. Coil lengths and diameters are determined by the feed rate per coil, coil metallurgy in respect of temperature capability, and the rate of coke deposition in the coil. Coils range from a single, small diameter tube with low feed rate and many tube coils per furnace to long, large-diameter tubes with high feed rate and fewer coils per furnace. Longer coils can consist of lengths of tubing connected with U-turn bends. Various combinations of tubes can be employed. For example, four narrow tubes in parallel can feed two larger diameter tubes, also in parallel, which then feed a still larger tube connected in series. Accordingly, coil lengths, diameters, and arrangements in series and/or parallel flow can vary widely from furnace to furnace. Furnaces, because of proprietary features in their design, are often referred to by way of their manufacturer.

[0043] Downstream processing of the cracked hydrocarbons issuing from the furnace varies considerably, and particularly based on whether the initial hydrocarbon feed is a gas or a liquid. With a liquid hydrocarbon feedstock downstream processing, although it can vary from plant to plant, typically employs an oil quench of the furnace effluent after heat exchange of same in, for example, the transfer-line exchanger. Thereafter, the cracked hydrocarbon stream is subjected to primary fractionation to remove heavy liquids, followed by compression of uncondensed hydrocarbons, and acid gas and water removal. Various desired products are then individually separated, e.g., ethylene, propylene, a mixture of hydrocarbons having four carbon atoms per molecule, fuel oil, pyrolysis gasoline, and a high purity hydrogen stream.

[0044] Heavy components present in the hydrocarbon feed such as asphaltene and other non-volatile large organic molecules tend to deposit in the convection tubes and form coke. The coke formed in the convection tubes can block the gas flows and reduce heat transfer across the convection tube walls to the feed. As a result, the pyrolysis furnace has to be shut down so the convection tubes can be decoked. Typically, the decoking is performed by feeding an oxygen-containing gas to the convection tube to burn off the coke. This invention removes at least a portion of the heavy components from the feed thus reduces coking in the convection tubes and extends the run length of the cracker.

Example 1. Adsorption In Batch Test

[0045] Alba condensate (78 g) is mixed with K10 montmorillonite clay powder (Aldrich, 7.8 g) in a 250-mL Erlenmeyer flask. The slurry is stirred with a magnetic stirrer bar for 24 h at ambient temperature (approximately 75 F). The mixture is filtered. The color of the filtrate is measured according to ASTM D1500 method. The results are presented in Table 1.

[0046] The above test is repeated with the following adsorbents: Westvaco Nuchar® activated carbon powder (General Filtration, Ontario, Canada), KSF montmorillonite clay powder (Aldrich).

[0047] Significant reduction in color is seen in each test. A change in color indicates that certain moieties had been removed from the condensate by each of these absorbents.

TABLE 1

Sample	Color ASTM D1500
Untreated Alba condensate	3.5
Treated with K10 montmorillonite clay powder	0.3
Treated with Westvaco Nuchar ® carbon	0.2
Treated with KSF montmorillonite clay powder	2.3

Example 2. Fouling Test

[0048] Alba condensate (780 g) and Calgon CAL® 12×40 (0.78 g) is mixed in a 2-L Erlenmeyer flask. The mixture is stirred with a magnetic stirrer bar for 24 h at ambient temperature. The color of the filtrate is measured.

[0049] The filtrate is fed at a rate of 0.2 mL/min co-currently with nitrogen (0.125 standard liters per minute) into an Inconel (600 HT) tube (ID ¼", length 12") maintained at 1000 F with an electric heater. The test is terminated after 6 h. The tube is weighed after it is cooled to room temperature. The amount of deposit is 3.6 mg. The amount of deposit is confirmed by decoking the tube by flowing air to the tube at 1500 F to burn the deposit and measuring the amount of carbon dioxide and carbon monoxide collected. The fouling test is used to simulate the fouling in the convection section of a steam cracker.

[0050] The above procedure is repeated except that 3.92 g Calgon CAL® 12×40 activated carbon is used. The amount of deposit is 2.1 mg. The fouling test is repeated with an untreated Alba condensate. The amount of deposit is 5.3 mg.

[0051] The data in Table 2 show that treating Alba condensate with an activated carbon reduces fouling in the tube reactor.

TABLE 2

Sample	Color ASTM D1500	Deposit (mg)
Untreated Alba condensate	3.5	5.3
Treated by 0.1 wt % Calgon CAL ® 12 × 40	3.0	3.6
Treated by 0.5 wt % Calgon CAL ® 12 × 40	1.3	2.1

Example 3. Fixed Bed Adsorption

[0052] A cylindrical absorption vessel is charged with Calgon CAL® 12×40 activated carbon (63.9 g) to form a bed 3" high and 2" in diameter. The vessel is filled with a Bejaia condensate to wet the carbon. Bejaia condensate is fed to the vessel (down flow) at a rate of 234 g/h. A back-pressure regulator is used to maintain 20 psig pressure in the vessel. The test is conducted at ambient temperature (approximately 75° F.). Samples are collected during at various times.

[0053] The fouling test procedure described in Example 2 is repeated with samples collected from the above fixed-bed test. The results are shown in Table 3. The data show that the activated carbon is effective in reducing the color and fouling of Bejaia condensate.

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TABLE 3

Sample (Hours on stream)	Color ASTM D1500	Deposit (mg)
Untreated Feed	2.2	2.9
3	0.2	0.3
131	0.6	1.0
224	1.0	1.8

We claim:

1. A process, comprising: (a) contacting a liquid hydrocarbon feed with a solid adsorbent to produce a treated feed; and (b) cracking the treated feed to produce a reaction mixture in a steam cracker.

2. The process of claim 1 wherein the treated feed has reduced heavy components compared to the hydrocarbon feed.

3. The process of claim 1 wherein the treated feed has reduced color compared to the hydrocarbon feed, as measured by ASTM D1500.

4. The process of claim 1 wherein the treated feed has reduced carbon residue value as compared to the hydrocarbon feed, as measured by ASTM D4530-07.

5. The process of claim 1 wherein the feed comprises crude oil.

6. The process of claim 1 wherein the feed comprises natural gas condensate.

7. The process of claim 1 wherein the adsorbent is selected from the group consisting of carbon, silica, alumina, zeolites, clay, polymeric resin, and mixtures thereof.

8. The process of claim 1 wherein the adsorbent is selected from the group consisting of carbon, clay, polymeric resin, and mixtures thereof.

9. The process of claim 1 wherein the adsorbent is a carbon.

10. The process of claim 1 wherein the adsorbent is an activated carbon.

11. The process of claim 9 wherein the activated carbon has a surface area of at least 100 m^2/g.

12. The process of claim 1 wherein the adsorbent is a polymeric resin.

13. The process of claim 1 wherein step (a) is conducted in a batch mode.

14. The process of claim 1 wherein step (a) is conducted in a fixed-bed mode.

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