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(54) **SOLVENT DE-ASPALTING WITH CYCLONIC SEPARATION**

LÖSUNGSMITTELENTASPHALTIERUNG MIT ZYKLONENABSCHEIDUNG

DÉSASPALTAGE PAR SOLVANT AVEC SÉPARATION CYCLONIQUE

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Description

[0001] The present invention relates to a method of improving a heavy hydrocarbon, such as bitumen, to a lighter more fluid product and, more specifically, to a final hydrocarbon product that is refinery-ready and meets pipeline transport criteria without the addition of diluent. A solid asphaltene by-product is created for easy handling and further processing. The invention is targeted to enhance Canadian bitumen, but has general application in improving any heavy hydrocarbon.

BACKGROUND OF THE INVENTION

[0002] Refining sweet crude resources require less capital input and have a much lower cost of processing than heavy sour crudes. However, the global availability of light, sweet crude to supply to refineries for the production of transportation fuels is on the decline making the processing of heavy sour crude an increasingly important option to meet the world's demand for hydrocarbon-based fuels.

[0003] Most (if not all) commercial upgraders for processing heavy crude have been built to convert heavy viscous hydrocarbons into crude products that range from light sweet to medium sour blends. Heavy oil upgraders basically achieve this by high intensity conversion processes which either release up to 20% by weight of the feedstock as a coke byproduct and another 5% as off-gas product, or require hydro-processing such as hydrocracking and hydro-treating to maximize the conversion of the heavy components in the feedstock to lighter, lower sulfur liquid products and gas.

Description of Prior Art

[0004] Processes have been disclosed to convert and/or condition Oil Sands bitumen into pipeline transportable and refinery acceptable crude. Of note, thermal cracking, catalytic cracking, solvent deasphalting and combinations of all three (for example, visbreaking and solvent deasphalting) have been proposed to convert bitumen to improve its characteristics for transport and use as a refinery feedstock.

Thermal Cracking

[0005] Visbreaking or viscosity breaking, a form of thermal cracking, is a well known petroleum refining process in which heavy and/or reduced crudes are pyrolyzed, or cracked, under comparatively mild conditions to provide products that have lower viscosities and pour points, thus reducing required amounts of less-viscous and increasingly costly to obtain blending hydrocarbons known as diluent to improve fluidity of the crude, and make the crude meet minimum transport pipeline specifications (minimum API gravity of 19).

[0006] There are two basic visbreaking configurations, the coil-only visbreaker and the coil-and-soak visbreaker. Both require heaters to heat the crude, with the coil-only style employing cracking only in the heater tubes. Coil-only visbreakers operate at about 900°F at the heater outlet with a residence time of about 1 minute. Gas oil is recycled to quench the reaction. In the coil-and-soak visbreaker, a vessel is used at the outlet of a furnace to provide additional residence time for cracking of the crude. The crude sits and continues to crack/react as the temperature slowly reduces. The coil-and-soak visbreaker runs at heater outlet temperatures of 800°F. The soaker drum temperature reduces down to 700°F at the outlet with aggregate residence times of over 1 hour.

[0007] Examples of such visbreaking methods are described in Beuther et al., "Thermal Visbreaking of Heavy Residues", The Oil and Gas Journal. 57:46, Nov 9, 1959, pp. 151-157; Rhoe et al., "Visbreaking: A Flexible Process", Hydrocarbon Processing, January 1979, pp. 131-136; and US Pat. No. 4,233,138. The yield structure is approximately same for either configuration: 1-3% light ends, 5%(wt) naphtha and 15%(vt) gas oil. The remainder remains as heavy oil or bitumen. The products are separated in a distillation column for further processing or blending.

[0008] A concern with standard visbreaking schemes is that for Canadian Bitumen, the operating temperatures are above the limit (around 700°F-720°F) where significant coking impacts operability (Golden and Bartletta, Designing Vacuum Units (for Canadian heavy crudes), Petroleum Technology Quarterly, Q2, 2006, pp. 105). In addition, heat is added over a short period of time in the heater, so local heat fluxes are not uniform and can peak well above coking initiation limits; and the heat is not maintained consistently allowing for condensation reactions to occur. Attempting to apply conventional visbreaking to Canadian Bitumen is limited due to the propensity for coking and inability of these systems to manage this issue.

[0009] In the first part of US Pat. No. 6,972,085 and in patent application US2008/0093259 an attempt is made to address the desire for a constant and sustained application of heat to the crude over an extended period of time. Essentially, the heater and the holding vessel are merged into one vessel to create a continuous heated bath for the crude. Multiple heating levels are applied to the crude at various times. This is an improvement over standard visbreaking but does not eliminate hot spots within the processed crude, permitting coking due to temperature peaks above optimal levels for cracking.

Combination of Thermal/Catalytic Cracking and Solvent Deasphalting

[0010] In U.S. Pat. No. 4,454,023 a process for the treatment of heavy viscous hydrocarbon oil is disclosed, the process comprising the steps of: visbreaking the oil; fractionating the visbroken oil; solvent deasphalting the non-distilled portion of the visbroken oil in a two-stage deasphalting process to produce separate asphaltene, resin, and deasphalted oil fractions; mixing the deasphalted oil ("DAO") with the visbroken distillates; and recycling and combining resins from the deasphalting step with the feedstock initially delivered to the visbreaker. The U.S. '023 patent provides a means for upgrading lighter hydrocarbons (API gravity>15) than Canadian Bitumen but is burdened by the misapplication of the thermal cracking technology that will over-crack and coke the hydrocarbon stream, and by the complexity and cost of a two-stage solvent deasphalting system to separate the resin fraction from the deasphalted oil. In addition, the need to recycle part of the resin stream increases the operating costs and complexity of operation.

[0011] In U.S. Pat. No. 4,191,636, heavy oil is continuously converted into asphaltenes and metal-free oil by hydrotreating the heavy oil to crack asphaltenes selectively and remove heavy metals such as nickel and vanadium simultaneously. The liquid products are separated into a light fraction of an asphaltene-free and metal-free oil and a heavy fraction of an asphaltene- and heavy metal-containing oil. The light fraction is recovered as a product and the heavy fraction is recycled to the hydrotreating step. Catalytic conversion of Canadian heavy bitumen (API gravity<10) using this '636 process is a high-intensity process that tends to have reliability issues with rapid catalyst deactivation impacting selectivity and yield.

[0012] In U.S. Pat. No. 4,428,824, a solvent deasphalting unit is installed upstream of a visbreaking unit to remove the asphaltenes from the visbreaking operation. In this configuration, the visbreaking unit can now operate at higher temperatures to convert the heavier molecules to lighter hydrocarbon molecules without fouling, since the asphaltenes are removed from the product stream entirely. However, the yield of the bitumen is greatly reduced (by 10-15%) since the early removal of the asphaltenes in the process prevents thermal conversion of this portion of the crude into a refinable product.

[0013] As in U.S. Pat. 4,428,824, U.S. Pat No 6,274,032, disclosed a process for treating a hydrocarbon feed source comprising a fractionator to separate the primary crude components, followed by a Solvent Deasphalting (SDA) unit to work on the heavier crude asphaltene rich component, and a mild thermal cracker for the non-asphaltene stream. The asphaltene rich stream is processed in a gasification unit to generate syngas for hydrogen requirements. Placing an SDA unit upstream of a thermal cracker reduces the overall yield of the bitumen as refinery feed, since the asphaltene portion of the crude, comprising up to 15% of Canadian bitumen, is removed from consideration for inclusion in some format as crude. This loss in product yield is not compensated for by the increased cracking in the visbreaker.

[0014] In U.S. Pat. No. 4,686,028 a process for the treatment of whole crude oil is disclosed, the process comprising the steps of deasphalting a high boiling range hydrocarbon in a two-stage deasphalting process to produce separate asphaltene, resin, and deasphalted oil fractions, followed by upgrading only the resin fraction by hydrogenation or visbreaking. The U.S. Pat. No. 4,686,028 invention applies visbreaking to a favourable portion of the whole crude stream to minimize coke generation. However, PAT '028 is limited by missing a large part of the crude that could benefit from optimal conversion and thus a large portion of the crude does not end up as pipeline product without the need of transport diluent.

[0015] In U.S. Pat. No. 5,601,697 a process is disclosed for the treatment of topped crude oil, the process comprising the steps of vacuum distilling the topped crude oil, deasphalting the bottoms product from the distillation, catalytic cracking of the deasphalting oil, mixing distillable catalytic cracking fractions (atmospheric equivalent boiling temperature of less than about 593 degrees C (1100 degrees F)) to produce products comprising transportation fuels, light gases, and slurry oil. U.S. Pat. No. '697 is burdened by the complexity, cost, and technical viability of vacuum distilling a topped heavy crude to about 454°C (850°F) and catalytic cracking the deasphalted oil to produce transportation fuels.

[0016] In U.S. Pat. 6,533,925, a process is described involving the integration of a solvent deasphalting process with a gasification process and an improved process for separating a resin phase from a solvent solution comprising a solvent, deasphalted oil (DAO) and resin. A resin extractor with the solvent elevated in temperature above that of the first asphaltene extractor is included in the '925 invention. The asphaltene stream is treated but removed prior to any thermal conversion eliminating the possibility of obtaining a value uplift into useable refinery feedstock. The impact is a reduction in the potential overall yield of the crude stream.

[0017] In U.S. Patent application 2007/0125686, a process is disclosed where a heavy hydrocarbon stream is first separated into various fractions via distillation with the heavy component sent to a mild thermal cracker (visbreaker). The remaining heavy liquid from the mild thermal cracker is solvent deasphalted in an open art SDA unit. The asphaltenes separated from the SDA are used as feed to a gasifier. The deasphalted oil is blended with the condensed mild thermal cracker vapour to form a blended product. As stated with Pat'023 above, visbreaking faces the challenges of early coke generation. Specifically, the '686 patent application explains that the intent of this mild thermal cracker is to crack the non-asphaltene material exclusively, which is also not practical with Canadian bitumen. In addition, additional energy is required in the distillation steps with most of the separated components being recombined for pipeline transport.

Treatment of SDA generated Asphaltene-Rich Stream

[0018] In US Patent# 4,421,639 a solvent deasphalting process uses a 2nd asphalt extractor to concentrate asphaltene material (and recovery of more deasphalted oil). The concentrated asphalt stream is sent through a heater to get to 218°C (425°F) at 124 kPa (18 psia) and uses a flash drum and stream stripper to separate solvent (in this case propane) from the asphalt stream. Asphalt product, in liquid form, is pumped to storage. This arrangement only works if the asphalt rich stream is liquid at these conditions. It is burdened by plugging if any appreciably solid asphaltenes are present as in asphaltene-rich streams like bitumen.

[0019] In US Patent# 3,847,751, the concentrated asphaltene product from the SDA unit is mixed with solvent to transport as a liquid solution to a spray dryer. The spray nozzle design and pressure drop dictates the size of liquid droplets that are formed. The smaller the light hydrocarbon (solvent) droplet, the faster it will flash completely to vapour. The smaller the heavy hydrocarbon (asphaltene) particle the more surface area available for heat transfer to cool the heavy droplets down with the goal of producing a dry, non-sticky solid particle. Additional cold gas is added to the bottom of the spray dryer to enhance cooling by additional convective heat transfer as well as increasing the droplet residence time by slowing its descent rate (via upward cooling gas flow) in order to reduce the size of the vessel (which tend to be extremely large). This arrangement is not required if the asphaltene particles that have settled out in the extractor are in a solid form in the solvent at the process operating temperature.

