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(54) Title: METHOD OF PROCESSING A BITUMINOUS FEED AND CONTAMINATED WATER

(57) Abstract: A method of processing a bituminous feed and contaminated water comprises contacting the bituminous feed with an extraction liquor and the contaminated water to form an initial slurry. The initial slurry is solvent extracted to form an extracted slurry comprising solids, contaminated water, and a bitumen extract. The solids are separated from the bitumen extract. Solvent is recovered from the bitumen extract to form a bitumen product. High quality water and solvent are recovered from the solids. In addition to extracting bitumen, the method converts contaminated water into high quality water which can be used in water-based hydrocarbon extraction or in-situ thermal hydrocarbon recovery.



METHOD OF PROCESSING A BITUMINOUS FEED AND CONTAMINATED WATER

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the priority benefit of Canadian Patent Application 2,747,913 filed August 2, 2011 entitled METHOD OF PROCESSING A BITUMINOUS FEED
5 AND CONTAMINATED WATER, the entirety of which is incorporated by reference herein.

FIELD

[0002] The present disclosure relates generally to the field of hydrocarbon extraction from mineable deposits, such as bitumen from oil sands.

BACKGROUND

10 **[0003]** Oil sands are sand deposits which in addition to sand, comprise clays, connate water, and bitumen. Depending on geographic location, bitumen may be recovered by mining methods or in-situ recovery methods. These recovery methods typically require the extensive use of heat and water. Additionally, the effectiveness of these processes depends heavily on the quality of the water used.

15 **[0004]** Examples of thermal oil recovery processes include, but are not limited to, steam-assisted gravity drainage (SAGD), cyclic steam stimulation (CSS), and various derivatives thereof, such as solvent-assisted SAGD (SA-SAGD), steam and gas push (SAGP), combined vapor and steam extraction (SAVEX), expanding solvent SAGD (ES-SAGD), constant steam drainage (CSD), and liquid addition to steam for enhancing recovery
20 (LASER), as well as water flooding and steam flooding processes.

[0005] The in-situ thermal oil recovery of highly viscous bitumen from the oil sands poses numerous challenges, particularly since large quantities of water must be turned into steam for the extraction of bitumen within the oil sands reservoir. In order to generate steam from water, a suitable water quality with a limited amount of solids and dissolved solids is
25 required. For example, produced water from the reservoir is often sent to a costly water treatment plant sub-system in order to produce high quality water that can be sent to the steam generators. In the absence of suitable high quality water, special types of steam generators that are often expensive and unreliable are needed. In general, there is a need to develop a cost effective method of providing water with limited solids and dissolved solids
30 for use in the thermal oil recovery of bitumen.

[0006] Evaporation-based water treatment plants have been used for the water

treatment of produced water from thermal oil recovery. An example is described by Heins in U.S. Patent No. 6,733,636. Heins describes an elaborate process to produce high quality water suitable for the production of 100% quality steam from packaged boilers. Ikebe et al., in U.S. Patent Publication No. 2010/0264068, describe a simplified water treatment process
5 comprised of membrane-based treatment followed by evaporation-based treatment to produce high quality water suitable for steam generation. Regardless of the method of water treatment, a concentrated wastewater stream is produced that must be properly disposed of.

[0007] Water treatment plants and certain steam generators of thermal oil recovery facilities produce wastewater streams that may contain 5 to 10 times or more the solids and
10 dissolved solids content of the feed water. In certain situations, it may not be possible to inject the wastewater stream into the earth via deep wells. In these situations, it is common practice to further treat the wastewater stream, such as in a crystallizer system, to produce additional high quality water and a dry solids product. The dry solids are readily disposed of within landfills. Crystallizer systems and other known methods of treating such wastewater
15 streams tend to be both expensive in capital cost and operating cost. Thus, there is a need to develop a cost effective method of treating wastewater streams from thermal oil recovery facilities.

