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(54) Title: HORIZONTAL-FLOW OIL SANDS SEPARATOR FOR A SOLVENT EXTRACTION PROCESS

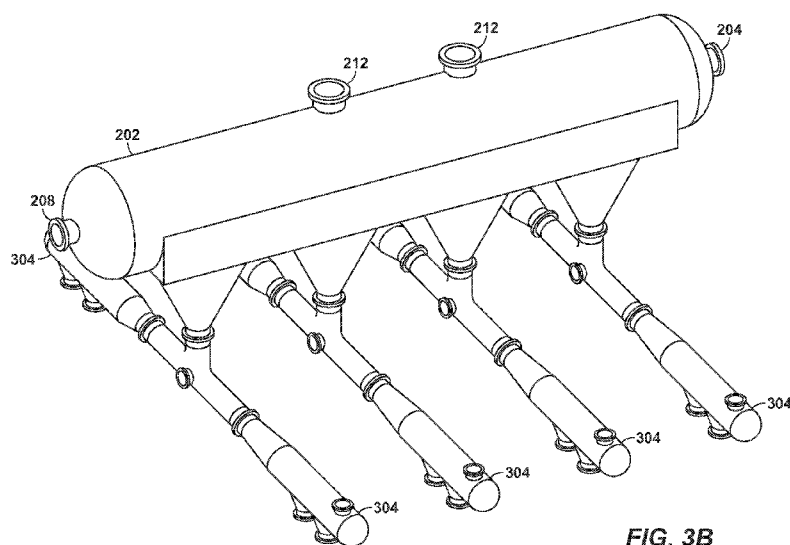


FIG. 3B

(57) Abstract: The disclosure includes techniques for recovering hydrocarbons from a bituminous feed in a non-aqueous extraction process, comprising a vessel that comprises a feed inlet on a proximate end of the vessel, a feed outlet on a distal end of the vessel, a bitumen outlet, and a plurality of hoppers, wherein each hopper comprises a tailing outlet.



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HORIZONTAL-FLOW OIL SANDS SEPARATOR FOR A SOLVENT EXTRACTION PROCESS

CROSS REFERENCE TO RELATED APPLICATIONS

- 5 [0001] This application claims the priority benefit of United States Patent Application 62/067,279 filed October 22, 2014 entitled HORIZONTAL-FLOW OIL SANDS SEPARATOR FOR A SOLVENT EXTRACTION PROCESS, the entirety of which is incorporated by reference herein.

BACKGROUND

- 10 [0002] This section is intended to introduce various aspects of the art, which may be associated with the present disclosure. This discussion is believed to assist in providing a framework to facilitate a better understanding of particular aspects of the present disclosure. Accordingly, it should be understood that this section should be read in this light, and not necessarily as admissions of prior art.
- 15 [0003] Oil sands are sand deposits which in addition to sand comprise clays, connate-water and bitumen. Depending on the depth of the deposit, bitumen may be recovered by mining or in situ thermal methods. Oil sand ore in a mining and extraction operation is typically processed using mechanical means and chemicals addition to separate the bitumen from the sands. Recovering the highly viscous bitumen from the oil sand poses numerous
- 20 challenges, particularly since large quantities of heat and water are required to extract the bitumen. Further, most oil sand deposits are located in remote areas (such as, for example, in northeastern Alberta, Canada), which can contribute to increased costs for transportation and processing, especially in harsh weather conditions. Because of these challenges, obtaining a good yield of bitumen product from the oil sands is desired in order to reduce costs and
- 25 waste.
- [0004] In conventional gravity separators, a slurry stream comprising liquid and solid particles is delivered to a vessel where the solid particles settle by gravity and are removed from the bottom of the vessel, while the clarified liquid is removed from the top of the vessel. In most processes, the solid particles are distributed in size, where the large particles settle
- 30 more quickly and the small particles settle more slowly. Particles that have settling velocities smaller than the upward flux (superficial velocity) of the liquid may not settle at all, but may

instead be carried over with the clarified liquid. Conventional separators generally achieve their optimum separation efficiency by having a uniform upward velocity distribution as this determines the theoretical limit of the maximum particle size that can be carried over. Increasing the vessel size, for example, decreases the upward velocity and thereby reduces the size of the largest particles that carry-over, thereby increasing the fraction of particles that report to the underflow.

[0005] The water-based extraction process (WBE) is a commonly used process to extract bitumen from mined oil sands. In another technique, a non-water-based extraction process can be used to treat the strip or surface mined oil sands. The non-water-based extraction process may interchangeably be referred to as a solvent based extraction process or an oil sands solvent extraction process. The commercial application of a solvent based extraction process has, for various reasons, eluded the oil sands industry. A major challenge associated with the solvent based extraction process is the tendency of fine particles within the oil sands to hamper the separation of solids from the heavy oil extracted. The heavy oil extracted may interchangeably be referred to as bitumen extract. Fine particles may interchangeably be referred to as a fine solids stream or fines.

[0006] One proposed way to handle the challenge of fine particles is described in Canadian Patent No. 1,169,002 (Karnofsky). Karnofsky describes a process wherein an oil sands slurry is separated into a coarse solids stream and a fine solids stream by gravity separation. Bitumen extract is removed from the coarse solids stream by using a series of percolating beds. Bitumen extract is removed from the fines solids stream by using a complicated system of clarifiers, thickeners, and filters. Despite the process described in Karnofsky, solid-liquid separation of the fines solids stream remains a challenge.

[0007] Another proposed way to handle the challenge of fine particles is by using a solid agglomeration process. The solid agglomeration process was coined Solvent Extraction Spherical Agglomeration (SESA). A description of the SESA process can be found in Sparks et al., Fuel 1992(71); pp 1349-1353. Previously described methodologies for SESA have not been commercially adopted. In general, the SESA process involves mixing oil sands with a hydrocarbon solvent to form an oil sands slurry, adding an aqueous bridging liquid to the oil sands slurry to form a mixture, agitating the mixture in a slow and controlled manner to nucleate particles, and continuing such agitation so as to permit these nucleated particles to form larger multi-particle spherical agglomerates for removal. The aqueous bridging liquid may be water or an aqueous solution since the solids of oil sands are mostly hydrophilic and

water is immiscible to hydrocarbon solvents. The aqueous bridging liquid preferentially wets the solids. With the right amount of the aqueous bridging liquid and suitable agitation of the slurry, the aqueous bridging liquid displaces the suspension liquid on the surface of the solids. As a result of interfacial forces among three phases (i.e. the aqueous bridging liquid, the suspension liquid, and the solids), fine particles within the solids consolidate into larger, compact agglomerates that are more readily separated from the suspension liquid.

[0008] U.S. Patent No. 4,719,008 (Sparks) describes a process that applies SESA using a micro-agglomerate procedure. In Sparks, the SESA process occurs within a slowly rotating horizontal vessel. The conditions of the slowly rotating horizontal vessel are that which favor the formation of large agglomerates; however, a light milling action is used to continuously break down the agglomerates. The micro-agglomerates are formed by obtaining an eventual equilibrium between cohesive and destructive forces. Since rapid agglomeration and agglomerates of large size can lead to bitumen recovery losses owing to entrapment of bitumen extract within the agglomerated solids, the level of bridging liquid is kept to as low as possible commensurate with achieving economically viable solid-liquid separations.