[0020] In US Patent# 4,278,529, a process for separating a solvent from a bituminous material by pressure reduction without carry-over of bituminous material is illustrated. The fluid-like phase comprising bituminous material and solvent is reduced in pressure by passage through a pressure reduction valve and introduced into a steam stripper. The pressure reduction vaporizes part of the solvent and also disperses a mist of fine bituminous particles in the solvent. The concern with this approach is that the remaining asphaltene remains wet and sticky and has not enough solvent left to keep the heavy bituminous phase (with many solids) flowable.

[0021] In US PAT# 4,572,781 a solvent deasphalting process for separating substantially dry asphaltenes of high softening point from heavy hydrocarbon material using a centrifugal decanter to separate a liquid phase from a highly concentrated slurry of solid asphaltenes is described. This process attempts to handle a rich asphaltene stream that has solid particles but is a highly costly process since the separation of the solids is done through a solid/liquid separation with additional solvent needed to make the material flow to the decanter. Invariably, the separated solid material is still relatively wet and needs another drying step to recover the solvent as a vapour. The solvent vapour needs to be condensed for re-use, another high energy step.

[0022] In US Patent# 7,597,794, a dispersion solvent is introduced into the asphalt phase after separation by solvent extraction and the asphalt phase undergoes rapid phase change in a gas-solid separator and is dispersed into solid particles while the solvent vaporizes, resulting in low temperature separation of asphalt and solvent with adjustable size of the asphalt particles. The challenge with flash/spray driers using liquid solvent as the transport media is the propensity for the asphaltenes generated in this integrated process to remain wetted before, during and after the flash drying phase. In addition, with this integrated process, the asphaltene continues to liquefy at elevated temperatures. A wetted asphaltene sticks to all surfaces and fouls and plugs the equipment readily. The reduced reliability from using this approach makes this operation costly for heavy crudes with high asphaltenic content.

[0023] In US Patent# 7,964,090 a method for upgrading heavy asphaltenic crudes using SDA and gasification is shared. Of interest in this patent, a stream to a gasifier is generated by mixing a hydrocarbon comprising one or more asphaltenes and one or more non-asphaltenes with a solvent, wherein a ratio of the solvent to the hydrocarbon is about 2:1 to about 10:1. The asphaltene rich stream is transferred out of the SDA to a gasifier as a liquid stream. The large quantities of solvent used in transport are consumed in the gasifier, downgraded in value to a fuel gas equivalent. Since the asphaltenes tend to be liquid, using a solvent to transport the material in the quantities stated is feasible. For a solid asphaltene, this method would require 10-20 times more solvent to transport and this quantity of expensive solvent would be consumed and its value reduced.

[0024] WO 2011/106878 discloses a process for producing a refinery-ready feedstock from heavy crudes.

SUMMARY OF THE INVENTION

[0025] It is to be understood that other aspects of the present invention will become readily apparent to those skilled in the art from the following detailed description, wherein various embodiments of the invention are shown and described by way of illustration. Accordingly the drawings and detailed description are to be regarded as illustrative in nature and not as restrictive.

[0026] The present invention provides a continuous process for producing enhanced refinery feedstock and dry thermally-affected asphaltene solids from heavy hydrocarbon, said process comprising:

(a) pre-heating the heavy hydrocarbon as a process fluid in a heater to a designed temperature;

(b) moving the pre-heated process fluid to a single thermal conversion reactor with an overhead partial condenser to convert asphaltenes in the heavy hydrocarbon process fluid to produce a stream of non-condensable vapour and lighter liquid hydrocarbons, and a second stream of thermally-affected asphaltene-rich fractions from the process fluid; wherein the thermal conversion reactor process conditions are within the following parameters:

- (i) a uniform heat flux of between 22.1-37.9 kW/m² (7000-12000 BTU/hr. sq.ft.) introduced to the process fluid within the reactor;
- (ii) a sweep gas of between 4.8-19.3sm³ of gas/m³ of process fluid (20-80 scf/bbl (gas/process fluid)) is introduced to the process fluid within the reactor;
- (iii) residence time of the process fluid within the reactor of between 40-180 minutes;
- (iv) a substantially uniform temperature of the process fluid of between 357-413°C (675-775°F) in the reactor; and
- (v) a near atmospheric pressure of <345 kPa (<50 psig) in the reactor;

(c) deasphalting the thermally-affected asphaltene rich fractions obtained from step

(b) with a solvent extraction process into a stream of deasphalted oil (DAO) and a second stream containing solid precipitated thermally-affected asphaltene;

(d) separating dry precipitated thermally-affected asphaltene solids from the second stream obtained from step (c) in a vapour-solid separation unit which separates the asphaltene solids from the solvent vapour and gas remaining in the second stream obtained from step (c) using one or more forces, such as centrifugal, gravitational, and inertial, to give a dry, solid asphaltene which contains no more than 20% moisture, wherein said vapour-solid separation unit is selected from a settling chamber, baffle chamber or centrifugal collector;

(e) the refinery feedstock comprising of at least one of the produced streams.

[0027] The bitumen is thermally treated to remove and convert/crack selected asphaltenes, which are then sufficiently separated in a more efficient solvent extraction process, reducing production of coke and isolating undesirable contaminants (like metals, MCR, and remaining asphaltenes).

[0028] Considering the relative complexity and high degree of side chains on the Canadian bitumen asphaltenes, under the operating conditions of the invention disclosed here, the side chains are preferentially cleaved from the core asphaltene molecule to make desired vacuum gas oil to light hydrocarbon range components. The remaining polyaromatic asphaltene cores remain solid at elevated temperatures and pressures above operating conditions and thus separate more readily than non-thermally affected asphaltenes resulting in improved separation processes, such as solvent deasphalting (50) and vapour-solid separation like inertial separation (110).

[0029] Further, the heavier hydrocarbons in the bitumen are also mildly cracked to vacuum gas oil, gasoline and distillate boiling range components, all desirable for separation and conversion in refineries. Any major deviations in temperature and heat flux within the bitumen pool in the reactor will lead to coking and increased gas yield and a reduction in the overall crude yield of the original bitumen, and reduced reliability of the operation, increasing the operating cost of the facility.

[0030] The invention provides an improved method for producing a pipeline-ready and refinery-ready feedstock from heavy, high asphaltene crudes (for example Canadian bitumen), and feedstock, with utility for any virgin or previously processed hydrocarbon stream.

[0031] A sweep gas is deployed in the reactor, and can be preheated to provide a heat flux source other than the reactor's heaters; similarly, the sweep gas assists in the removal of reactor vapour products.

[0032] Deasphalting can be achieved using an open-art solvent extraction process; since the initial process fluid has been separated so that only the heavy asphaltene-rich fractions require deasphalting, extraction processes using high solvent-to-oil ratios are feasible and economical. Improved solvent-extraction performance, using lower solvent to oil ratios and improved DAO yield can be achieved by further concentrating the asphaltene rich fraction before a final extraction step. The process improves on open-art solvent deasphalting utilizing an additional solvent extraction column (rinse column) operating on the asphaltene-rich stream from the primary solvent extraction column to increase pipeline crude recovery and quality.

[0033] The SDA process may allow for some portion of the heavy asphaltene-rich hydrocarbon stream to be recycled and blended with the fresh feed to the reactor.

[0034] The resulting concentrated thermally-affected asphaltenes are successfully processed in a vapour-solid separation unit selected from a settling chamber, baffle chamber or centrifugal collector to generate a dry, solid asphaltene by-product.

[0035] In an embodiment, the refinery feedstock comprises a blend of at least two of the produced streams to be pipeline ready, having an API of greater than 19 degrees gravity, and a viscosity less than 350 Cst at 8°C; one or more of the produced streams is treated to remove olefins.

[0036] In another embodiment, the refinery feedstock comprises one or more of the produced streams, suitable for

diverse refinery types by virtue of its proportion of vacuum residue.

[0037] This disclosure further provides a process where the integrated process is applied to an existing coker-based bitumen upgrader or refinery by accepting as feedstock the upgrader's or refinery's virgin or processed heavy hydrocarbon streams and providing light liquid hydrocarbon, and heavy deasphalted hydrocarbon process streams to the upgrader or refinery.

[0038] In a further embodiment, the integrated process is applied to an existing residue hydrocracking upgrader or refinery by accepting as feedstock the upgrader's or refinery's virgin or processed heavy hydrocarbon streams and providing light liquid hydrocarbon, and heavy deasphalted hydrocarbon process stream to the upgrader or refinery.

[0039] In yet a further embodiment, the integrated process is applied to a new bitumen Upgrader, new "sweet crude" refinery or an existing "sweet crude" refinery in lieu of a coking process by accepting as feedstock the upgrader's or refinery's virgin or processed heavy hydrocarbon streams and providing light liquid hydrocarbon, and heavy deasphalted hydrocarbon process streams to the upgrader or refinery.

BRIEF DESCRIPTION OF THE DRAWINGS

[0040] Referring to the drawings wherein like reference numerals indicate similar parts throughout the several views, several aspects of the present invention are illustrated by way of example, and not by way of limitation, in detail in the figures, wherein:

Fig. 1 is a process diagram for forming a pipeline transportable hydrocarbon product from a heavy hydrocarbon feedstock; and

Fig. 2 is a process diagram pertaining specifically to a cracking process and liquid separation process; and

Fig. 3 is a process diagram for an exemplary solvent de-asphalting process.

Fig. 4 depicts an illustrative application of an integrated mild thermal cracking and improved solvent deasphalting process with an existing upgrader or refinery with a vacuum and/or coking unit according to one or more embodiments described.

Fig. 5 depicts a specific illustrative application from Fig. 4 of an integrated mild thermal cracking and improved solvent deasphalting process fed a vacuum bottoms stream from an existing upgrader or refinery with the various products from the integrated cracker/SDA sent to hydrocracking, resid [residual] hydrocracking and gasification units according to one or more embodiments described.

Units, Streams and Equipment in the Figures

[0041] The lists of Units, Process Streams and Equipment elements provided below are indexed to numbered components in the Figures, and are provided for the readers' reference.