[0008] Oil sands ore in a mining and extraction operation is typically processed using mechanical and chemical techniques to separate the bitumen from the sands. In general,
20 water-based extraction and solvent-based extraction are the two processes that have been proposed or used to extract bitumen from mined oil sands. In the case of water-based extraction, water is the dominant liquid in the process and the extraction occurs by having water displace the bitumen on the surface of the solids. In the case of solvent-based extraction, the solvent is the dominant liquid and the extraction of the bitumen occurs by
25 dissolving bitumen into the solvent.

[0009] One of the most commonly employed water-based extraction processes is bitumen froth flotation. In this process, hot water, air and typically process aids are agitated with the oil sands resulting in bitumen droplets that attach to or coat air bubbles. The aerated bitumen rises under gravity to form a distinct hydrocarbon phase, known as bitumen
30 froth, which can be separated from the aqueous layer. The remaining aqueous phase, comprised of sand, clay, water and un-recovered bitumen, is known as tailings. A typical composition of the bitumen froth stream is about 60 wt% bitumen, 30 wt% water, and 10 wt% solids. The water and solids in the froth are considered as contaminants and are reduced in a froth treatment process to a level suitable for feed to an oil refinery or an
35 upgrading facility.

[0010] The water-based extraction of bitumen from oil sands poses numerous challenges, particularly since a large quantity of water is needed for the extraction process. In a typical extraction process, 6 to 8 barrels of water are used in a process that produces one barrel of bitumen. In fully mature extraction facilities, about 4 to 6 of those barrels of water are recycled from the tailings. However, the recycle water usually includes more solids and dissolved salts than that of fresh water.

[0011] The quality of the extraction water has a significant impact on the froth flotation process. The presence of fine solids and dissolved solids within the extraction water increases the tendency of the fine solids to coat the bitumen droplets. The solid coating then acts to impede the air bubbles from attaching to the bitumen droplets, which reduces bitumen flotation. Furthermore, an increased presence of fine solids and dissolved solids within the extraction water increases the viscosity of the slurry. The increase in viscosity makes it difficult for aerated bitumen to rise under gravity to form the distinct hydrocarbon phase. Thus, there is a need to develop a cost effective method of providing water with limited solid and dissolved solids for use in the water-based extraction of mined oil sands.

[0012] Attempts to recover high quality water from the oil sands extraction process have been described, for instance in U.S. Patents Nos. 4,343,691 (Minkkinen); 4,561,965 (Minkkinen); and 4,240,897 (Clarke), and are directed to heat and water vapor recovery from tailings for use in the extraction process using a humidification / dehumidification cycle. PCT Patent Publication WO 2004/060812, to Klausner et al., describes using waste heat from an industrial source for desalinating contaminated water, specifically sea water, for potable use. Cold water provided from deep ocean water is used to condense water from the air, and low grade heat is discharged to the environment with the seawater.

[0013] In certain prior process, the amount of water recovered from tailings or other methods is typically in the range of 0 to 5%. This low water recovery is somewhat insignificant in comparison to overall water usage requirements for an oil sands mining operation for bitumen recovery and thus makes very little impact on the commercial process.

[0014] Solvent-based extraction processes for the recovery of bitumen from mined oil sands have been proposed as an alternative to water-based extraction since, among other benefits, solvent-based extraction processes have the potential to use much less water and water of lower quality than that used by water-based extraction processes. However, the commercial application of a solvent-based extraction process has, for various reasons, eluded the oil sands industry. A major challenge to the application of solvent-based

extraction to oil sands is the tendency of fine particles within the oil sands to hamper the separation of solids from the bitumen extract. Solvent extraction with solids agglomeration is a technique that has been proposed to deal with this challenge. The original application of this technology was coined Solvent Extraction Spherical Agglomeration (SESA). A more recent description of the SESA process can be found in Sparks et al., Fuel 1992(71); pp 5 1349-1353.