[0009] With the formation of micro-agglomerates, the process of solid-liquid separation using common separation devices is easier compared to a situation where fine particles are not micro-agglomerated. Applicable separation devices include at least one of gravity separators, centrifuges, cyclonic separation devices, screens and filters. Although the separation devices have been shown to be effective in separating agglomerates from liquids, they have disadvantages that may limit their application in an oil sands solvent extraction process. For example, gravity separators, such as clarifiers and incline plate separators, can result in a bitumen extract of low solids content; the underflow from the gravity separators is expected to have a substantial amount of bitumen extract entrained within the underflow. Because of this bitumen entrainment in the underflow, a significant amount of wash solvent and many wash stages is needed to separate the substantial amount of bitumen extract – interchangeably referred to as residual bitumen – from the solids. Cyclonic separation devices, such as hydrocyclones, are compact and allow for rapid separation of solids from liquids. However, it is difficult to use cyclonic separation devices to clarify the bitumen extract and concentrate the solids stream to, say, greater than 50 wt.% solids. In solid-liquid separation processes, paste thickeners, centrifuges or filters are known to produce solid slurries of greater than 50 wt.%. The paste thickeners, centrifuges or filters have moving parts that may challenge their reliability in the high solids content and hydrocarbon

environment of the solvent extraction process.

[0010] Consequently, a need exists for an efficient oil sands separator in an oil sands solvent extraction process that reduces the space requirements at the site. Further, a need exists for an efficient oil sands separator for an oil sands solvent extraction process that
5 reduces the difficulties and/or expenses associated with manufacture and/or transportation to remote sites.

[0011] Bitumen product cleaning generally refers to another stage within the oil sands process wherein solid separation is required. In a bitumen product cleaning process, bitumen extracted from the ore yet still containing varying amounts of water and solids is subjected to
10 a deasphalting process, which forms asphaltene-rich aggregates that can be removed with residual solids and water via gravity settling. Conventional gravity settling may generally refer to techniques for separating a feed containing immiscible phases of different densities, e.g., settling of a feed in a vessel to obtain a heavier phase zone in the vicinity of the base and a lighter phase zone above an interface with the heavier phase zone. U.S. patent publication
15 number 2012/014,653, titled "Apparatus and Method for Separating a Feed Material Containing Immiscible Phases of Different Densities," contains a representative gravity settling approach.

SUMMARY

[0012] One embodiment includes a system for recovering hydrocarbons from a
20 bituminous feed in an oil sands solvent extraction process, comprising a vessel comprising a feed inlet on a proximate end of the vessel, a feed outlet on a distal end of the vessel, a bitumen outlet, and a plurality of hoppers, wherein each hopper comprises a tailing outlet.

[0013] Another embodiment includes a method for recovering hydrocarbons in an oil sands solvent extraction process, comprising passing a bituminous feed through an inlet of a
25 vessel, passing the bituminous feed across a plurality of hoppers disposed on a lower end of the vessel, separating the bituminous feed into a stream comprising bitumen and a stream comprising tailings, passing the stream comprising bitumen from the vessel, and passing the stream comprising tailings from the vessel.

[0014] Still another embodiment includes a system for separating a bituminous feed in an
30 oil sands solvent extraction process, comprising a vessel, an inlet device coupled to a vessel and configured to receive the bituminous feed, an outlet device coupled the vessel and configured to discharge a tailings feed, a plurality of bitumen outlets disposed on the vessel, a

plurality of hoppers disposed on a lower end of the vessel, wherein each hopper comprises a tailing outlet, and a secondary extraction vessel operatively coupled to the outlet device so as to pass bitumen extracted in the secondary extraction vessel to the inlet device in a counter-current extraction.

5 BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The advantages of the present techniques are better understood by referring to the following detailed description and the attached drawings, in which:

[0016] FIG. 1 is a schematic diagram of a separator system for separating a bituminous feed in an oil sands solvent extraction process.

10 [0017] FIG. 2 is a cross section of a horizontal-flow separator system for recovering hydrocarbons from a bituminous feed in an oil sands solvent extraction process.

[0018] FIG. 3A is an inlet side view cross sectional diagram of a system for recovering hydrocarbons from a bituminous feed in an oil sands solvent extraction process.

15 [0019] FIG. 3B is a perspective view of the system for recovering hydrocarbons from a bituminous feed in an oil sands solvent extraction process.

[0020] FIG. 4 is a block diagram describing a process for recovering hydrocarbons from a bituminous feed in an oil sands solvent extraction process.

[0021] FIG. 5 is a block diagram describing a continued process for recovering hydrocarbons from a bituminous feed in an oil sands solvent extraction process.

20 [0022] FIG. 6 is an embodiment of system for recovering hydrocarbons from a bituminous feed in an oil sands solvent extraction process.

DETAILED DESCRIPTION

25 [0023] In the following detailed description section, specific embodiments of the present techniques are described. However, to the extent that the following description is specific to a particular embodiment or a particular use of the present techniques, this is intended to be for exemplary purposes only and simply provides a description of the exemplary embodiments. Accordingly, the techniques are not limited to the specific embodiments described herein, but rather, include all alternatives, modifications, and equivalents falling within the true spirit and scope of the appended claims.

30 [0024] Disclosed herein is a horizontal-flow separator for separating bitumen/water/solids

stream(s) in oil sands operations. Many configurations are possible, some including small diameter fingers to accomplish polishing of the solvent/bitumen prior to further processing and commercialization. For example, the primary separator vessel may be the first stage separator in a process, with the smaller fingers serving as the second stage separator.

5 Alternately, both stages could simultaneously accomplish one step of separation in the overall process. Some embodiments place feeds or draws between these two parts of a separation system. Conical section(s) in the first and/or second stage separators may have different base angles and/or sizes depending on the various physical properties and/or characteristics of the liquids and solids being processed.

10 **[0025]** Horizontal-flow separators may be inherently better at remove smaller particles often found in oil sands tailings. Additionally, horizontal-flow separators may allow designers an additional degree of freedom in sizing the separator(s). Owing to Stokes' Law, vertical-flow separators depend on the upflow velocity to determine the theoretical particle cut-size obtainable with the separator. Both diameter (superficial fluid velocity) and length
15 (residence time) can be adjusted for horizontal-flow separators to meet product stream specifications based upon Stokes' Law settling. However, disclosed horizontal-flow designs allow designers additional degrees-of-freedom in configuring the separator(s). As the disclosed separators include generally smaller diameter vessels (or even pipe size fingers), it is likely to facilitate manufacture and transport to remote sites, resulting in capital savings
20 over the current separator technology. Labor costs to erect the separator should also be reduced in view of the above.

[0026] At the outset, for ease of reference, certain terms used in this application and their meanings as used in this context are set forth. To the extent a term used herein is not defined herein, it should be given the broadest definition persons in the pertinent art have given that
25 term as reflected in at least one printed publication or issued patent. Further, the present techniques are not limited by the usage of the terms shown herein, as all equivalents, synonyms, new developments, and terms or techniques that serve the same or a similar purpose are considered to be within the scope of the present claims.

[0027] As used herein, the term "Bitumen" is a naturally occurring heavy oil material.
30 Generally, it is the hydrocarbon component found in oil sands. Bitumen can vary in composition depending upon the degree of loss of more volatile components. It can vary from a very viscous, tar-like, semi-solid material to solid forms. The hydrocarbon types found in bitumen can include aliphatics, aromatics, resins, and asphaltenes. A typical

bitumen might be composed of:

19 weight (wt.) % aliphatics (which can range from 5 wt. % - 30 wt. %, or higher);

- 5 19 wt. % asphaltenes (which can range from 5 wt. % - 30 wt. %, or higher);
 30 wt. % aromatics (which can range from 15 wt. % - 50 wt. %, or higher);
 32 wt. % resins (which can range from 15 wt. % - 50 wt. %, or higher); and
 some amount of sulfur (which can range in excess of 7 wt. %).

10 In addition, bitumen can contain some water and nitrogen compounds ranging from less than 0.4 wt. % to in excess of 0.7 wt. %. The percentage of the hydrocarbon found in bitumen can vary. The term “heavy oil” includes bitumen as well as lighter materials that may be found in a sand or carbonate reservoir.