Units in Figure 1

- 10 = Process
- 20 = Feed Heater
- 30 = Reactor
- 40 = Gas Liquid Separator
- 50 = High Performance Solvent Extraction
- 110 = Inertial Separation Unit

Streams in Figure 1

- 12 = Fresh Bitumen Feed
- 14 = Complete feed to heater
- 21 = Feed to Reactor
- 32 = Reactor Overhead

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34 = Reactor bottoms

36 = Sweep Gas to Reactor

5 43 = non-Condensable vapour

44 = Light hydrocarbon liquid from 40

10 52 = DAO

54 = Resin

58 = Asphaltene Rich Stream 60 = Product

15 70 = Resin Recycle

111 = Asphaltene Solids

20 112 = Solvent for Recycle

Units in Figure 2

30 = Reactor - Optimal Asphaltene Conversion Unit -

41 = Overhead Condenser

25 42 = Vapour/Liquid Separator

Streams in Figure 2

30 21 = Feed to Reactor

22 = Energy/Heat addition to Reactor

32 = Reactor Overhead

34 = Reactor bottoms

36 = Sweep Gas to Reactor

35 43 = non-Condensable vapour

44 = Light hydrocarbon liquid from 42

45 = Feed to vapour/liquid separator 42

46 = Light, light hydrocarbon liquid from 42

Equipment in Figure 3-

40 50a = pipe with static mixers (co-current primary extractor)

50b = cooler

45 50c = clarifier/settler

50d = heater

50 50e = rinse column (secondary asphaltene extractor)

50f = resin extractor

50g = solvent extractor

55 Streams in Figure 3-

34 = Feed to SDA unit from reactor bottoms

52 = DAO to product blending

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54 = resin bottoms product to solvent extraction
55 = outlet of co-current pipe/static mixers
56 = feed to clarifier
57 = solvent addition
58 = Asphaltene-Rich stream
59 = clarifier overhead to resin column 61 = clarifier bottoms to rinse column 62 = feed to rinse column
63 = make-up solvent
64 = rinse overhead outlet to resin column
65 = make-up solvent
66 = resin extractor overheads to solvent extractor (50g)
67 = Recovered solvent for reprocessing

Units in Figure 4-

20,30,40 = Mild Thermal Cracker
50,110 = SDA + ISU
200 = Vacuum Unit and/or Catalytic Cracking Unit
300 = Coking or FCC unit or Asphalt Plant
400 = Hydrocracking & Hydrotreating Complex

Streams in Figure 4-

5 = Heavy Hydrocarbon streams
34 = Reactor bottoms
43 = non-Condensable vapour
44 = Light hydrocarbon liquid from reactor 52 = DAO
54 = Resin
111 = Asphaltene Solids
301 = Coker, FCC, light hydrocarbons
302 = Solids
401 = finished transportation products for sale

Units in Figure 5-

20,30,40 = Mild Thermal Cracker
50,110 = SDA + ISU
200 = Vacuum Unit and/or Catalytic Cracking Unit
400 = Hydrocracking & Hydrotreating Complex
500 = Residual Hydrocracker
600 = Gasification Unit

Streams in Figure 5-

5 = Heavy Hydrocarbon streams
34 = Reactor bottoms
43 = non-Condensable vapour
44 = Light hydrocarbon liquid from reactor
52 = DAO
54 = Resin
111 = Asphaltene Solids
205 = Light liquid hydrocarbon from Vacuum unit
301 = Light liquid hydrocarbon from Residual Hydrocracker
302 = Heavy hydrocarbon from Residual hydrocracker bottoms
401 = Finished transportation products for sale

DETAILED DESCRIPTION OF VARIOUS EMBODIMENTS

[0042] The detailed description set forth below in connection with the appended drawings is intended as a description

of various embodiments of the present invention and is not intended to represent the only embodiments contemplated by the inventor. The detailed description includes specific details for the purpose of providing a comprehensive understanding of the present invention. However, it will be apparent to those skilled in the art that the present invention may be practiced without these specific details.

[0043] Figure 1 is a process flow diagram depicting a process 10 for forming a hydrocarbon product 60 from a hydrocarbon feedstock 12, where the final hydrocarbon product 60 has sufficient characteristics to meet minimum pipeline transportation requirements (minimum API gravity of 19) and is a favourable refinery feedstock. A process fluid 14 formed from a feedstock 12 of heavy hydrocarbon can be routed through a heater 20 to heat the process fluid 14 to a desired temperature level before it is routed to a reactor 30 where the process fluid 14 is controlled and maintained while it undergoes a mild controlled cracking process. After the mild cracking process, a light top fraction 32 can be routed from the reactor 30 to a gas liquid condensing separator process 40 and a heavy bottom fraction 34 can be routed to a high performance solvent extraction process 50. Some of the outputs 44 from the gas liquid separation process 40 can be blended with some of the outputs 52, 54 of the high performance solvent extraction process 50 to result in a hydrocarbon product 60 that has sufficient physical characteristics to enable it to meet the required pipeline transport criteria without having to mix the final hydrocarbon product 60 with diluents from external sources, or requiring much reduced volumes of such diluent.

[0044] The feedstock 12 can be a heavy hydrocarbon (virgin or a previously processed stream), such as the heavy hydrocarbon obtained from a SAGD (steam assisted gravity drainage) process, for example Canadian Oil sands bitumen, or from any other suitable source of heavy hydrocarbon. In one aspect, the feedstock 12 can have an API gravity in the range of 0 to 14.

[0045] In one aspect, a recycled portion 70 of the resin stream 54 output from the high performance solvent extraction process 50 can be blended with the incoming feedstock 12 to form the process fluid 14 that passes through process 10. The resin stream may be added to the process fluid in instances in which further crude yield, and/or lighter crude, and/or asphaltene suppression is desired in order to meet treated product characteristic targets. The resin recycle provides the operator with flexibility, through an adjustable flow parameter, to meet production specifications, and allows the plant to handle feedstock variations robustly.

[0046] The resin product 54 from the solvent extraction process 50 will typically have a relatively low API gravity. In one aspect, the API gravity of the resin product 54 can have an API gravity between 0 and 10. Depending on the characteristics of the feedstock 12 and the amount of resin product 54 blended with the feedstock 12, the resulting process fluid 14 can have a range of characteristics and particularly a range of API gravities.

[0047] The process fluid 14 (obtained entirely from the feedstock 12 or formed as a blend of feedstock 12 and resin product 54 from the solvent extraction process 50) can be routed to the heater 20 where the process fluid 14 can be heated to a desired temperature as it passes through the heater 20 before being routed to the reactor 30 to undergo mild thermal cracking. Reactor 30 maintains a consistent fluid temperature through a uniform application of heat throughout the reactor to allow for mild thermal cracking to occur without coking being a concern or detrimental to the operation and/or performance of the reactor.

[0048] In one aspect, the heater 20 will heat the process fluid 14 to a temperature between 357-413°C (675-775°F) before the process fluid 14 is introduced into the reactor 30.

[0049] In the reactor 30, the process fluid 14 (heated to between 357-413°C (675-775°F) by the heater 20) undergoes a mild controlled cracking process. Appropriately located heaters are provided in this reactor 30 to maintain the desired constant temperature generated in heater 20 and to apply uniform heat flux for the fluid 14. The heaters provide indirect heat through any source readily available (electric, heat transfer fluid, radiant etc.). To ensure a uniform heat flux, mixing can be applied to the process fluid on a continuous or intermittent basis.

[0050] The reactor 30 can be operated in a manner, through optimizing primarily five inter-related process variables (Temperature, Pressure, Residence Time, Sweep Gas and Heat Flux), so as to reduce or even prevent coke from forming during the reaction, and minimizing gas production, while also providing optimal conversion of the asphaltene portion of the heavy hydrocarbon to refinery-ready feedstock components.

[0051] The first and second variables involve applying a uniform heat flux between 22.1-37.9 kW/m² (7000-12000 BTU/hr sq.ft) to the entire pool of process fluid in the reactor and maintaining a single operating temperature in the reactor between 357-413°C (675-775°F). This may be achieved by the presence of appropriately sized and located heating devices in the reactor. The number of heaters will be set by calculating the optimal dispersion of heat between any two heaters so as to have a uniform temperature throughout the pool and to avoid peak or spot temperatures significantly higher than the target temperature in the reactor.

[0052] The third reactor variable, residence time, can be between 40-180 minutes in the reactor.

[0053] The fourth reactor variable, operating pressure, can be maintained at near atmospheric pressure, in any case, to be less than 345 kPa (50 psig) with standard pressure control principles used for consistent performance. The pressure range is controlled on the low end to prevent excessive, premature flashing of hydrocarbon, essentially bypassing the reactor, and limited on the high end to reduce secondary cracking and consequent increased gas yields.

[0054] The fifth reactor variable, hot sweep gas 36, in the same temperature range as the process fluid 357-413°C (675-775°F) 21, is added to the process fluid 14 in the reactor 30 in the range of 4.8-19.3 sm³/m³ (20-80 scf/bbl).

[0055] The sweep gas 36 can be natural gas, hydrogen, produced/fuel gas from the process, steam, nitrogen or any other non-reactive, non-condensable gas that will not condense to a liquid.

[0056] Sweep gas in the dosage of 4.8-19.3 sm³/m³ (20-80 scf/bbl) of feed is provided to remove the "lighter" hydrocarbon products (i.e. methane to <399°C (<750°F) boiling point hydrocarbons) as soon as they are formed in the reactor 30 so that there is a minimum of secondary cracking which could increase gas make and potentially increase olefinic naphtha/distillate production.

[0057] The sweep gas may also allow the reactor to operate closer to the desired operating pressure <345 kPa (<50 psig) and temperature. The sweep gas 36 can also be used to provide additional heat and/or mixing to the process fluid 14 in the reactor 30.

[0058] As discussed with respect to Figures 1 and 2, the heat energy stream 22, for reactor 30 is uniformly 22.1-37.9 kW/m² (7000-12000 BTU/hr sq.ft) applied throughout the hydrocarbon residence time (40-180 minutes) in the reactor at the desired temperature 357-413°C (675-775°F) and pressure (less than 345 kPa (50 psig)) to minimize any local peak fluid temperatures which can initiate coking, and thereby allowing an increased thermal transfer of heat at a higher bulk temperature improving the conversion of hydrocarbons within reactor 30. At these operating conditions, the reaction kinetics favour optimum conversion of the asphaltenes that preferentially cleaves the outlying hydrocarbon chains creating desirable hydrocarbons (VGO and diesel range hydrocarbons) for the refiner without causing coking or increased gas production in the reactor. As an example, Table 4 illustrates different configurations of asphaltenes for different types of crudes. The proposed operating conditions of reactor 30 factor in the relative complexity and high degree of side chains on different crudes.

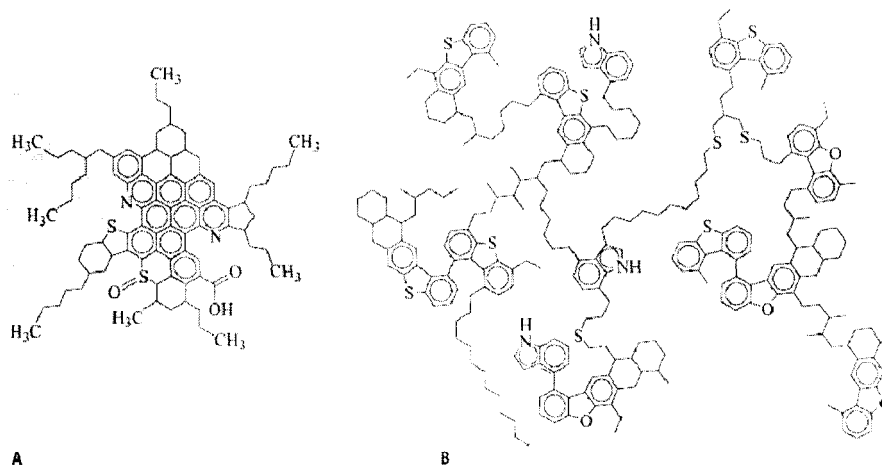


Table 4 - Average molecular structures representing asphaltene molecules from different sources: A, asphaltenes from traditional heavy crudes; B, asphaltenes from Canadian bitumen (Sheremata et al., 2004).