[0015] Previously described methodologies for SESA have not been commercially adopted. In general, the SESA process involves mixing oil sands with a hydrocarbon solvent, adding a bridging liquid to the oil sands slurry, agitating the mixture in a slow and controlled manner to nucleate particles, and continuing such agitation to permit these 10 nucleated particles to form larger multi-particle spherical agglomerates for removal. The bridging liquid is preferably water or an aqueous solution since the solids of oil sands are mostly hydrophilic and water is immiscible with hydrocarbon solvents. It has been found that the bridging liquid used in the process can be water with both a high fines and dissolved 15 solids content. In fact, in certain embodiments of the SESA process, it may be preferable to have aqueous bridging liquid with either high fines content and/or high dissolved solid content.

[0016] The SESA process described by Meadus et al. in U.S. Patent No. 4,057,486, involves combining solvent extraction with solids agglomeration to achieve dry tailings 20 suitable for direct mine refill. In the process, organic material is separated from oil sands by mixing the oil sands material with an organic solvent to form a slurry, after which an aqueous bridging liquid is added in the amount of 8 to 50 wt% of the feed mixture. By using controlled agitation, solid particles from oil sands come into contact with the aqueous bridging liquid and adhere to each other to form macro-agglomerates of a mean diameter of 2 mm or 25 greater. The formed agglomerates are more easily separated from the organic extract compared to un-agglomerated solids. The organic extract free agglomerates can be sintered at high temperatures to make useful construction material. For example, halide salts such as NaCl, KCl, and CaCl₂ can be dissolved in the aqueous bridging liquid to form agglomerates that, when sintered at elevated temperatures, produce very strong 30 aggregates.

[0017] The macro-agglomeration process described by Meadus et al. may be suitable for oil sands feeds comprising greater than 15 wt% fines. For oil sands with a lesser amount of fines, it was found to be beneficial to have a water and fine particle slurry as the bridging liquid. U.S. Patent No. 3,984,287 (Meadus et al.) describes that middlings of a 35 primary separation vessel of a water-based extraction process or sludge from the water-

based extraction tailings ponds may be used as the bridging liquids with high fines content. It has been shown that when sludge is used as the bridging liquid, the addition of the same amount of sludge per unit weight of oil sands feed may result in the production of agglomerates of the same drainage properties regardless of oil sands quality.

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SUMMARY

[0018] The present disclosure relates to a method of processing a bituminous feed and contaminated water. The bituminous feed is contacted with an extraction liquor and the contaminated water to form an initial slurry. The initial slurry is solvent extracted to form an extracted slurry comprising solids, contaminated water, and a bitumen extract. The solids
10 are separated from the bitumen extract. Solvent is recovered from the bitumen extract to form a bitumen product. High quality water and solvent are recovered from the solids. In addition to extraction bitumen, the method converts contaminated water into high quality water which can be used in water-based hydrocarbon extraction or in-situ thermal hydrocarbon recovery.

15 **[0019]** In a first aspect, the present disclosure provides a method of processing a bituminous feed and contaminated water, the method comprising: a) contacting the bituminous feed with an extraction liquor and the contaminated water to form an initial slurry, wherein the extraction liquor comprises a solvent; b) solvent extracting the initial slurry to extract bitumen from the bituminous feed to form an extracted slurry comprising solids, the
20 contaminated water, and a bitumen extract; c) separating the solids and the contaminated water from the bitumen extract; d) recovering solvent from the bitumen extract to form a bitumen product; e) recovering solvent and high quality water from the solids to form dry tailings; and f) separating the high quality water from the solvent.

[0020] Other aspects and features of the present disclosure will become apparent to
25 those ordinarily skilled in the art upon review of the following description of specific embodiments in conjunction with the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] Embodiments of the present disclosure will now be described, by way of example only, with reference to the attached figures.

30 **[0022]** Fig. 1 is a schematic illustrating a disclosed embodiment.

[0023] Fig. 2 is a schematic illustrating a disclosed embodiment.

[0024] Fig. 3 is a schematic illustrating a disclosed embodiment.