15 **[0028]** As used herein, the term “bituminous feed” refers to a stream derived from oil sands that requires downstream processing in order to realize valuable bitumen products or fractions. The bituminous feed is one that comprises bitumen along with undesirable components. Such a bituminous feed may be derived directly from oil sands, and may be, for example, raw oil sands ore. Further, the bituminous feed may be a feed that has already realized some initial processing, e.g., non-aqueous extraction (NAE) processing, solvent extraction processing, etc., but nevertheless requires further processing. Also, recycled streams that comprise bitumen in combination with other components for removal as
20 described herein can be included in the bituminous feed. A bituminous feed need not be derived directly from oil sands, but may arise from other processes. For example, a waste product from other processes which comprises bitumen that would otherwise not have been recovered, may be used as a bituminous feed. Such a bituminous feed may be also derived directly from oil shale oil, bearing diatomite or oil saturated sandstones.

25 **[0029]** As used herein, the phrase “fine particles” means those solids having a size of less than 44 microns (μm), that is, material that passes through a 325 mesh (44 micron). The aforementioned range includes any number within the range.

30 **[0030]** As used herein, the phrase “coarse particles” means those solids having a size of greater than 44 microns (μm). The aforementioned range includes any number within the range.

[0031] As used herein, the phrase “Heavy oil” includes oils which are classified by the American Petroleum Institute (“API”), as heavy oils, extra heavy oils, or bitumens. The term

“heavy oil” includes bitumen. Heavy oil may have a viscosity of about 1,000 centipoise (cP) or more, 10,000 cP or more, 100,000 cP or more, or 1,000,000 cP or more. In general, a heavy oil has an API gravity between 22.3° API (density of 920 kilograms per meter cubed (kg/m^3) or 0.920 grams per centimeter cubed (g/cm^3)) and 10.0° API (density of 1,000 kg/m^3 or 1 g/cm^3). An extra heavy oil, in general, has an API gravity of less than 10.0° API (density greater than 1,000 kg/m^3 or 1 g/cm^3). For example, a source of heavy oil includes oil sand or bituminous sand, which is a combination of clay, sand, water and bitumen. The recovery of heavy oils is based on the viscosity decrease of fluids with increasing temperature or solvent concentration. Once the viscosity is reduced, the mobilization of fluid by steam, hot water flooding, or gravity is possible. The reduced viscosity makes the drainage quicker and therefore directly contributes to the recovery rate.

[0032] As used herein, the terms “bitumen”, “bitumens”, and “bituminous feed” are used interchangeably.

[0033] As used herein, the term “solvent” can refer to either a single chemical component, or a mixture of chemical components, to promote the dissolution of other chemical compounds.

[0034] As used herein, the terms “solvent extracted bitumen” and “solvent diluted bitumen” refer to bitumen that is dissolved into another hydrocarbon. This other hydrocarbon could refer to a solvent used to extract the bitumen to facilitate removal from the other ore components or alternatively could refer to a solvent that dissolves only a portion of the bitumen molecules.

[0035] As used herein, the term “hopper” means a container with a narrow opening at bottom. This definition is intended to encompass frustum-shaped hoppers, e.g., pyramidal frustum, conical frustum, square frustum, pentagonal frustum, etc., as well as various prisms and other slant geometries that may be suitably be employed by those of skill in the art to practice the techniques described herein.

[0036] As used herein, the term “hydrocarbon” means an organic compound that primarily includes the elements of hydrogen and carbon, although nitrogen, sulfur, oxygen, metals, or any number of other elements may be present in small amounts. Hydrocarbons generally refer to components found in heavy oil or in oil sands. However, the techniques described are not limited to heavy oils but may also be used with any number of other reservoirs to improve gravity drainage of liquids. Hydrocarbon compounds may be aliphatic

or aromatic, and may be straight chained, branched, or partially or fully cyclic.

[0037] As used herein, the term “macro-agglomeration” means the consolidation of both fine particles and coarse particles that make up the oil sands. Macro-agglomerates may have a mean diameter of 2 millimeters (mm) or greater.

5 [0038] As used herein, the term “micro-agglomeration” means the consolidation of fine particles that make up the oil sands. Micro-agglomerates may have a mean diameter of less than 2 millimeters (mm).

[0039] As used herein, the term “tailings” means an underflow material remaining in a mixture after bitumen is separated from an oil sands or a bituminous feed. Tailings generally
10 comprise the refuse material comprising fine and/or coarse particles of sand and/or clay, traces of bitumen, asphaltenes, etc. remaining after the bitumen has been extracted from the bituminous feed.

[0040] As used herein, the phrase “product cleaning” refers to a process wherein bitumen is subjected to a process to reduce impurities (including, but not limited to, water and solids)
15 to levels that allow for direct marketing to refineries or to match feed requirements for other conversion technologies focused on generating a synthetic crude oil or to meet pipeline product specifications.

[0041] As used herein, the phrases “solvent-based recovery process” or “solvent extraction process” include any type of hydrocarbon recovery process that uses a solvent, at
20 least in part, to enhance the recovery, for example, by diluting or lowering a viscosity of the hydrocarbon. Solvent-based recovery processes may be used in combination with other recovery processes, such as, for example, thermal recovery processes. As used herein, the terms “a” and “an,” mean one or more when applied to any feature in embodiments of the present inventions described in the specification and claims. The use of “a” and “an” does
25 not limit the meaning to a single feature unless such a limit is specifically stated.

[0042] As used herein, the term “about” means $\pm 10\%$ of the subsequent number, unless otherwise stated.

[0043] As used herein, the terms “approximate,” “approximately,” “substantial,” and “substantially,” mean a relative amount of a material or characteristic that is sufficient to
30 provide the intended effect. The exact degree of deviation allowable in some cases may depend on the specific context. It should be understood by those of skill in the art who review this disclosure that these terms are intended to allow a description of certain features

described and claimed without restricting the scope of these features to the precise numeral ranges provided. Accordingly, these terms should be interpreted as indicating that insubstantial or inconsequential modifications or alterations of the subject matter described and are considered to be within the scope of the disclosure.

- 5 [0044] As used herein, the definite article “the” preceding singular or plural nouns or noun phrases denotes a particular specified feature or particular specified features and may have a singular or plural connotation depending upon the context in which it is used.

[0045] FIG. 1 is a schematic diagram of a conventional separator system **100** for separating a bituminous feed in an oil sands solvent extraction process. The separator system
10 **100** includes a deep cone settler **102** is depicted for receiving agglomerated slurry **104** from an agglomerator (not depicted). The deep cone settler **102** permits settling of agglomerated solids to the lower region **106**, while a low solids bitumen extract **108** can be drawn off as overflow. A pump **110** is used to convey the overflow to further cleaning or solvent removal in a solvent recovery unit. A vent gas **112a** and **112b** is provided to and removed from the
15 deep cone settler **102** to provide a low oxygen environment within the deep cone settler **102**. One or more pumps **114** may be used to pump agglomerates **116** to a counter-current washer **118**, e.g., a belt filter or a rotary pan filter, for effecting recovery of residual bitumen from agglomerates.