[0059] Each variable may be changed independently, within the ranges suggested, based on the quality of feedstock provided or based on the quality of output desired. Since the 5 noted process variables are inter-related, a multi-variable process control scheme with a prescribed objective function (maximum yield to meet minimum product specifications) will be beneficial to ensure the process operates at an optimal point when any one of the variables is changed or the feed/product situation is altered.

[0060] Once the process fluid 14 has remained in the reactor 30 for a sufficient amount of time so that the characteristics of the outputs of the reactor 30 reach desired qualities, a light overhead fraction 32 and a heavy bottoms fraction 34 can be removed from the reactor 30.

[0061] The light overhead fraction 32 of the output from the reactor 30 can contain non-condensable vapor products, light liquid hydrocarbon and heavier liquid hydrocarbon. The vapor products can be vapors released from the process fluid 14, such as sour gas, while undergoing thermal cracking, as well as introduced and unconverted or unused sweep gas 36 that has passed through the reactor 30.

[0062] The overhead liquid fraction 32 will have a much higher API gravity than the bottom fraction 34. For example, the overhead liquid fraction 32 could typically have an API gravity of 26 or greater. The overhead fraction 32 can be directed to a gas liquid separation unit 40, which can comprise a cooler 41 and separation drum 42, as an example, in which a portion of the overhead fraction 32 that is a condensable liquid product containing naphtha and heavier hydrocarbons can be separated from the gaseous components of the overhead fraction 32. An off-gas line 43 containing

undesirable gases such as sour gas, can be provided at the separation drum 42 for those gases to be disposed of, recycled, or subjected to further treatment.

[0063] One or more liquid hydrocarbon streams can be produced from separation drum 42. Stream 44, a heavier hydrocarbon than stream 46, can be sent to product blending, while stream 46 can be considered for further bulk hydro-

treating prior to product blending.

[0064] The bottom fraction 34 can contain hydrocarbons, and modified asphaltenes. Although the characteristics of the bottom fraction 34 taken from the reactor 30 will vary depending on the process fluid 14 input into the reactor 30 and the reactor's operating parameters, in one aspect the bottom fraction 34 can have an API gravity ranging between -5 and 5.

[0065] Controllable process variables allow an operator to vary the performance of the reactor 30 to meet the needs of the final product based on changing characteristics of the incoming process fluid 14.

[0066] The controllability of the five inter-related variables, residence time, sweep gas, heat flux, temperature and pressure in the reactor 30 allow an operator to vary the performance of the reactor 30.

[0067] In this manner, when the characteristics of the feedstock 12 are changed either as different fresh feed or more or less resin recycle 70, the five inter-related process variables can be optimized to avoid the production of coke and minimize the production of non-condensable vapors are produced in the reactor 30. For example, the operator can vary the residence time of the process fluid 14 in the reactor 30 based on the characteristics of the process fluid 14 to obtain the desired yields and/or quality of the outputs 32, 34. Alternatively, the operator can vary the sweep gas, temperature or pressure to achieve similar outcomes. The process variables are inter-related and the minimization of coke and avoidance of excess gas make is challenging and is best determined by pilot operations.

[0068] The bottom fraction 34 from the reactor 30 can be fed to a high performance solvent extraction process 50 that can produce a thermally affected asphaltene stream 58, an extracted oil stream 52 and a resin stream 54. The reactor 30 is operated in a manner that significantly limits and even prevents the formation of coke and reduces gas production while converting asphaltenes into more suitable components for downstream processing. Consequently, modified asphaltenes and other undesirable elements remain in the bottom fraction 34 that is removed from the reactor 30.

[0069] To maximize the recovery of the desirable refinery feedstock crude the undesirable elements that remain in the bottom fraction 34, the bottom fraction 34 from the reactor 30 must be further treated using, for example, a high performance solvent extraction process 50. The treatment of the bottom fraction 34 by solvent extraction process 50 allows the reactor 30 and the solvent extraction process 50 to be used in conjunction, to produce a suitable full range refinery feedstock crude.

[0070] The solvent extraction process 50 can comprise any suitable solvent extraction process. In one aspect, it can be a three stage super-critical solvent process that separates the asphaltenes from the resins in the bottom fraction 34. The output of the solvent extraction process 50 can be an asphaltene stream 58, an extracted oil stream 52 and a resin stream 54. The asphaltene stream 58 is typically undesirable and is removed from the process 10. The extracted oil stream 52 can be of a relatively high quality, with an API gravity range of 9 to 15. The resin stream 54 is typically of a lower quality than the extracted oil stream 52, with an API gravity lower than the extracted oil stream 52. In one aspect, the resin stream 54 can have an API gravity in the range of 0 to 10 API gravity.

[0071] The extracted oil stream 52 and the resin stream 54 from the solvent extraction process 50 can be blended along with the liquid product stream 44 obtained from the liquid gas separator 40 to form a final hydrocarbon product 60 meeting the specifications of the pipeline and/or the refinery. In one aspect, this final hydrocarbon product 60 would have an API gravity greater than 19. Typically, the final hydrocarbon product 60 would have a viscosity of 0.00035 m²/s (350 centiStokes "cSt") or less. Hydrotreating may be applied to the blended stream 60 in the event olefins need to be reduced to meet a specific pipeline and/or refinery specification.

[0072] The resin stream 54 is typically of a lesser quality than the extracted oil stream 52. The recycle portion 70 of the resin stream 54 can be blended with the feedstock 12 to be reprocessed in order to form the final hydrocarbon product 60. As a result, this recycling portion of the resin stream will improve the quality of the final hydrocarbon product 60.

[0073] In another aspect, to increase overall recovery of product hydrocarbon from reactor 30 and reduce solvent circulation rates, a high-performance solvent extraction process 50 may include a supplemental extraction process step, rinse column 50e, upstream of the asphaltene stream 58. Instead of sending stream 61, the bottoms of the primary extractor 50c, to an asphaltene stripper or spray dryer as is the case in conventional SDA units known in the art, stream 61 can be sent to a secondary solvent extraction column. Conventionally, additional solvent extraction is performed on the primary deasphalted oil, in the form of a resin extractor 50f, to provide a separate deasphalted heavy oil stream 66. The additional solvent extraction step on the asphaltene-rich stream by rinse column 50e as shown in figure 3 uses standard liquid-liquid extraction with the same solvent used in the primary extractor. The placement of this standard liquid-liquid column on the asphaltene-rich stream is unique and is beneficial, since the solvent to oil ratio can be economically increased within this column up to 20:1 to increase the recovery of deasphalted oil, while the overall solvent use is reduced. Solvent in stream 63 is added to the asphaltene-rich stream 61 to a very high solvent to oil ratio and is cooled further to enhance asphaltene precipitation and thus oil recovery within column 50e. The deasphalted oil stream 64, is sent to the resin extractor 50f, to be further refined for product blending. The bottoms stream, comprising concen-

trated thermally-affected asphaltenes and solvent, from the rinse column 50e becomes stream 58, and is sent for solvent recovery via distillation, stripping or flash drying.

[0074] Overall solvent use to achieve high hydrocarbon recovery in stream 60 can be 25% less than using comparable open art processes. To obtain desired yields of 99+% DAO (deasphalted oil) recovery in stream 60 while still meeting pipeline and refinery specifications, typical 3-stage extraction processes require solvent to oil ratios in the 8-9:1 range for Canadian Oil Sands bitumen (www.uop.com). As an example, for a 60,000 BPD bitumen flow, the minimum solvent needed is 480,000-540,000 BPD. Using the rinse column 50e arrangement helps to reduce the total solvent circulated since the process step specifically targets the molecules (asphaltenes) that need to be separated from the desired crude (heavy oil). A solvent-to-oil ratio of 3-4:1 in the main extractor 50 a.b.c is only needed (240,000 BPD) to precipitate all of the thermally affected asphaltenes with minimum DAO entrainment. The rinse column, 50e, will have a feed of approximately 6,000 BPD of asphaltene-based components and 750-1000 BPD of crude. A solvent to oil ratio of 15-20:1 in the rinse column 50e would extract the remaining crude requiring up to 140,000 BPD of additional solvent. The total solvent circulated is 380,000 BPD with the rinse column configuration shown as 50e, resulting in a 25% reduction in the amount of solvent circulated. The result is a significant reduction in energy consumption compared to a state of the art 3-stage extraction process. This high performance solvent extraction scheme, including column 50e, can be applied to an existing open-art solvent extraction scheme in operation to further increase crude yield and/or reduce operating costs by reducing total solvent circulation. In another aspect, the new scheme can be used as an improvement to designs in heavy oil recovery that would normally use state-of-the-art solvent deasphalting.

[0075] The resulting asphaltene stream 58 can be processed in a 20% smaller asphaltene separation unit, 110. The core portion of the remaining concentrated thermally-affected asphaltenes are solid even at elevated temperatures (above 371°C (700°F)) with the side hydrocarbon chains removed, resulting in less volume for the asphaltene separation unit to handle. In addition, the modified nature of the asphaltenes provides for the opportunity for more effective metals reclamation and better feedstock for a clean energy conversion technology (e.g. gasification, catalytic gasification, oxy-combustion for enhanced SAGD production).

[0076] The vapour-solid (e.g. inertial) separation unit, 110, separates the asphaltene solids from the solvent vapour and gas remaining in stream 58 using one or more forces, such as centrifugal, gravitational, and inertial. These forces move the asphaltene solid to an area where the forces exerted by the gas stream are minimal. The separated solid asphaltene is moved by gravity into a hopper, where it is temporarily stored. Unit 110 can be either a settling chamber, baffle chamber or centrifugal collector; a device that provides separation of solid and gas. Centrifugal collectors can either be single or multi-staged cyclones. In the event the SDA unit, 50, is overly effective in separating the asphaltenes from the resin, DAO and solvent, stream 58 can be injected with suitable low molecular weight gas (ex. Natural gas, or nitrogen) to provide pneumatic conveyance to the asphaltene solids, that otherwise would be provided by flashing solvent in the line. A pneumatic conveying system may transport solids up to approximately 50 mm size. The solid must be dry, with no more than 20% moisture and not sticky. The thermally-affected asphaltene solids meet the above criteria and thus the process benefits from the ability to use an inertial separation unit, 110.

[0077] In a pneumatic conveying system, most of the energy is used for the transport of the gas itself. The energy efficiency of a pneumatic conveying plant is therefore relatively low, but this is often outweighed by easy handling and, in well designed systems, dust free solutions. In general the length of a pneumatic system should not extend 300 m for each pneumatic unit. The products can be conveyed over long distances by connecting the systems in series. There are three basic designs of pneumatic transport systems that can be considered for transporting stream 58 to unit 110:

- dilute phase conveying at a high gas speeds (e.g. 20 - 30 m/s)
- strand conveying at a limited gas speeds (e.g. 15 - 20 m/s)
- dense phase conveying at a low gas speeds (e.g. 5 - 10 m/s)

[0078] Process 10 provides a crude feedstock that is pipeline compliant and is optimal for high conversion refiners. Stream 60 has low metals (<20 wppm Ni+V), low asphaltenes (<0.3 wt%), a very low TAN number (<0.3 mg KOH/mg), no diluent, and is high in VGO range material (30-50% of crude). For high conversion refiners (>1.4:1 conversion to coking), the distillation quality of the crude produced in stream 60 will improve utilization of the highest profit-generating units while filling out the remaining units. Table 5 shows the distillation curve of a representative feedstock (dilbit) and the produced refinery-ready feedstock which is a well-balanced crude when compared to other heavy refinery feedstock crudes such as WCS (Western Canada Select). WCS has more heavy residue (510+°C (950+°F) material) requiring intense conversion and more light material than refiners can profitably refine to transportation fuels.