[0025] Fig. 4 is a schematic illustrating a disclosed embodiment.

[0026] Fig. 5 is a schematic illustrating a disclosed embodiment.

DETAILED DESCRIPTION

5 **[0027]** 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
10 realized some initial processing but nevertheless requires further processing. Also, recycled streams that comprise bitumen in combination with other components for removal as 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 extraction processes which comprises bitumen that would otherwise not
15 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.

[0028] As used herein, the term "agglomerate" refers to conditions that produce a cluster, aggregate, collection or mass, such as nucleation, coalescence, layering, sticking, clumping, fusing and sintering, as examples.

20 **[0029]** As used herein, the term "high quality water" means water with a solids concentration of less than 1 wt.%, preferably less than 0.5 wt.%, and with a monovalent cation concentration of less than 2000 wppm, preferably less than 1000 wppm, and more preferably less than 100 wppm. Monovalent cations may include, but are not limited to sodium cations.

25 **[0030]** As described in the summary section, the present disclosure relates to a method of processing a bituminous feed and contaminated water. The bituminous feed is contacted with an extraction liquor and the contaminated water to form an initial slurry. The initial slurry is solvent extracted to form an extracted slurry comprising solids, the contaminated water, and a bitumen extract. The solids are separated from the bitumen
30 extract. Solvent is recovered from the bitumen extract to form a bitumen product. High quality water and solvent are recovered from the solids. In addition to extracting bitumen, the method converts contaminated water into high quality water which can be used in water-based hydrocarbon extraction or in-situ thermal hydrocarbon recovery.

- [0031]** One embodiment relates to a method for using a solvent-based extraction process for extracting bitumen from mined oil sands and recovering high quality water from contaminated water. Bituminous feed is dissolved and extracted via an extraction liquor and solid-liquid separation is assisted by the presence of the contaminated water. The contaminated water comprises fine solids and/or dissolved solids. The amount of fine solids and/or dissolved solids within the contaminated water is of a quantity such that the contaminated water is not suitable or not preferable for use within in-situ thermal hydrocarbon recovery or water-based hydrocarbon extraction processes. The contaminated water does not meet the high-quality water specifications provided above.
- [0032]** Figure 1 illustrates one embodiment. As shown in Figure 1, bituminous feed (**102**) is mixed with extraction liquor (**104**) and contaminated water (**106**) within a solvent-based extraction process (**107**) forming an initial slurry (within **107**) and then an extracted slurry (**108**). The majority of the solids and water (together **110**) are separated using a solid-liquid separator (**112**) from the bitumen extract (**114**) and then, if required, washed with a second solvent (not shown) in order to remove residual bitumen within the solids. Solvent and water vapor (together **121**) are then evaporated from the solids (**110**) in a tailings solvent recovery unit (TSRU) (**116**) in order to form environmentally acceptable dry tailings (**120**). Dry tailings may have a water:solids mass ratio of less than 0.15:1. Additional contaminated water (**118**) may be added to the TSRU (**116**) in order to maintain a specified level of water within the tailings (**120**), and to recover heat and additional high quality water. Solvent and water vapor (together **121**) from the TSRU (**116**) are condensed and then separated in order to recover high quality water (**122**) with reduced solids and dissolved solids content and solvent (**123**). Solvent (**124**) is removed from the bitumen extract (**114**) using a solvent recovery unit (**126**) in order to form a bitumen product (**128**).
- [0033]** Suitable solvent-based extraction processes may include any solvent-based extraction process that uses an aqueous stream in the extraction process. It is preferable that the solvent-based extraction process be a process that is not adversely or too adversely affected by the use of an aqueous stream with a significant amount of solids and/or dissolved solids. Exemplary solvent-based extraction processes include, but are not limited to, those described in the background section, those described below, and those described in Canadian Patent Application Serial No. 2,724,806 ("Adeyinka et al."), filed December 10, 2010 and entitled "Process and Systems for Solvent Extraction of Bitumen from Oil Sands".