[0046] FIG. 2 is a cross section of a horizontal-flow separator system **200** for recovering
20 hydrocarbons from a bituminous feed in an oil sands solvent extraction process. The system **200** includes a vessel **202** having a feed inlet **204** on a proximate end **206** of the vessel **202** and a feed outlet **208** on a distal end **210** of the vessel **202**. The vessel **202** also has a plurality of bitumen outlets **212** on an upper end **214** of the vessel **202** and hoppers **216** having solvent and/or tailing outlets **218** on a lower end **221** of the vessel **202**. The vessel
25 **202** optionally houses a plurality of internal flow path obstructions or baffles **220**, e.g., perforated baffles, disposed across the internal surface of the vessel **202**. The bitumen outlets **212** optionally comprise outlet baffles **222**, e.g., perforated baffles. While shown at approximately the midline of the top of the vessel **202**, those of skill in the art will recognize that the bitumen outlets **212** may alternately or additionally be located elsewhere on the upper
30 end **214** of the vessel **202**, e.g., on or towards the distal end **210**, within the scope of this disclosure. Similarly, while shown at approximately the centerline of the vessel **202**, those of skill in the art will appreciate that a plurality of suitable locations exist for placement of the feed inlet **204** and the feed outlet **208**, e.g., on the upper end **214**, the lower end **221**, or a

side, upper, or lower wall of the vessel **202** at the proximate end **206** or distal end **210** of the vessel **202**. Such alternate placement may be based on a variety of considerations, e.g., obtaining a desired flowpath into and/or out of the vessel **202**, structural limitations external to the vessel **202**, etc. The vessel **202** may optionally include one or more injection inlets
5 (not depicted) for injecting water and/or solvent.

[0047] In operation, a bituminous feed may enter the vessel **202** through the feed inlet **204**. The feed may flow horizontally across the vessel **202** and the hoppers **216** to the feed outlet **208**. As feed flows across the hoppers **216**, the angle of the wall(s) of each hopper **216** and the upflow (rise) created by feed incidence against the wall(s) of each hopper **216** may cause separation according to known particle settling principles, e.g., Stokes' Law settling.
10 This process causes bitumen to float to the top of the vessel **202** where it may be collected via bitumen outlets **212**. In some embodiments, the size, shape, and/or narrowing angle of the hopper (or incidence wall angle) of the hoppers **216** are varied from one hopper **216** to another, e.g., to obtain bulk and fine settling, to alter the rate of rise and/or settling, etc. In
15 some embodiments, separation may alternatively or be additionally accomplished through horizontal flow settling as in traditional three-phase separators. Thus, hoppers **216** may function to collect high solid component streams for ease of continuous removal (e.g., separation may not necessarily be created by upflow caused by impedance against hopper walls).

[0048] The velocity of the bituminous feed flow may be altered by a variety of techniques known in the art, e.g., via pressurization, preliminary feed treatment, additional pumps, etc., in order to obtain certain desired separation characteristics within the vessel **202**. Alternately or additionally, as described above, baffles **220** and/or **222** may be optionally added at various points to impede or direct flow. Additionally, some embodiments may inject water
25 and/or solvent into the feed stream via an injection inlet disposed on the vessel **202** in order to alter one or more characteristics of the feed, e.g., viscosity, separation, disaggregation, etc. As the feed separates, water and/or tailings, may pass through the solvent and/or tailing outlets **218** as bitumen is collected through the bitumen outlets **212**. A feed stream comprising substantially unseparated bituminous feed may continue through the feed outlet
30 **208**. In some embodiments, at least a portion of the discharge through the feed outlet **208** is recycled through the vessel **202**. In some embodiments, at least a portion of the discharge through the feed outlet **208** is passed to a second vessel **202** to substantially repeat the process.

[0049] FIG. 3A is an inlet side view cross sectional diagram of a system **300** for recovering hydrocarbons from a bituminous feed in a solvent extraction process. FIG. 3B is a perspective view of the system **300** for recovering hydrocarbons from a bituminous feed in a solvent extraction process. The components of the system **300** may be substantially the same as the corresponding components of FIG. 2 unless otherwise noted. The system **300** comprises a secondary separator **302** commonly coupled to the tailing outlets **218**. Some embodiments may attach a secondary separator **302** to less than all of the tailing outlets **218**, and other embodiments may attach separate secondary separators **302** to one or more of the tailing outlets **218**. The secondary separator **302** has a water and/or solvent injection inlet **303** for injecting water and/or solvent. Those of skill in the art will appreciate that in some embodiments the solvent injection inlet **303** may optionally comprise a common injection header spanning the length of a common secondary separator **302** or a plurality of secondary separators **302** (in suitable embodiments) for distributing the water and/or solvent. The secondary separator **302** has a plurality of secondary vessels **304**, also referred to herein as “fingers” **304**, having a plurality of secondary hoppers **306** with secondary water and/or tailings outlets **308**. While depicted with a plurality of secondary hoppers **306**, alternate embodiments may have more, fewer, or even no secondary hoppers **306**. Further, different fingers **304** may have differing numbers of secondary hoppers **306**, and may include differing sizes, shapes, and/or narrowing angles of any of the secondary hoppers **306**. The fingers **304** each have a hydrocarbon or bitumen outlet **310** for passing hydrocarbons therethrough. Although not depicted, those of skill in the art will appreciate that a plurality of baffles may be optionally added in the secondary separator **302** as described above with respect to the baffles **220** and/or **222** in the vessel **202**.

[0050] In operation, the vessel **202** portion of the system **300** may function as described above in connection with the system **200**. Namely, a bituminous feed may enter the vessel **202** through the feed inlet **204**. The feed may flow horizontally across the vessel **202** and the hoppers **216** to the feed outlet **208**. As feed flows across the hoppers **216**, the angle of the wall(s) of each hopper **216** and the upflow (rise) created by feed incidence against the wall(s) of each hopper **216** causes separation according to known particle settling principles. This process causes bitumen to float to the top of the vessel **202** where hydrocarbons may be collected via bitumen outlets **212**. As the feed separates, a stream comprising substantially unseparated bituminous feed may continue through the feed outlet **208** as bitumen is collected through the bitumen outlets **212**. Solvent, tailings, and/or some amount of

bituminous feed (collectively, the “secondary bituminous feed”) may pass through the solvent and/or tailing outlets **218** and into the secondary separator **302**. Solvent may be injected into the secondary separator **302** at the solvent injection inlet **303** in order to alter one or more characteristics of the secondary bituminous feed, e.g., viscosity, separation, disaggregation, etc. It will be noted that a variety of locations are available for placing the injection inlet **303**, including at each water and/or tailings outlet **218**, and such alternate embodiments are within the scope of this disclosure. The secondary bituminous feed may be passed through the fingers **304** for secondary or second phase separation. Second phase separation in each of the fingers **304** may occur in substantially the same the same way as the initial or first phase separation in the vessel **202**. Specifically, as the secondary bituminous feed flows across the secondary hoppers **306**, the angle of the wall(s) of each hopper **306** and the upflow (rise) created by feed incidence against the wall(s) of each hopper **306** causes separation according to known particle settling principles. This process causes hydrocarbons or bitumen to float to the top of the fingers **304** where the hydrocarbons or bitumen may be collected via bitumen outlets **310**. The remainder of the secondary bituminous feed, which may comprise substantially tailings, may be discharged through the secondary water and/or tailings outlets **308**. Following discharge, the remaining secondary bituminous feed may be recirculated and/or otherwise combined with the bituminous feed, may be sent for further processing, may be collected and disposed of as tailings, or may undergo another process as optionally determined according to the skill of those in the art.

[0051] FIG. 4 is a block diagram describing a process **400** for recovering hydrocarbons in a solvent extraction process. At block **402**, the process **400** may pass a bituminous feed through an inlet, e.g., the feed inlet **204** of FIG. 2, of a vessel, e.g., the vessel **202** of FIG. 2. At block **404**, the process **400** may flow the solvent extracted bitumen across a plurality of hoppers, e.g., the hoppers **216** of FIG. 2, disposed on a lower end of the vessel. At block **406**, the process **400** may separate the solvent extracted bitumen to obtain bitumen and tailings. Separating the solvent extracted bitumen may include flowing the solvent extracted bitumen across the hoppers. In so doing, the angle of the wall(s) of each hopper and the upflow (rise) created by feed incidence against the wall(s) of each hopper may cause separation according to known particle settling principles, e.g., Stokes’ Law settling. At block **408**, the process **400** may remove the hydrocarbons and/or solvent extracted bitumen from the vessel, e.g., via bitumen outlets **212**. At block **410**, the process **400** may remove at least a portion of the tailings created from the separation process from the vessel. For example, the tailings may be

discharged through one or more solvent and/or tailing outlets, e.g., the solvent and/or tailing outlets **218** of FIG. 2. At block **412**, the process **400** may pass at least a portion of the solvent extracted bitumen through an outlet, e.g., the feed outlet **208** of FIG. 2, of the vessel.