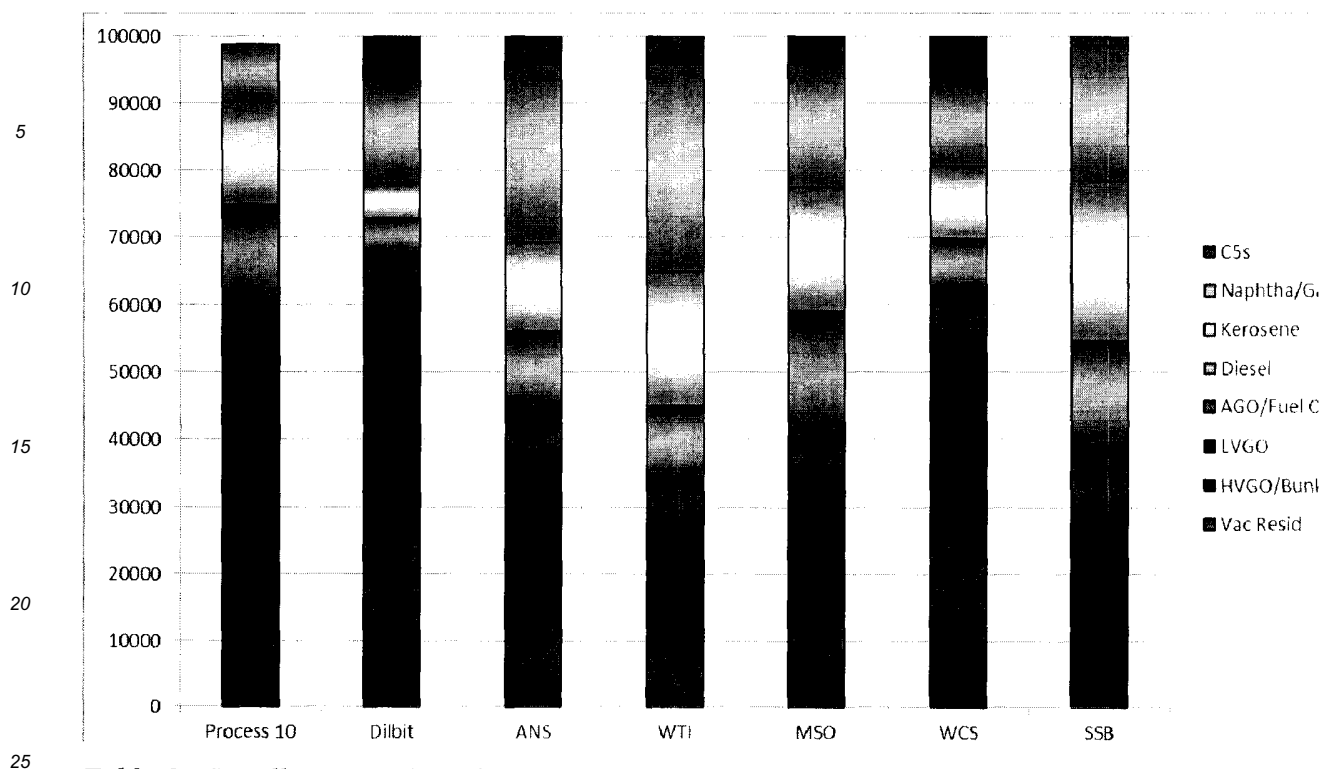


Table 5 – Distillation analysis for various crudes including Process 10 Product

[0079] The combination of reactor 30, high performance solvent extraction process unit 50, and vapour-solid (e.g. inertial) separation unit, 110, exhibits a reduced process complexity. This may be expressed as a Nelson complexity index value of 4.0-4.5, significantly less than 9.0-10.0 for a coking and/or hydroprocessing scheme. Another illustration of improved performance is the reduced energy requirement of 3.93 GJ/tonne feed when compared to a delayed coking process that requires an energy input of 4.70 GJ/tonne feed to operate. This is a 16.4% reduction in energy intensity compared to a delayed coking process. This corresponds to a specific greenhouse gas (GHG) output of 0.253 tonne CO₂/tonne feed for the Delayed Coking process and 0.213 tonne CO₂/tonne feed for the proposed process. On a product comparison basis, the energy reduction is approximately 25-27% versus a coking process.

[0080] When compared to a coking upgrading process and standard reactor and solvent extraction process, process 10 provides a significant improvement in yield by minimizing by-products (Coke and non-condensable hydrocarbons) as noted in Table 6.

Table 6 - Product (stream 60) yield comparison

	Volume %	Mass %
Coking	80-84	78-80
Standard reactor/solvent extraction process	86	80-82
Process 10	>88	83-85

[0081] As well as being suitable for new grassroots facilities, Figure 4 shows an illustrative application of the integrated controlled thermal cracker and improved SDA to an existing upgrader. The proposed integrated process, reactor 20, improved SDA 50, and asphaltene recovery, 110, can be placed upstream of a refiner's/upgrader's coking unit. The benefit to a refiner/upgrader is the ability to debottleneck the vacuum and coking unit and accept more heavy crude to the unit. More barrels processed on existing equipment equates to larger profits and economic returns. In addition, with a higher quality material being sent to the coking unit, 300, the operating severity can be decreased, increasing the life of the coker by increasing the cycle time for the coker (from 12 to 24 hours), and producing less gas and coke and more product. Capital costs to replace equipment can be delayed and an increased yield can be realized (approx. 2-3%). The solid asphaltenes captured in the SDA have a readily available disposition, stream 302, the existing coke gathering and transport systems making the addition of the proposed integrated process more cost effective and highly profitable.

[0082] Stream 5 can be the bottoms streams from an atmospheric column, vacuum column, or a catalytic cracking unit, noted as unit 200 in Figure 4. The integrated cracker and SDA process produces a DAO stream, 52, that can be further processed into transportation fuels, stream 401, in a hydrocracking and hydrotreating complex, unit 400. The integrated cracker and SDA process also can produce a resin quality stream, 54, that can be sent to a coking, FCC (fluidized catalytic cracking) and/or an asphalt plant for further processing into finished products. As stated previously, the solid asphaltenes generated as stream 111, can either be mixed with the coke generated in unit 300 or sent off-site for further processing (energy generation and/or sequestration).

[0083] As an example, Figure 5 shows a specific embodiment for a new design or revamp opportunity for a refinery and/or upgrader. Unit 200 is a vacuum unit and the bottoms stream 5 is sent to the integrated cracker/SDA process, units 20,30,40,50,110. The DAO stream, 52, is sent to the hydrocracking and hydrotreating unit, 400, along with stream 205 from the vacuum unit. A resin stream, 54, is produced from unit 50, and sent to a residue hydrocracking unit, 500. With less asphaltenes, that are highly exothermic when reacted, sent to unit 500, the residue hydrocracker can run at higher conversions (+8-15%) producing more material as final transportation fuel product. The solid asphaltene stream, 111, from unit 110 can be sent to the gasification unit for hydrogen generation.

[0084] As in Figure 4, the benefits of adding the integrated unit in Figure 5 are:

1. Maximum yield of incoming crude to plant.
2. Debottlenecking, if existing, or reduction of coking unit size
3. Debottlenecking, if existing, or reduction of residue hydrocracking size
4. Debottlenecking, if existing, or reduction of gasification unit size
5. Overall carbon footprint reduced for complex.

[0085] The integrated process in Figure 3 can also can help sweet, low complexity (hydro-skimming) refiners take heavier, cheaper crudes which are more readily available, and thus reposition assets to capture more value. The integrated process can be placed at the front of the refinery to provide the initially conditioning of the heavier crude.

[0086] The previous description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the present invention. Various modifications to those embodiments will be readily apparent to those skilled in the art. Thus, the present invention is not intended to be limited to the embodiments shown herein, but is to be accorded the full scope consistent with the claims, wherein reference to an element in the singular, such as by use of the article "a" or "an" is not intended to mean "one and only one" unless specifically so stated, but rather "one or more". All structural and functional equivalents to the elements of the various embodiments described throughout the disclosure that are known or later come to be known to those of ordinary skill in the art are intended to be encompassed by the elements of the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims.

Claims

1. A continuous process for producing enhanced refinery feedstock and dry thermally-affected asphaltene solids from heavy hydrocarbon, said process comprising:

(a) pre-heating the heavy hydrocarbon as a process fluid in a heater to a designed temperature;
 (b) moving the pre-heated process fluid to a single thermal conversion reactor with an overhead partial condenser to convert asphaltenes in the heavy hydrocarbon process fluid to produce a stream of non-condensable vapour and lighter liquid hydrocarbons, and a second stream of thermally-affected asphaltene-rich fractions from the process fluid; wherein the thermal conversion reactor process conditions are within the following parameters:

- (i) a uniform heat flux of between 22.1-37.9 kW/m² (7000-12000 BTU/hr. sq.ft.) introduced to the process fluid within the reactor;
- (ii) a sweep gas of between 4.8-19.3m³ of gas/m³ of process fluid (20-80 scf/bbl (gas/process fluid)) is introduced to the process fluid within the reactor;
- (iii) residence time of the process fluid within the reactor of between 40-180 minutes;
- (iv) a substantially uniform temperature of the process fluid of between 357-413°C (675-775°F) in the reactor; and
- (v) a near atmospheric pressure of <345 kPa (<50 psig) in the reactor;

(c) deasphalting the thermally-affected asphaltene rich fractions obtained from step (b) with a solvent extraction process into a stream of deasphalted oil (DAO) and a second stream containing solid precipitated thermally-

affected asphaltene;

(d) separating dry precipitated thermally-affected asphaltene solids from the second stream obtained from step (c) in a vapour-solid separation unit which separates the asphaltene solids from the solvent vapour and gas remaining in the second stream obtained from step (c) using one or more forces, such as centrifugal, gravitational, and inertial, to give a dry, solid asphaltene which contains no more than 20% moisture, wherein said vapour-solid separation unit is selected from a settling chamber, baffle chamber or centrifugal collector;

(e) the refinery feedstock comprising of at least one of the produced streams.

2. The process of claim 1, wherein the sweep gas is nitrogen, steam, hydrogen and/or a light hydrocarbon.

3. The process of claim 1, wherein the sweep gas is preheated.

4. The process of claim 1, wherein the heat flux is delivered in the thermal reactor by one or more heating devices appropriately located to obtain substantially uniform in-reactor process fluid temperatures.

5. The process of claim 1, wherein a recycle stream of resin collected from the deasphalting process of step (c) is mixed with the feedstock upstream of the reactor to form the process fluid.

6. The process of claim 1, wherein the refinery feedstock comprises a blend of at least two of the produced streams to be pipeline ready, having an API of greater than 19 degrees gravity (0.94 specific gravity) and a viscosity less than 0.00035 m²/s (350 cst) at 8°C.