Summary of Processes of Solvent Extraction Described in Adeyinka et al.

- [0034]** One method of extracting bitumen from oil sands in a manner that employs

solvent extraction with solids agglomeration is described by Adeyinka et al. In this process, a solvent is combined with a bituminous feed derived from oil sands to form an initial slurry. Separation of the initial slurry into a fine solids stream and a coarse solids stream may be followed by mixing a bridging liquid with the fine solid stream and agglomeration of solids from the fine solids stream to form an agglomerated slurry. The agglomerated slurry can be separated into agglomerates and a low solids bitumen extract. Optionally, the coarse solids stream may be reintroduced and further extracted in the agglomerated slurry. A low solids bitumen extract can be separated from the agglomerated slurry for further processing. Optionally, the mixing of a second solvent with the low solids bitumen extract to extract bitumen may take place, forming a solvent-bitumen low solids mixture, which can then be separated further into low grade and high grade bitumen extracts. Recovery of solvent from the low grade and/or high grade extracts is conducted, to produce bitumen products of commercial value.

Embodiments with Solvent Extraction with Solids Agglomeration:

[0035] One embodiment relates to a method for using a solvent extraction with solids agglomeration process for extracting bitumen from mined oil sands and recovering high quality water from contaminated water. Bituminous feed is dissolved and extracted via an extraction liquor and solids are agglomerated via contact with a bridging liquid and agitation. As described further below, contaminated water is used herein as the bridging liquid or as part of the bridging liquid. The contaminated water may be, for instance, from a water-based hydrocarbon extraction process or from an in-situ thermal hydrocarbon recovery facility. The contaminated water may comprise fine solids and/or dissolved solids. The amount of fine solids and/or dissolved solids within the water is of sufficient quantity such that said contaminated water is not suitable or not preferable for use within thermal oil recovery or water-based extraction processes.

[0036] Figure 2 illustrates one embodiment. As illustrated in Figure 2, within a solvent-extraction process, bituminous feed (**202**) is mixed with extraction liquor (**204**) in a mixing vessel (**206**) to form an initial slurry (**208**). The initial slurry (**208**) is passed to an agglomerator (**210**) where contaminated water (**212**) is added, forming an agglomerated slurry (**214**). The contaminated water (**212**) is used as a bridging liquid to assist solids agglomeration of the slurry (**208**) in order to improve subsequent solid-liquid separation. The majority of the agglomerated solids (**216**) are separated from the bitumen extract (**218**) in a solid-liquid separator (**220**) and then, if required, washed with a second solvent in order to remove any residual bitumen within the solids (not shown). Solvent and water vapor (together **221**) are then evaporated from the agglomerates (**216**) in a tailings solvent

recovery unit (TSRU) (220) in order to form environmentally acceptable dry tailings (222). Additional contaminated water (224) may be added to the TSRU (220) in order to maintain a specified level of water within the tailings. Solvent and water vapor (together 221) from the TSRU (220) are condensed and then separated in order to recover high quality water (226) with reduced solids and dissolved solids content, and solvent (227). Solvent (228) is removed from the bitumen extract (218) using a solvent recovery unit (229) in order to form a bitumen product (230).

[0037] In one embodiment, the bituminous feed is oil sands. The oil sands feed may be contacted with extraction liquor that is free of contaminated water or other bridging liquid in a slurry system to produce a pumpable slurry. The oil sands feed may be heated to evaporate connate water from the oil sands in order to recover high quality water and to minimize feed variability due to water content. The slurry may be well mixed in order to dissolve the bitumen. In this embodiment, the bitumen is first extracted from the oil sands prior to agglomeration in order to prevent (or limit) the agglomeration process from hampering the dissolution of bitumen into the extraction liquor and prevent (or limit) bitumen occlusion within the agglomerate. In another embodiment, the contaminated water may be directly mixed with the oil sands before or at the same time as the extraction liquor so that bitumen extraction and agglomeration occur simultaneously. In this embodiment, the contaminated water may be added before or at the same time as the extraction liquor in order to minimize the dispersion of fines, which may reduce the solids content of the bitumen extract after the agglomeration process. Additionally, the contaminated water may be added before or at the same time as the extraction liquor in order to minimize the adsorption of solvent onto the surface of the solids, which may reduce the energy required for tailings solvent recovery.