[0052] FIG. 5 is a block diagram describing a continued process **500** for recovering hydrocarbons in a solvent extraction process. The process **500** may comprise the process **400** and may begin after block **412** of FIG. 4. At block **502**, the at least a portion of the solvent extracted bitumen, or secondary solvent extracted bitumen stream, is passed to a secondary separator, e.g., the secondary separator **302** of FIG. 3. At block **504**, the secondary solvent extracted bitumen stream is fed to at least one secondary vessel finger, e.g., a finger **304** of FIG. 3. At block **506**, each finger may separate the secondary solvent extracted bitumen stream. For example, each finger may comprise at least one hopper, e.g., a secondary hopper **306** of FIG. 3, and may flow the secondary solvent extracted bitumen across the hopper to obtain a desired settling of the secondary solvent extracted bitumen. At block **508**, hydrocarbons or bitumen may be collected through one or more finger outlets, e.g., a bitumen outlet **310**, and the remainder of the secondary solvent extracted bitumen, which may comprise substantially tailings, may be discharged through one or more outlets, e.g., solvent and/or tailings outlets **308** of FIG. 3.

[0053] FIG. 6 is an embodiment of a system **600** for recovering hydrocarbons from a bituminous feed in a solvent extraction process. The components of the system **600** may be substantially the same as the components of the system **300** of FIG. 3 except as otherwise noted. The bituminous feed input **602** into the system **600** is configured to receive a bituminous feed comprising substantially solvent-extracted bitumen having agglomerated solids. The system **600** includes two separator systems **604a** and **604b**, e.g., each a system **300** of FIG. 3, modified as noted herein, arranged in a counter-current configuration. It will be appreciated that the systems **604a** and **604b** each comprise a unitary outlet for tailings, e.g., lines **606a** and **606b**, respectively. The output stream of tailings passed via line **606a** is passed to the system **604b**, e.g., serving as the bituminous feed input into the system **604b**, while the output stream of tailings from the system **604b** passed via line **606b** is passed to a solids desolventizer **608** in order to thereby pass a stream comprising dry solids via line **610**. The solvent recovered by the desolventizer **608** may be returned via line **612** to the stream of tailings in line **606a** for further processing via the system **604b**. Bitumen may exit the system **604a** and be split into two lines, **614a** and **614b**. Line **606a** may carry bitumen to a solvent recovery unit **616**. The solvent recovery unit **616** may separate the received feed into a

stream comprising bitumen, passed via line **618**, and a stream comprising “neat” or “lean” solvent, passed via line **620**. The stream comprising neat solvent passed via line **620** may join the stream comprising solvent passed via line **612**. Line **614b** may return at least a portion of the bitumen to the inlet of the system **604a**. To enable the counter-current configuration, rich solvent may exit the system **604b** via line **614c** and return to join the bituminous input feed **602**. Although depicted with only two wash stages, i.e., the configuration of systems **604a** and **604b**, the number of wash stages may be optionally extended, e.g., by passing the tailings stream to a series of wash stages arranged in a counter-current wash configuration, to meet a specified bitumen recovery requirement. As will be understood by those of skill in the art, in a counter-current configuration neat solvent is exposed to a solvent-diluted bitumen stream while rich solvent is exposed to a bitumen stream without or comprising comparatively less solvent than the solvent-diluted bitumen, e.g., the bituminous feed.

[0054] Fig. 6 provides another embodiment wherein the solvent extracted bitumen is subjected to a bitumen product cleaning stage. In this embodiment, solvent extracted bitumen enters at **602** and is contacted by paraffin-rich stream **614c** to promote partial deasphalting, or precipitating a portion of the asphaltenes from the bituminous feed. This combined stream enters the system **604a** to generate an overflow stream comprising solvent diluted bitumen **614a** (i.e., comprising both solvent and bitumen) and an underflow stream containing precipitated asphaltenes, water, and solids passed via line **606a**. This underflow stream is contacted by recycled paraffin-rich solvent, recycled via solvent recovery process desolventizer **608** and **616**, and sent to another system **604b**. The underflow from the system **604b** is subjected to solvent recovery process desolventizer **608** to generate a tailings stream **610** containing asphaltenes. The overflow stream **614a** from the initial system **604a** is subjected to solvent recovery **616**, generating a solvent recycle stream **620** and a bitumen product stream **618**.

[0055] While the present techniques may be susceptible to various modifications and alternative forms, the exemplary embodiments discussed herein have been shown only by way of example. However, it should again be understood that the techniques disclosed herein are not intended to be limited to the particular embodiments disclosed. Indeed, the present techniques include all alternatives, modifications, combinations, permutations, and equivalents falling within the scope of the disclosure and appended claims.

CLAIMS

What is claimed is:

1. A system for recovering hydrocarbons from a bituminous feed in an oil sands solvent extraction process, comprising:
 - 5 a vessel comprising:
 - a feed inlet on a proximate end of the vessel;
 - a feed outlet on a distal end of the vessel;
 - a bitumen outlet; and
 - a plurality of hoppers, wherein each hopper comprises a tailing outlet.
- 10 2. The system of claim 1, wherein the vessel further comprises at least one perforated baffle.
3. The system of claim 2 or claim 1, wherein at least one hopper is of a different size or shape than another hopper.
4. The system of claim 1 or claims 2-3, wherein the vessel further comprises a solvent
15 injection inlet.
5. The system of claim 1 or any of claims 2-4, further comprising a second separator operatively coupled to the feed outlet or a tailing outlet of a hopper.
6. The system of claim 5 or any of claims 1-4, wherein the secondary separator is operatively coupled to the tailing outlet of a hopper, wherein the secondary separator
20 comprises a plurality of secondary separator vessels, and wherein each secondary separator vessel comprises at least one secondary hopper.
7. A method for recovering hydrocarbons in an oil sands solvent extraction process, comprising:
 - passing a bituminous feed through an inlet of a vessel;
 - 25 passing the bituminous feed across a plurality of hoppers disposed on a lower end of the vessel;
 - separating the bituminous feed into a stream comprising bitumen and a stream comprising tailings;
 - passing the stream comprising bitumen from the vessel; and
 - 30 passing the stream comprising tailings from the vessel.