7. The process of claim 6, wherein one or more of the produced streams is treated to remove olefins.

8. The process of claim 1, wherein step (d) comprises an additional step of pneumatically transporting and handling the resulting dry thermally-affected asphaltene solids.

9. The process of claim 8, where transport gas is added to the second stream obtained from step (c) to enable and enhance pneumatic conveyance to the vapour-solid separator.

10. The process of claim 9, wherein transport gas for pneumatic conveyance can be any suitable light molecular weight gas.

11. The process of claim 1, wherein the heavy hydrocarbon preheated in step (a) is a virgin or processed heavy hydrocarbon stream provided by an existing coker-based bitumen upgrader or refinery and wherein the light liquid hydrocarbon produced in step (b) of the process and the stream of heavy deasphalted oil (DAO) produced in step (c) of the process are provided back to the upgrader or refinery.

12. The process of claim 1, wherein the heavy hydrocarbon preheated in step (a) is a virgin or processed heavy hydrocarbon stream provided by an existing residue hydrocracking upgrader or refinery and wherein the light liquid hydrocarbon produced in step (b) of the process and the stream of heavy deasphalted oil (DAO) produced in step (c) are provided back to the upgrader or refinery.

13. The process of claim 1, wherein the heavy hydrocarbon preheated in step (a) is provided from a new bitumen upgrader and wherein the light liquid hydrocarbon produced in step (b) of the process and the stream of heavy deasphalted oil (DAO) produced in step (c) of the process are provided back to the upgrader.

14. The process of claim 1, wherein the heavy hydrocarbon preheated in step (a) is a virgin or processed heavy hydrocarbon stream provided from a new or existing "sweet crude" refinery and wherein the light liquid hydrocarbon stream produced in step (b) of the process and the stream of heavy deasphalted oil (DAO) produced in step (c) of the process are provided back to the refinery.

Patentansprüche

1. Kontinuierliches Verfahren zur Herstellung eines verbesserten Raffinerie-Einsatzmaterials und von trockenen, thermisch beanspruchten Asphaltenfeststoffen aus schwerem Kohlenwasserstoff, wobei das Verfahren Folgendes umfasst:

(a) Vorerhitzen des schweren Kohlenwasserstoffs als Prozessfluid in einem Erhitzer auf eine ausgelegte Temperatur;

(b) Transportieren der vorgewärmten Prozessflüssigkeit zu einem einzelnen thermischen Umwandlungsreaktor mit einem Teilkopfcondensator, um Asphaltene in der schweren Kohlenwasserstoff-Prozessflüssigkeit umzuwandeln, um einen Strom aus nicht kondensierbarem Dampf und leichteren flüssigen Kohlenwasserstoffen und einen zweiten Strom aus thermisch beanspruchten asphaltenreichen Fraktionen aus der Prozessflüssigkeit herzustellen;

wobei die thermischen Umwandlungsreaktor-Prozessbedingungen innerhalb der folgenden Parameter liegen:

- (i) gleichmäßiger Wärmefluss zwischen 22,1 und 37,9 kW/m² (7000 bis 12000 BTU/Std. Quadratfuß), eingeführt in die Prozessflüssigkeit innerhalb des Reaktors;
- (ii) ein Spülgas zwischen 4,8 und 19,3 sm³ von Gas/m³ der Prozessflüssigkeit (20-80 scf/bbl (Gas/Prozessflüssigkeit)) wird in die Prozessflüssigkeit innerhalb des Reaktors eingeführt;
- (iii) Verweilzeit der Prozessflüssigkeit innerhalb des Reaktors zwischen 40 und 180 Minuten;
- (iv) eine im Wesentlichen einheitliche Temperatur der Prozessflüssigkeit zwischen 357 bis 413 °C (675 bis 775 °F) im Reaktor; und
- (v) nahe Atmosphärendruck von <345 kPa (<50 psig) im Reaktor;

(c) Entasphaltieren der aus Schritt (b) erhaltenen, thermisch beanspruchten, asphaltenreichen Fraktionen mit einem Lösungsmittelextraktionsverfahren in einen Strom aus entasphaltiertem Öl (DAO) und einen zweiten Strom, der festes, ausgefälltes, thermisch beanspruchtes Asphalt enthält;

(d) Abtrennen von trockenen, ausgefällten, thermisch beanspruchten Asphaltfeststoffen aus dem zweiten Strom, der aus Schritt (c) in einer Dampf-Feststoff-Trenneinheit erhalten wurde, die die Asphaltfeststoffe aus dem Lösungsmitteldampf und aus dem Gas, das in dem zweiten Strom verbleibt, der aus Schritt (c) erhalten wurde, unter Einsatz einer oder mehrerer Kräfte erzielt wie Zentrifugal-, Gravitations- und Inertialkräfte, um ein trockenes festes Asphalt zu erhalten, das nicht mehr als 20 % Feuchtigkeit enthält, wobei die Dampf-Feststoff-Trenneinheit aus einer Absetzkammer, einer Ablenkammer oder einem Zentrifugalsammler ausgewählt ist;

(e) das Raffinerie-Einsatzmaterial, das wenigstens einen der erzeugten Ströme umfasst.

2. Verfahren nach Anspruch 1, wobei das Spülgas Stickstoff, Dampf, Wasserstoff und/oder ein leichter Kohlenwasserstoff ist.

3. Verfahren nach Anspruch 1, wobei das Spülgas vorgewärmt wird.

4. Verfahren nach Anspruch 1, wobei der Wärmefluss in dem thermischen Reaktor durch eine oder mehrere Heizvorrichtungen geliefert wird, die geeignet angeordnet sind, um im Wesentlichen einheitliche Flüssigkeitstemperaturen im Reaktor zu erhalten.

5. Verfahren nach Anspruch 1, wobei ein Rückführstrom aus Harz aus dem Entasphaltierungsverfahren von Schritt (c) mit dem Einsatzmaterial stromaufwärts des Reaktors gemischt wird, um die Prozessflüssigkeit zu bilden.

6. Verfahren nach Anspruch 1, wobei das Raffinerie-Einsatzmaterial eine Mischung aus wenigstens zwei der erzeugten Ströme, die bereit für die Rohrleitung sein sollen, mit einem API-Grad von über 19 (0,94 spezifisches Gewicht) und einer Viskosität von unter 0,00035 m²/s (350 cst) bei 8 °C umfasst.

7. Verfahren nach Anspruch 6, wobei einer oder mehrere der erzeugten Ströme behandelt werden, um Olefine zu entfernen.

8. Verfahren nach Anspruch 1, wobei Schritt (d) einen zusätzlichen Schritt des pneumatischen Transports und der Handhabung der erzeugten trockenen, thermisch beanspruchten Asphaltfeststoffe umfasst.

9. Verfahren nach Anspruch 8, bei dem dem zweiten Strom, der aus Schritt (c) erhalten wird, Transportgas zugeführt wird, um die pneumatische Beförderung zur Dampf-Feststoff-Trenneinheit zu ermöglichen und zu verbessern.

10. Verfahren nach Anspruch 9, wobei das Transportgas zur pneumatischen Beförderung jedes geeignete Gas mit geringem Molekulargewicht sein kann.

11. Verfahren nach Anspruch 1, wobei der in Schritt (a) vorgewärmte schwere Kohlenwasserstoff ein reiner oder bear-

beiteter schwerer Kohlenwasserstoffstrom ist, der von einem vorhandenen kokereibasierten Bitumenveredler oder einer Raffinerie bereitgestellt wird, und wobei der in Schritt (b) des Verfahrens erzeugte leichte flüssige Kohlenwasserstoff und der in Schritt (c) des Verfahrens erzeugte Strom von schwerem entasphaltiertem Öl (DAO) dem Veredler oder der Raffinerie wieder zugeführt wird.

12. Verfahren nach Anspruch 1, wobei der in Schritt (a) vorgewärmte schwere Kohlenwasserstoff ein reiner oder bearbeiteter schwerer Kohlenwasserstoffstrom ist, der von einem vorhandenen Rückstand-Hydrocrack-Veredler oder einer Raffinerie bereitgestellt wird, und wobei der in Schritt (b) des Verfahrens erzeugte leichte flüssige Kohlenwasserstoff und der in Schritt (c) des Verfahrens erzeugte Strom von schwerem entasphaltiertem Öl (DAO) dem Veredler oder der Raffinerie wieder zugeführt wird.

13. Verfahren nach Anspruch 1, wobei der in Schritt (a) vorgewärmte schwere Kohlenwasserstoff aus einem neuen Bitumenveredler bereitgestellt wird und der in Schritt (b) des Verfahrens erzeugte leichte flüssige Kohlenwasserstoff und der Strom aus schwerem entasphaltiertem Öl (DAO), das in Schritt (c) des Prozesses erzeugt werden, dem Veredler zurückgegeben werden.

14. Verfahren nach Anspruch 1, wobei der in Schritt (a) vorgewärmte schwere Kohlenwasserstoff ein reiner oder bearbeiteter schwerer Kohlenwasserstoffstrom ist, der aus einer neuen oder vorhandenen Sweet-Crude-Raffinerie bereitgestellt wird, und wobei der in Schritt (b) des Prozesses erzeugte leichte flüssige Kohlenwasserstoffstrom und der in Schritt (c) des Prozesses erzeugte Strom von schwerem entasphaltiertem Öl (DAO) wieder der Raffinerie zugeführt werden.

Revendications

1. Procédé continu pour la production d'une charge d'alimentation de raffinerie améliorée et d'asphaltènes solides secs thermiquement affectés à partir d'hydrocarbures lourds, ledit procédé comprenant :

(a) le préchauffage des hydrocarbures lourds formant le fluide de procédé dans une chaudière jusqu'à une température prédéterminée ;

(b) le transfert du fluide de procédé préchauffé dans un unique réacteur de conversion thermique comportant un condenseur partiel de tête pour transformer les asphaltènes du fluide de traitement à base d'hydrocarbures lourds et produire un flux de vapeur non condensable et d'hydrocarbures liquides plus légers, ainsi qu'un second flux de fractions riches en asphaltènes thermiquement affectés à partir du fluide de traitement ;

dans lequel les conditions de traitement dans le réacteur de conversion thermique sont conformes aux paramètres suivants :

(i) un flux de chaleur uniforme de 22,1 à 37,9 kW/m² (7 000 à 12 000 BTU/h sq.ft.) introduit dans le fluide de traitement au sein du réacteur ;

(ii) un gaz d'entraînement est introduit, à hauteur de 4,8 à 19,3 sm³ de gaz/m³ de fluide de traitement (20 à 80 scf/bbl [gaz/fluide de traitement]), dans le fluide de traitement au sein du réacteur ;

(iii) un temps de séjour du fluide de traitement au sein du réacteur de 40 à 180 minutes ;

(iv) une température sensiblement uniforme du fluide de traitement de 357 à 413 °C (675 à 775 °F) au sein du réacteur et

(v) une pression quasi-atmosphérique, < 345 kPa (< 50 psig), au sein du réacteur ;

(c) le désasphaltage des fractions riches en asphaltènes thermiquement affectés obtenues à l'étape (b) par un procédé d'extraction par solvant donnant un flux d'huile désasphaltée et un second flux contenant de l'asphaltène thermiquement affecté précipité sous forme solide ;

(d) la séparation des asphaltènes solides secs thermiquement affectés issus du second flux obtenu à l'étape (c) dans une unité de séparation vapeur-solide, qui sépare les asphaltènes solides de la vapeur de solvant et du gaz toujours présents dans le second flux obtenu à l'étape (c) en utilisant une ou plusieurs forces, telles que les forces centrifuge, gravitationnelle et d'inertie, pour produire un asphaltène solide et sec qui ne contient pas plus de 20 % d'humidité, dans lequel ladite unité de séparation vapeur-solide est choisie parmi une chambre de sédimentation, une chambre à chicanes ou un séparateur centrifuge ;

(e) la charge d'alimentation de raffinerie comprenant au moins l'un des flux produits.