25 Integration of Solvent-Based Extraction with Water-Based Extraction:

[0038] In one embodiment, the solvent-based extraction facility is in proximity to a water-based extraction facility such that aqueous streams can be exchanged between the extraction facilities. A portion of water-based extraction streams may be pumped to the solvent-based extraction facility for use in a solvent extraction with solids agglomeration process. Suitable water-based extraction streams include, but are not limited to, middlings from primary separation, secondary and tertiary separation tailings, froth treatment tailings, mature fine tailings from a tailings pond, or a new stream resulting from passing any of these streams through a thickener, hydrocyclone, or other device. For example, middlings passed through a cyclone might generate an overflow stream and an underflow stream. Either stream could be used in the solvent extraction with solids agglomeration process.

Particularly suitable streams are water-based extraction streams having high solids and/or dissolved solids contents because they are unsuitable, as is, for use in the recovery of additional bitumen within a water-based extraction process. Thus, these water-based extraction streams are directed to a solvent-based extraction process to assist in the solvent extraction of additional bitumen from mined oil sands while simultaneously undergoing water treatment by evaporation that yields a high quality water with a reduced solids and dissolved solids content. The higher quality water can be directed back to the water-based extraction process to provide improved bitumen recovery.

[0039] Figure 3 provides a process flow diagram of an embodiment of integrating solvent-based extraction with water-based extraction in order to extract bitumen from mined oil sands and recovering high quality water from contaminated water. As illustrated in Figure 3, oil sand (302) is mixed with water (304) in a mix box (306) and passed to a primary separation vessel (PSV) (308). The bitumen froth (310) is sent to paraffinic froth treatment (PFT) (312). Primary separation and paraffinic froth treatment are known and an example is described in Canadian Patent No. 2,587,166 (Sury). The PFT (312) illustrated in Figure 3 includes a first froth separation unit (FSU) (314), a second froth separation unit (FSU) (316), a solvent recovery unit (SRU) (318), and a tailings solvent recovery unit (TSRU) (320). The PFT (312) yields a bitumen product (322) and PFT tailings (324). The PFT tailings (324) may be sent to solvent-based extraction (326).

[0040] PSV tailings (328), from the PSV (308), may also be sent to solvent-based extraction (326). A middling stream (330), from the PSV (308), is passed to flotation cells (332) producing a bitumen-rich stream (334) which is sent back into the PSV (308) and a flotation tailings stream (336) which may also be sent to solvent-based extraction (326). Additional oil sand (338) may also be added to the solvent-based extraction (326). The solvent-based extraction (326) produces a bitumen product (340), tailings (342), and high-quality water (344). As illustrated, the high-quality water (344) may be recycled into the water-based extraction process.

[0041] In some cases, it has been found that high quality water may not extract bitumen as well as process affected water. This may be mitigated in several ways; for example, by combining the high quality water with good quality process affected water, or by using the high quality water for a water wash within secondary recovery processes. In this way, certain water soluble organic compounds that are advantageous for extraction efficiency can be recovered to enhance bitumen recovery.

[0042] The aqueous stream from the water-based extraction process may undergo a

water treatment process prior to being directed to the solvent-based extraction process. The wastewater stream from the water treatment process, with concentrated solids and dissolved solids, is then directed to the solvent-based extraction process. Exemplary tailings treatment processes include, but are not limited to, those described in the background section and those described in Canadian Patent No. 2,609,419 (Speirs and Dunn) and Canadian Patent
5 Application No. 2,610,052 (Speirs and Dunn).