8. The method of claim 7, further comprising adjusting the flow rate of the bituminous feed flow based at least in part on the residence time required to obtain a predetermined separation.
9. The method of claims 7 or 8, further comprising passing the stream comprising
5 tailings to a secondary separator structure, wherein the secondary separator structure comprises a second vessel having a second plurality of hoppers.
10. The method of claim 9 or any of claims 7-8, further comprising injecting a solvent into the secondary separator structure, the vessel, or both.
11. The method of claim 9 or any of claims 7-8, wherein the secondary separator structure
10 comprises a plurality of second vessels each comprising at least one hopper.
12. The method of claim 9 or any of claims 7-8, further comprising:
passing the stream comprising tailings to a plurality of wash stages in a counter-current configuration.
13. The method according to claim 12, further comprising:
15 adding neat solvent to a final wash stage;
generating a stream comprising solvent diluted bitumen; and
generating a second stream comprising tailings.
14. The method according to claim 13, wherein the stream comprising solvent diluted bitumen is used as the wash fluid for preceding wash stages.
- 20 15. The method of any of claims 7-14, further comprising passing at least a portion of the additional bitumen to the inlet of first vessel.
16. The method of any of claims 7-15, wherein passing the stream comprising tailings from the vessel through an outlet of the vessel occur via a unitary outlet.
17. The method of any of claims 7-16, wherein the bituminous feed comprises a solvent-
25 extracted bitumen, further comprising:
passing the stream comprising bitumen to a solvent recovery unit; and
separating the stream comprising bitumen into a stream comprising a solvent-extracted bitumen and a stream comprising solvent.
18. The method according to claims 7-17, further comprising:
30 precipitating a portion of the asphaltenes from the bituminous feed;

separating the stream comprising solvent, bitumen, asphaltenes, and tailings into:

a solvent containing bitumen stream and

a tailings stream containing asphaltenes

19. The method of any of claims 7-18, wherein the bituminous feed comprises a
5 bituminous froth.

20. The method of any of claims 7-16, wherein separating the bituminous feed occurs substantially in a mine, further comprising transporting at least a portion of the stream comprising bitumen to a geographically remote location.

21. A system for separating a bituminous feed in an oil sands solvent extraction process,
10 comprising:

a vessel;

an inlet device coupled to a vessel and configured to receive the bituminous feed;

an outlet device coupled the vessel and configured to discharge a tailings feed;

a plurality of bitumen outlets disposed on the vessel;

15 a plurality of hoppers disposed on a lower end of the vessel, wherein each hopper comprises a tailing outlet; and

a secondary extraction vessel operatively coupled to the outlet device so as to pass bitumen extracted in the secondary extraction vessel to the inlet device in a counter-current extraction.

20 22. The system of claim 21, further comprising a secondary separator structure, wherein the secondary separator structure comprises a plurality of vessels having a second plurality of hoppers, wherein the secondary separator structure comprises an injection inlet for injecting water or a solvent, and wherein the injection inlet is coupled to an injection header extending to at least two of the plurality of vessels.

25 23. The system of claims 21 or 22, further comprising a solvent recovery unit operatively coupled to at least one bitumen outlet.

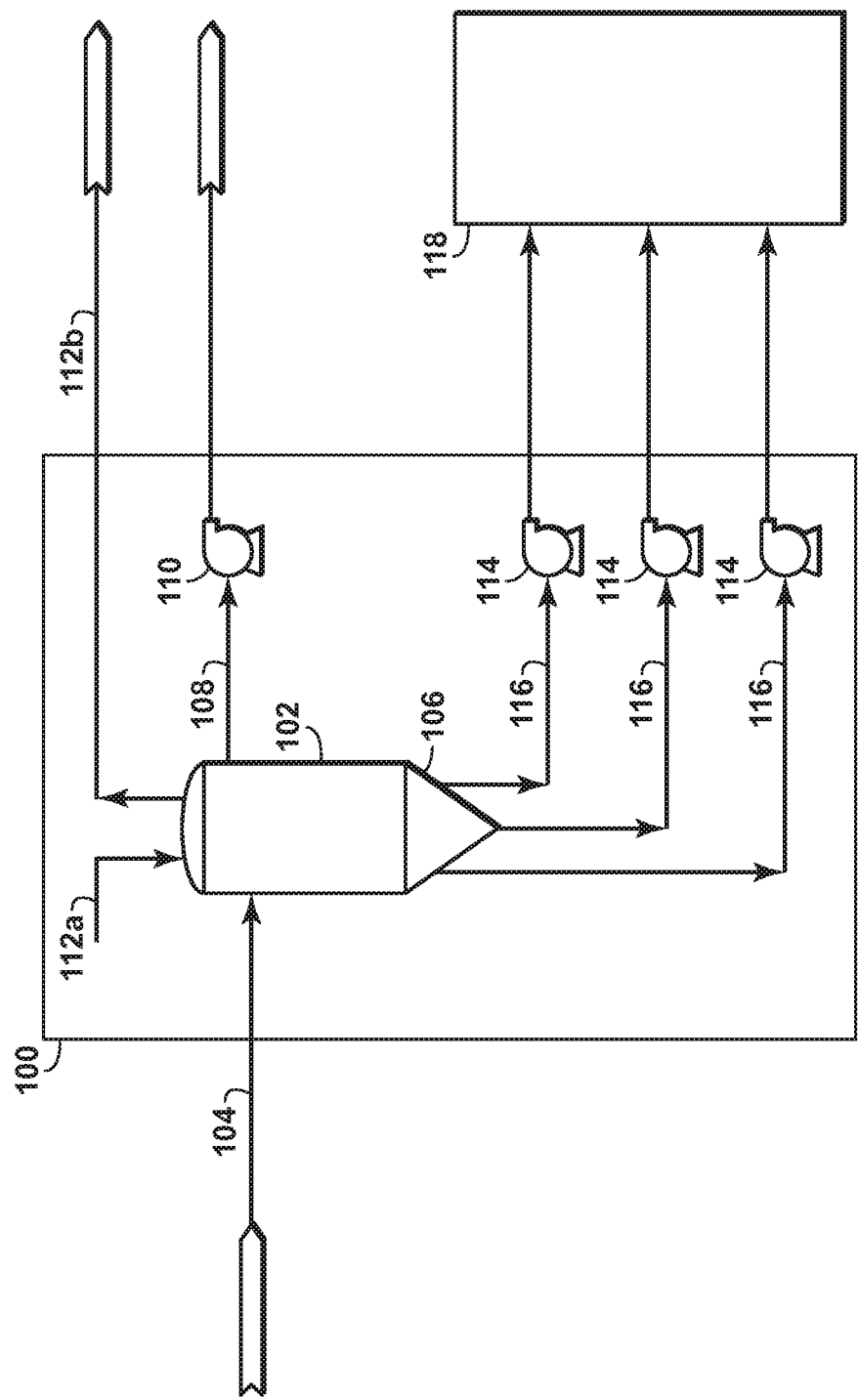
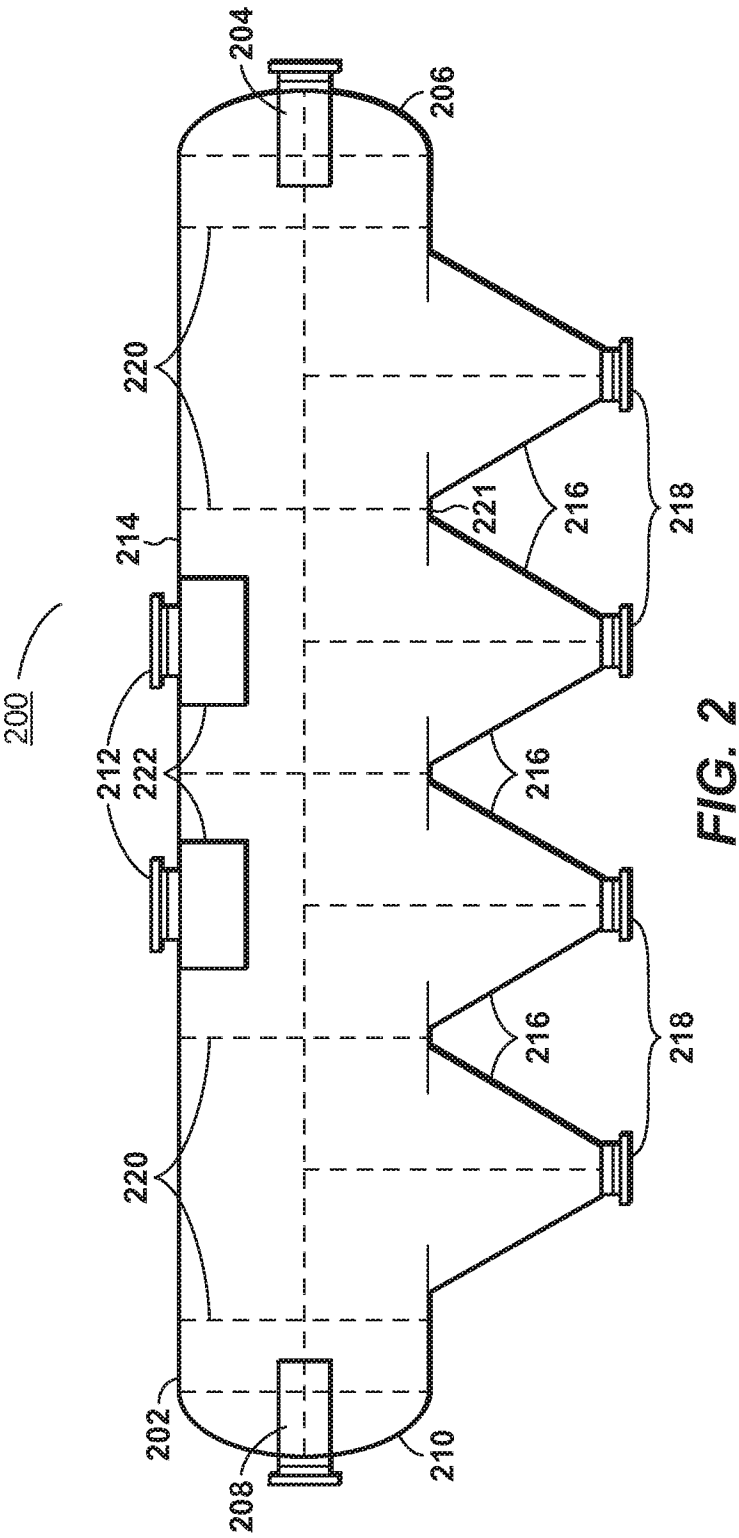