2. Procédé selon la revendication 1, dans lequel le gaz d'entraînement est l'azote, la vapeur, l'hydrogène et/ou un

hydrocarbure léger.

3. Procédé selon la revendication 1, dans lequel le gaz d'entraînement est préchauffé.

4. Procédé selon la revendication 1, dans lequel le flux de chaleur est libéré dans le réacteur thermique par un ou plusieurs dispositifs de chauffage convenablement disposés afin d'obtenir une température du fluide de traitement sensiblement uniforme à l'intérieur du réacteur.

5. Procédé selon la revendication 1, dans lequel un flux de recyclage de la résine recueillie à l'issue du processus de désasphaltage de l'étape (c) est mélangé avec la charge d'alimentation en amont du réacteur pour former le fluide de traitement.

6. Procédé selon la revendication 1, dans lequel la charge d'alimentation de raffinerie comprend un mélange d'au moins deux des flux produits, prêt au transport par pipeline, avec une densité API supérieure à 19 degrés (densité relative de 0,94) et une viscosité inférieure à 0,00035 m²/s (350 cst) à 8 °C.

7. Procédé selon la revendication 6, dans lequel un ou plusieurs des flux produits sont traités pour enlever les oléfines.

8. Procédé selon la revendication 1, dans lequel l'étape (d) comprend une étape supplémentaire de transport et de manipulation pneumatiques des asphaltènes solides thermiquement affectés obtenus.

9. Procédé selon la revendication 8, dans lequel du gaz de transport est ajouté au second flux obtenu à l'étape (c) pour permettre et améliorer le transport pneumatique vers le séparateur vapeur-solide.

10. Procédé selon la revendication 9, dans lequel le gaz de transport destiné au transport pneumatique peut correspondre à un quelconque gaz à bas poids moléculaire approprié.

11. Procédé selon la revendication 1, dans lequel les hydrocarbures lourds préchauffés à l'étape (a) constituent un flux d'hydrocarbures lourds bruts ou traités, provenant d'une raffinerie ou d'une installation existante de valorisation du bitume par cokéfaction et dans lequel les hydrocarbures liquides légers produits à l'étape (b) du procédé et le flux d'huile désasphaltée lourde produit à l'étape (c) du procédé sont renvoyés vers la raffinerie ou l'installation de valorisation.

12. Procédé selon la revendication 1, dans lequel les hydrocarbures lourds préchauffés à l'étape (a) constituent un flux d'hydrocarbures lourds bruts ou traités, provenant d'une raffinerie ou d'une installation de valorisation existante d'hydrocraquage de résidus et dans lequel les hydrocarbures liquides légers produits à l'étape (b) du procédé et le flux d'huile désasphaltée lourde produit à l'étape (c) sont renvoyés vers la raffinerie ou l'installation de valorisation.

13. Procédé selon la revendication 1, dans lequel les hydrocarbures lourds préchauffés à l'étape (a) proviennent d'une nouvelle installation de valorisation du bitume et dans lequel les hydrocarbures liquides légers produits à l'étape (b) du procédé et le flux d'huile désasphaltée lourde produit à l'étape (c) du procédé sont renvoyés vers l'installation de valorisation.

14. Procédé selon la revendication 1, dans lequel les hydrocarbures lourds préchauffés à l'étape (a) constituent un flux d'hydrocarbures lourds bruts ou traités provenant d'une raffinerie de « pétrole brut non corrosif », nouvelle ou existante, et dans lequel le flux d'hydrocarbures liquides légers produit à l'étape (b) du procédé et le flux d'huile désasphaltée lourde produit à l'étape (c) du procédé sont renvoyés vers la raffinerie.

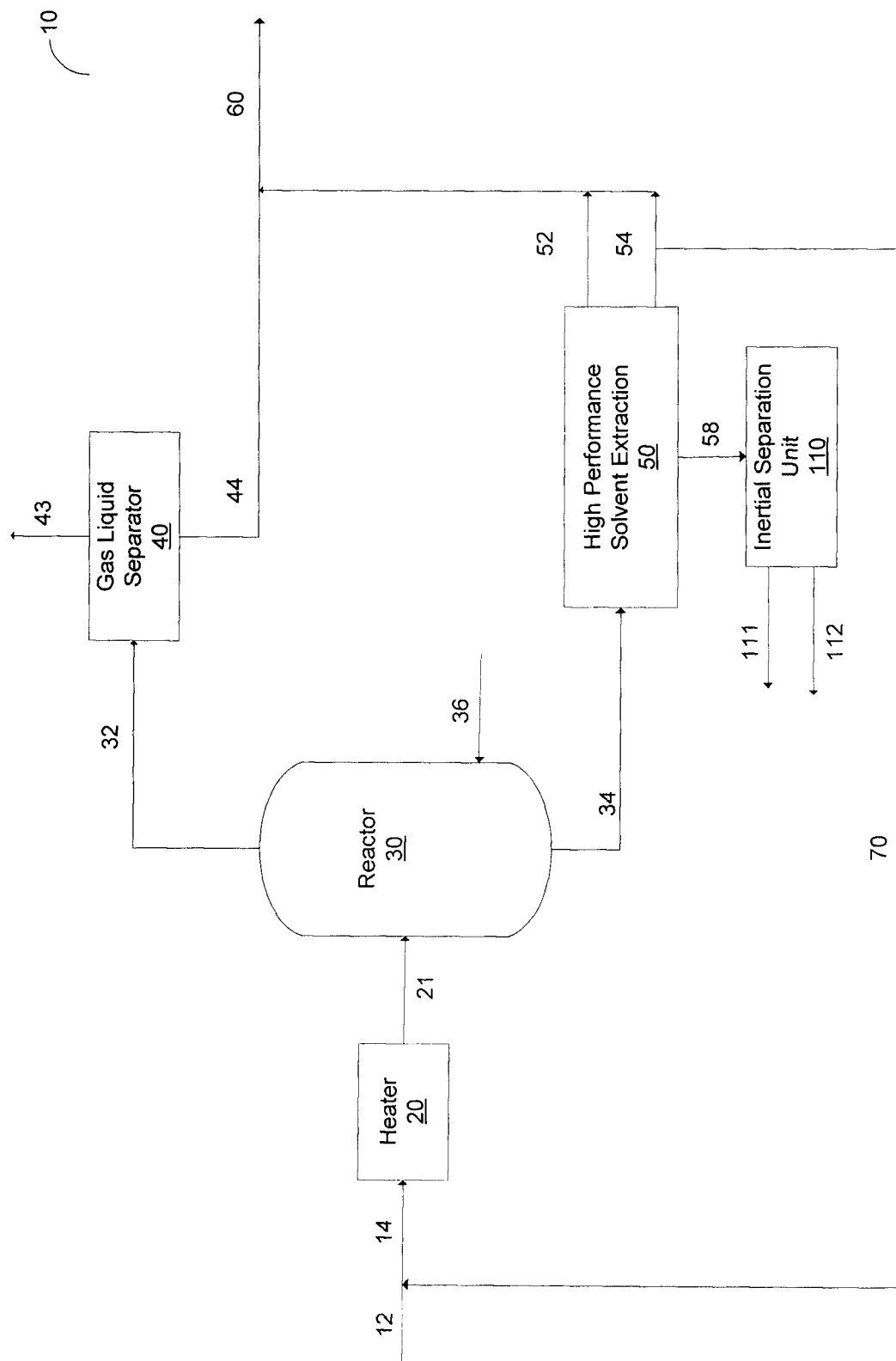


FIG. 1

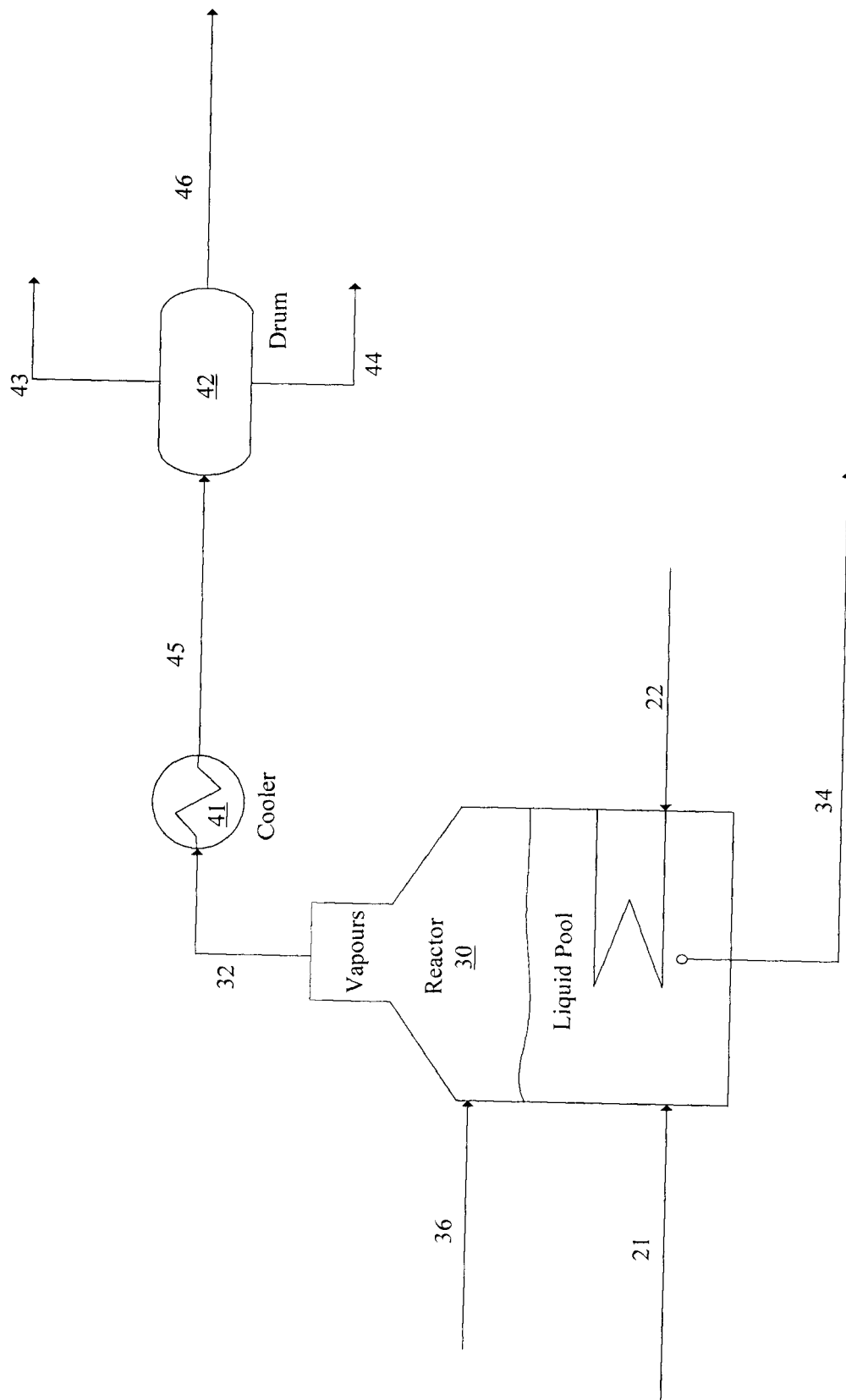


FIG. 2

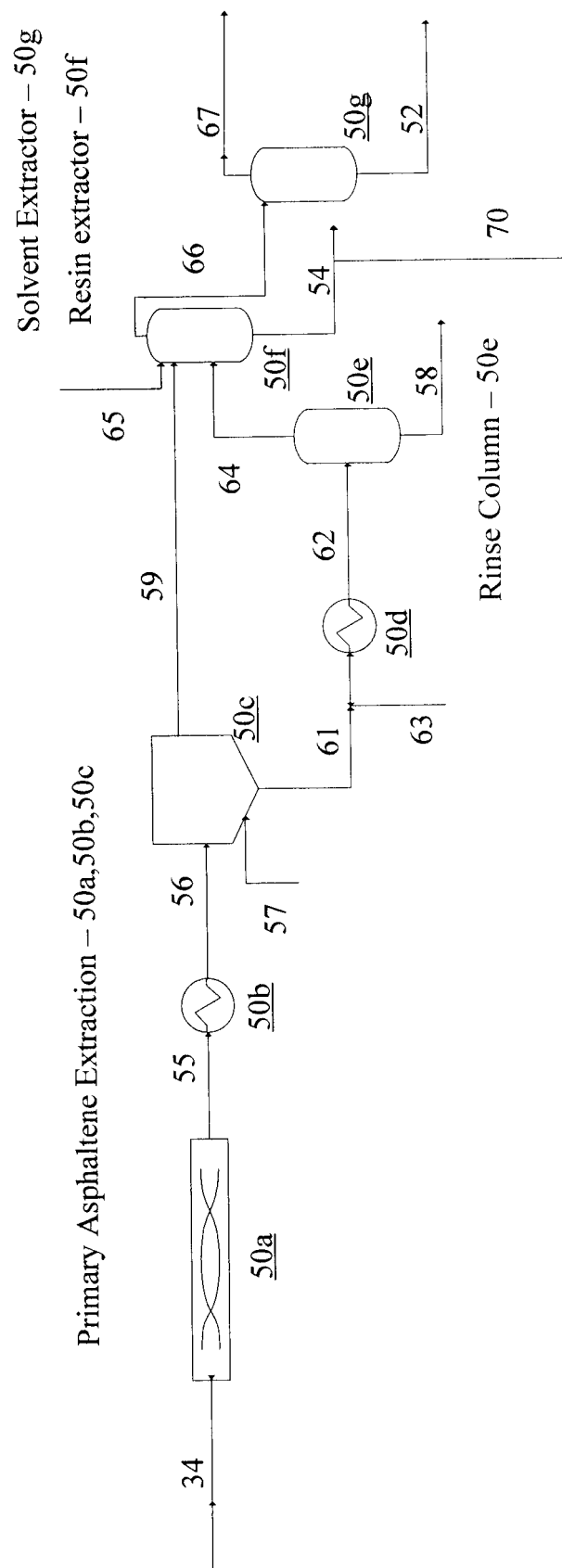
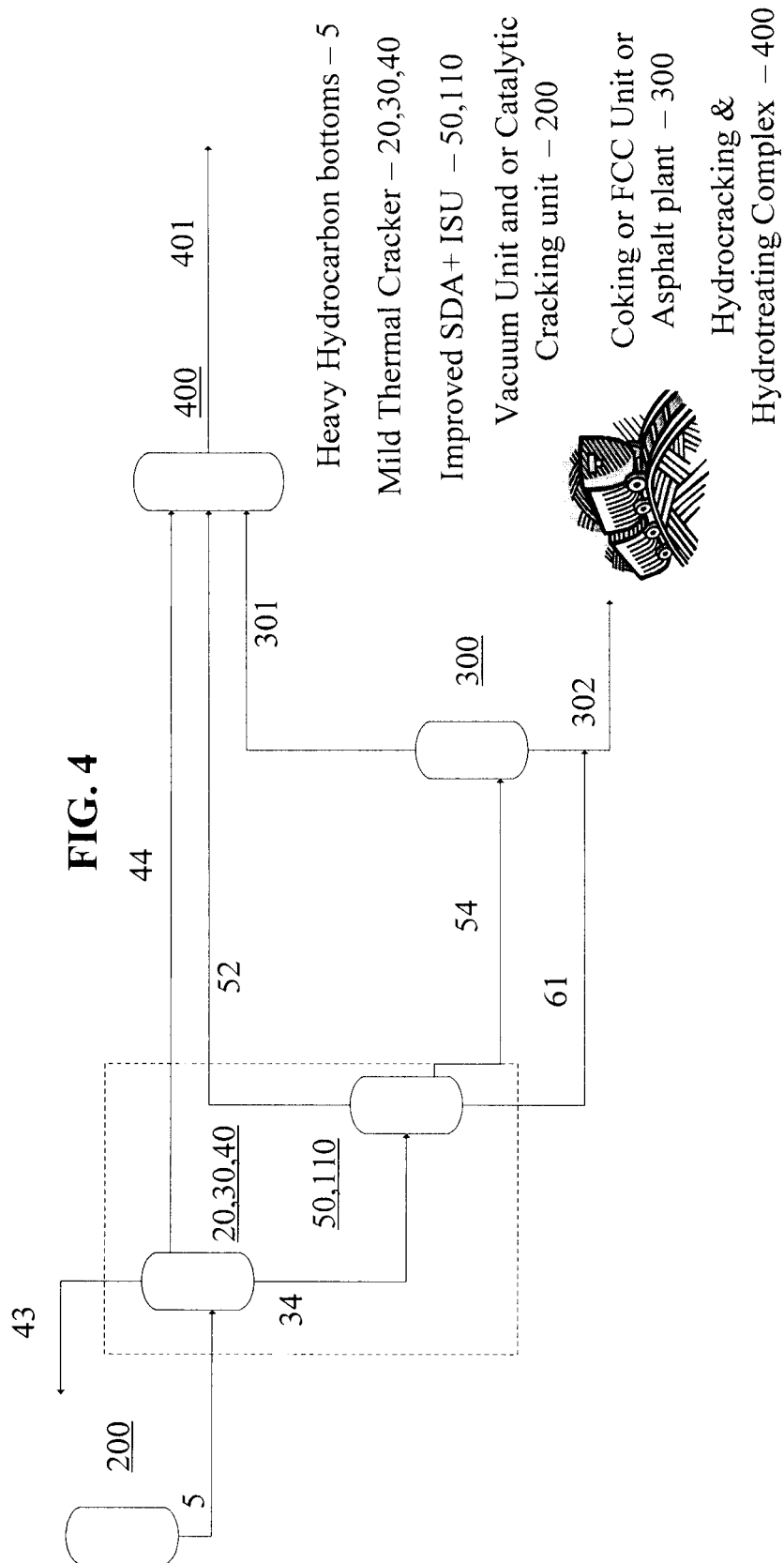
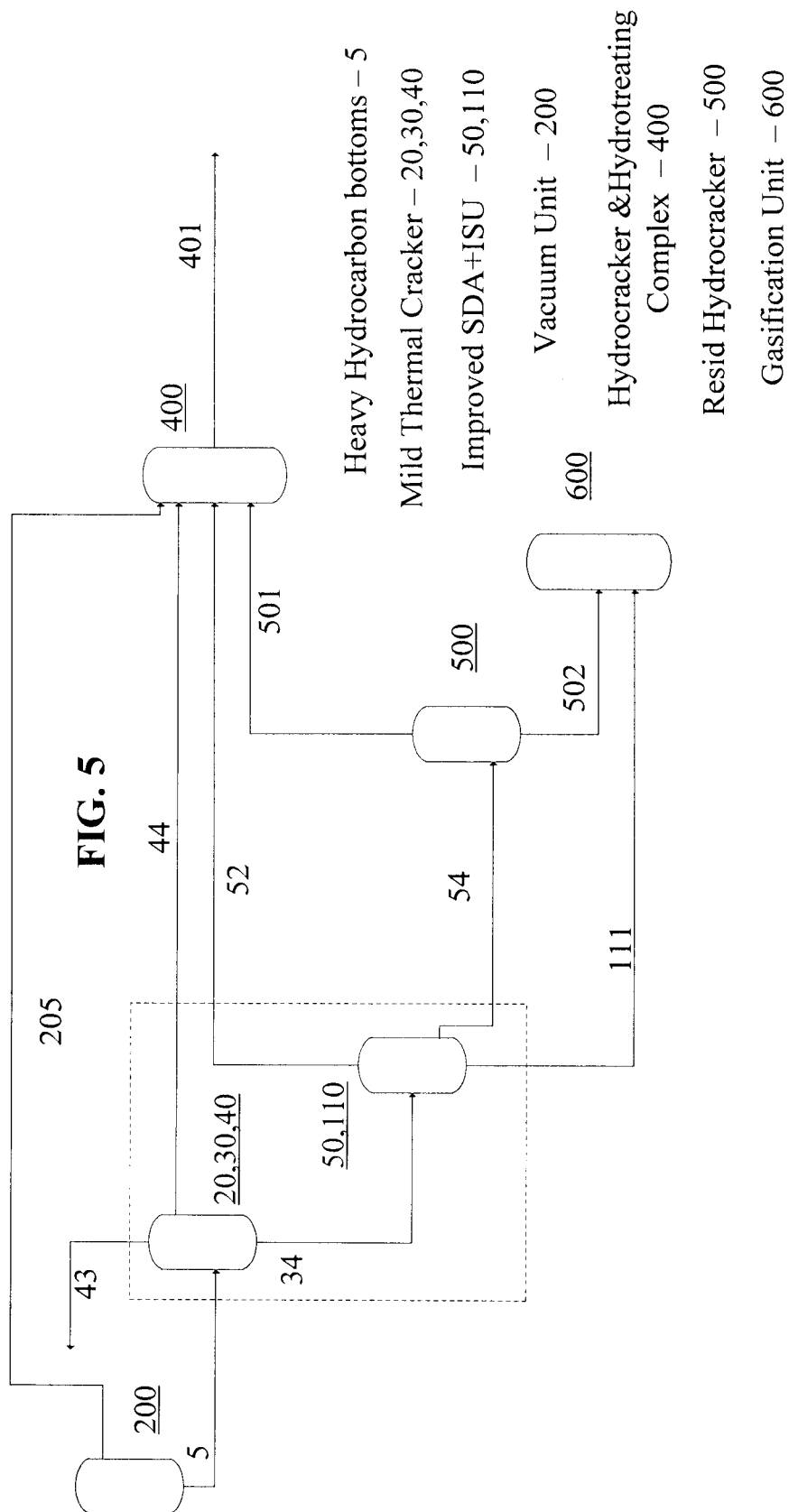


FIG. 3





REFERENCES CITED IN THE DESCRIPTION

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