FIG. 1



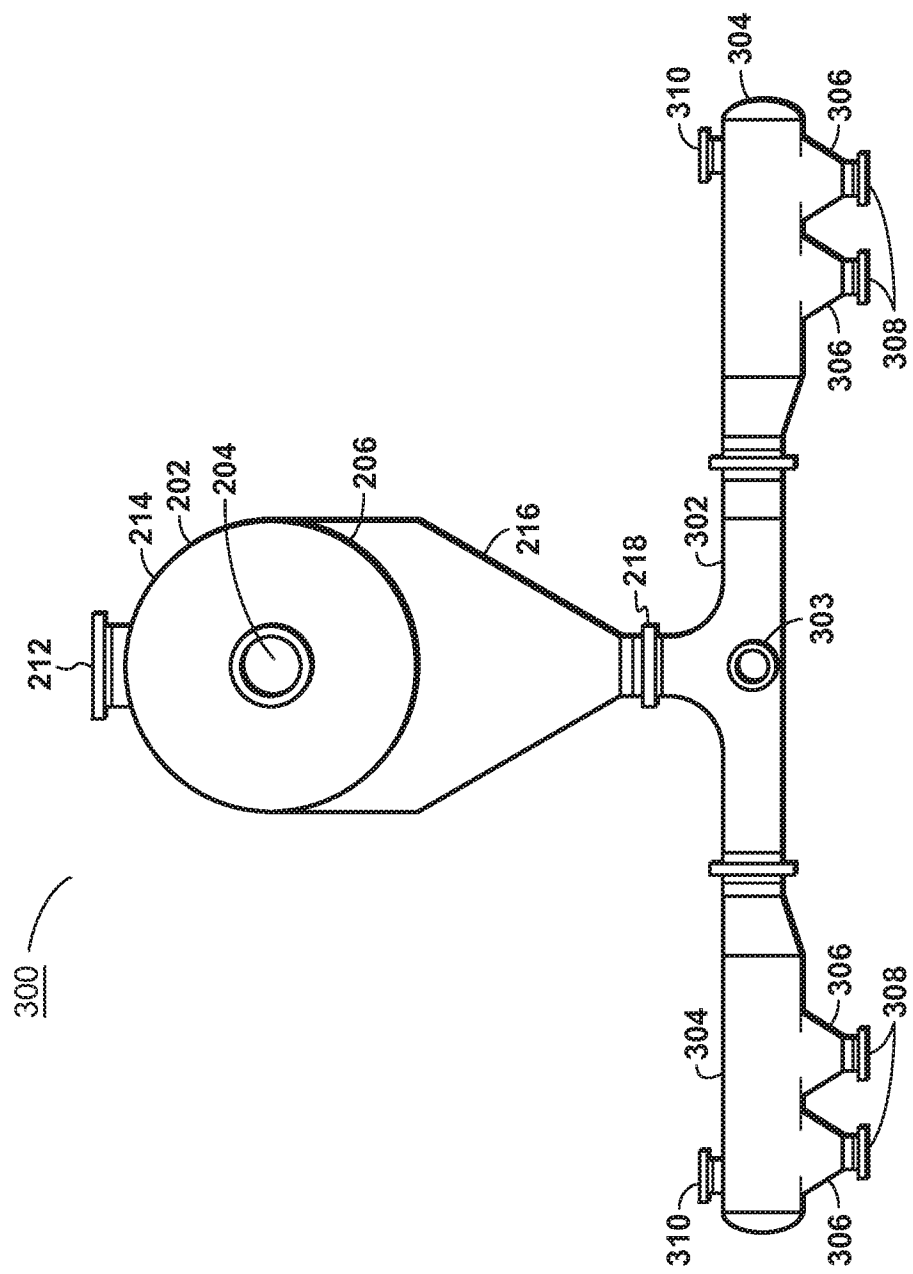


FIG. 3A

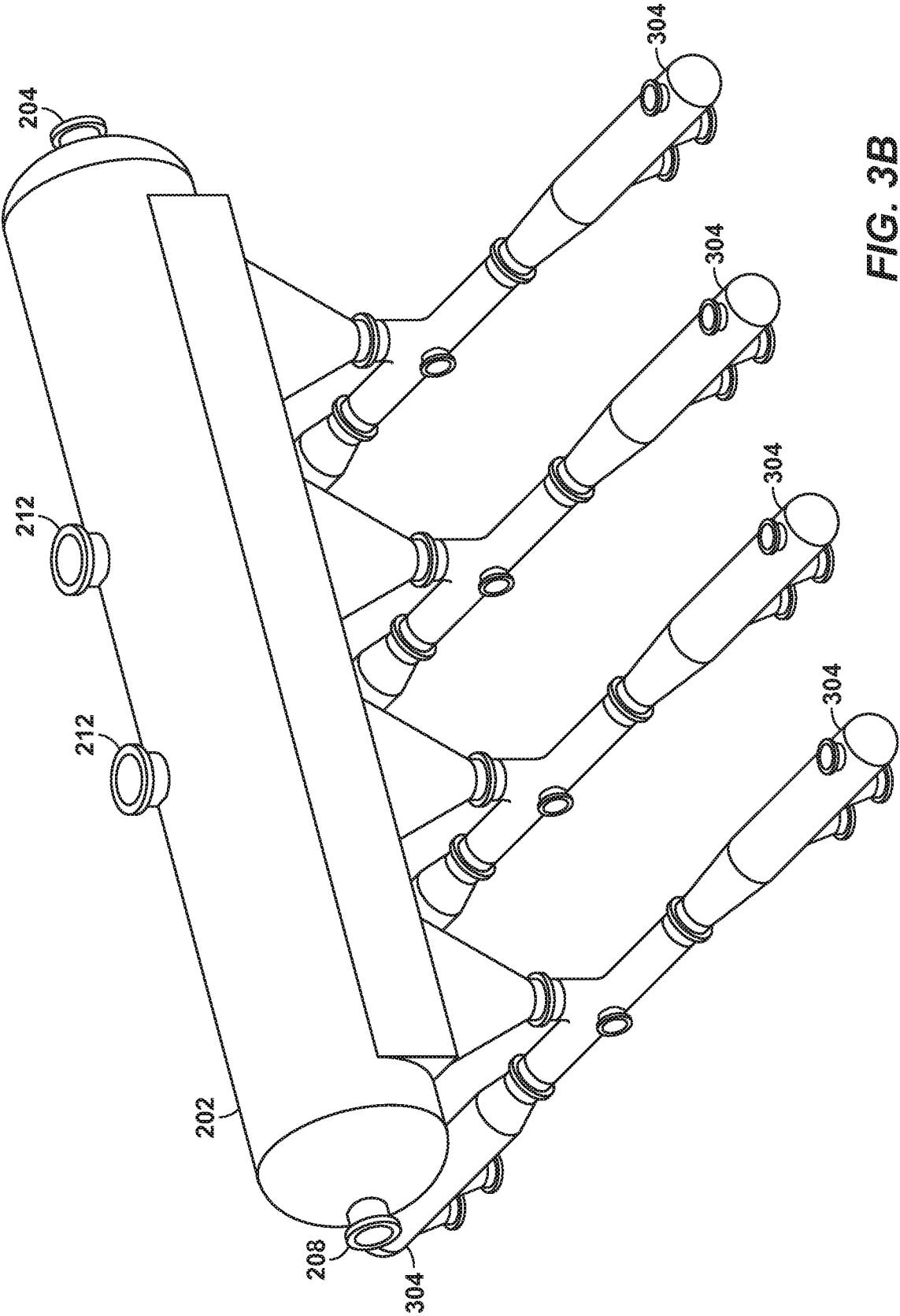
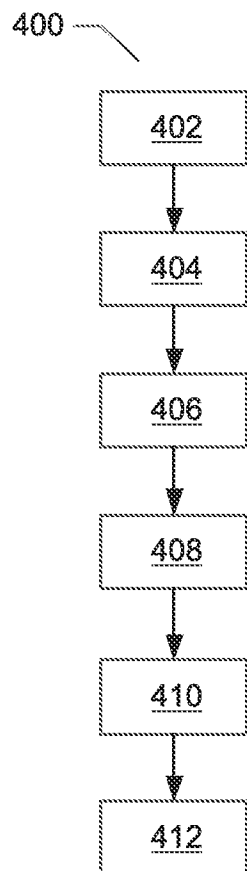
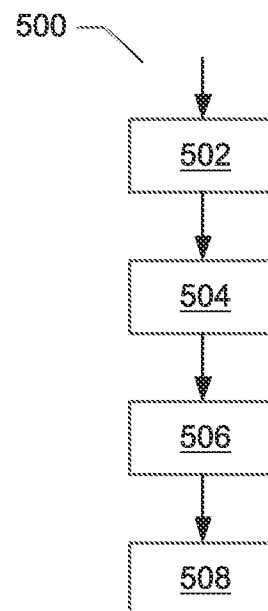


FIG. 3B

5/6

**FIG. 4****FIG. 5**

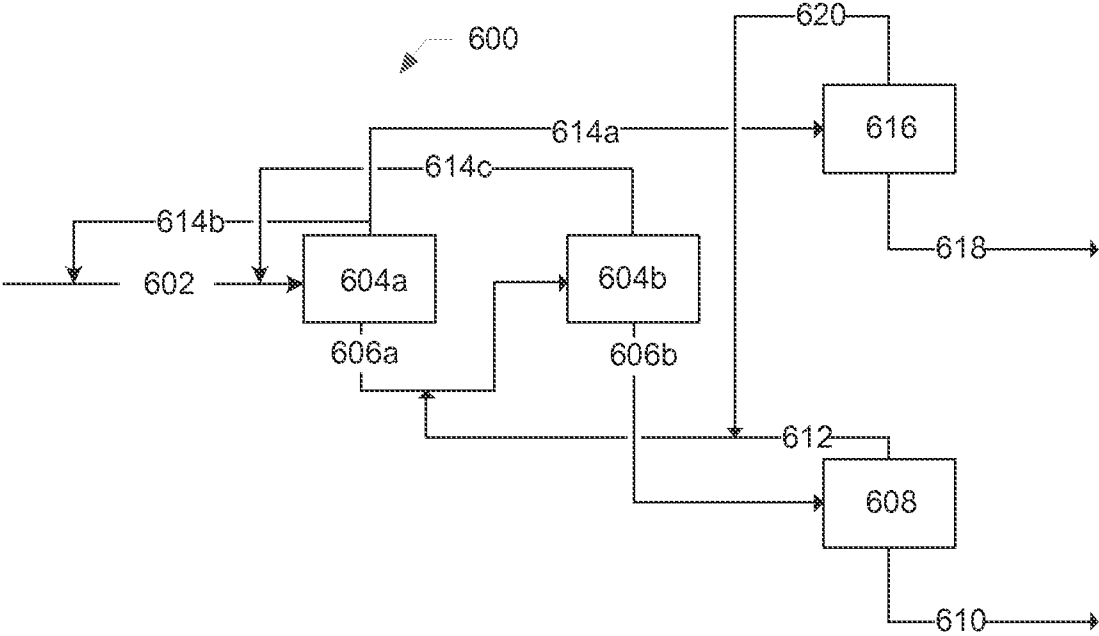


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/053230

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-20

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/053230

A. CLASSIFICATION OF SUBJECT MATTER
INV. C10G1/04 B01D11/00 B01D21/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C10G B01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 004 455 A (RENDALL JOHN S [US]) 21 December 1999 (1999-12-21) column 2, line 54 - line 57; figures 1-2 column 3, line 52 - column 4, line 9; claim 1	1-20
X	----- US 2009/134095 A1 (HANN THOMAS CHARLES [CA]) 28 May 2009 (2009-05-28) paragraphs [0002], [0068], [0070], [0071], [0072], [0074], [0080]; figure 2	1-20
A	----- US 5 695 655 A (SMATI ABDELLATIF [FR]) 9 December 1997 (1997-12-09) column 1, line 6 - line 10 column 4, line 62 - line 66; figure 1 ----- -/--	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

10 December 2015

Date of mailing of the international search report

22/02/2016

Name and mailing address of the ISA/

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Authorized officer

Chau, Thoi Dai

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/053230

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2 590 756 A (JULES COLIN ET AL) 25 March 1952 (1952-03-25) column 1, line 42 - line 43 claim 1; figure 1 -----	1-20
A	CA 1 140 081 A (KILBORN LIMITED) 25 January 1983 (1983-01-25) page 1, line 1 - line 2; figure 2 -----	1-20

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2015/053230

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US 2590756	A	25-03-1952	NONE

CA 1140081	A	25-01-1983	NONE

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-20

Method and system for recovering hydrocarbons from a bituminous feed in an oil sands solvent extraction process, comprising: a vessel comprising: a feed inlet on a proximate end of the vessel; a feed outlet on a distal end of the vessel; a bitumen outlet; and a plurality of hoppers, wherein each hopper comprises a tailing outlet.

2. claims: 21-23

A system for separating a bituminous feed in an oil sands solvent extraction process, comprising:
a vessel;
an inlet device coupled to a vessel and configured to receive the bituminous feed;
an outlet device coupled to the vessel and configured to discharge a tailings feed;
a plurality of bitumen outlets disposed on the vessel;
a plurality of hoppers disposed on a lower end of the vessel, wherein each hopper comprises a tailing outlet; and
a secondary extraction vessel operatively coupled to the outlet device so as to pass bitumen extracted in the secondary extraction vessel to the inlet device in a counter-current extraction.