Integration of Solvent-Based Extraction with Thermal Oil Recovery:

[0043] In one embodiment, the solvent-based extraction facility is in proximity to a thermal oil recovery facility such that aqueous streams can be exchanged between these
10 two facilities. A portion of thermal oil recovery aqueous streams may be pumped to the solvent-based extraction facility for use in a solvent extraction with solids agglomeration process. Suitable aqueous streams include, but are not limited to, produced water from the primary liquid-liquid separation vessels or other separation vessels downstream of the primary separation vessels, wastewater from the water treatment plants, and/or the
15 blowdown streams from the steam generators. Particularly suitable streams are aqueous streams from a thermal oil facility having high solids and/or dissolved solids contents because they are unsuitable, as is, for steam generation or other uses. Thus, these aqueous streams are directed to the described solvent-based extraction process to assist in the solvent extraction of additional bitumen from mined oil sands while simultaneously
20 undergoing water treatment by evaporation that yields a high quality water with reduced solids and dissolved solids content. The higher quality water can be directed back to the thermal oil recovery facilities or released into the environment.

[0044] Figure 4 illustrates one embodiment. As illustrated in Figure 4, a production well (402) produces bitumen and water (together 404), which is sent to a separator (406).
25 The separator produces bitumen (408) and water (410). The water (410) is sent to a filter (412), which produces bitumen (414) and water (416). The water (416) is sent to an evaporator (418), which produces wastewater (420) and high quality water with reduced solids and dissolved solids (422). The recycling step (424) of the evaporator (418) is also illustrated. The high quality water (422) is sent to a boiler (426), which produces steam
30 (428) and a blowdown stream (430). The wastewater stream (420) and blowdown stream (430) may be sent to solvent-based extraction (432) to produce a bitumen product (434), dry tailings (436), and high quality water (438). The high quality water (438) may be recycled into the boiler (426). Additional oil sand (440) may also be added to the solvent-based extraction (432).

[0045] The produced water from the primary separation vessel may comprise about 1000 to 3000 mg/L of bitumen. In conventional thermal oil recovery facilities, the bitumen is recovered from the produced water using sequential skim tanks, gas flotation vessels, and oil removal filters. In embodiments described herein, a portion of the produced water from the primary separation vessel may bypass these bitumen recovery stages and instead be pumped to the solvent-based extraction facility in order to both recover the residual bitumen and produce high quality water.

[0046] In conventional thermal oil recovery facilities, the produced water, after bitumen recovery, may be directed to a water treatment unit, such as an evaporator, as a means of producing high quality water with reduced dissolved solids. The wastewater stream from the water treatment unit is usually either disposed of by deep well injection, or is further concentrated to produce additional high quality water for steam generation and dry solids that can be buried. In embodiments described herein, a portion of the wastewater stream, concentrated with solids and dissolved solids, from the water treatment unit may be pumped to the solvent-based extraction facility to produce high quality water. The dissolved solids of the wastewater stream will end up solidified with the tailings of the solvent-based extraction process.

[0047] A typical steam generator used in thermal oil recovery facilities is a once-through-type boiler which often operates with a feed water containing about 2,000 to 12,000 mg/L of dissolved solids. In these boilers, about 80% of the feed water is turned into steam with the remaining 20% of the feed water becoming the blowdown stream with five times the dissolved solids concentration. The blowdown stream is of high pressure and thus can be flashed in a series of flash tanks to recovery lower pressures steam that can be used in other parts of the facilities. After the last flashing stage, the final blowdown stream is usually mixed with the wastewater stream from the water treatment unit and disposed of by the methods described above. In embodiments described herein, a portion of the blowdown streams from the steam generators may be pumped to the solvent-based extraction facility to produce high quality water.

Additional Embodiments with Solvent Extraction with Solids Agglomeration:

[0048] Figure 5 is a schematic of solvent-based extraction method with agglomeration and additional steps including downstream solvent and water recovery. The extraction liquor (502) is mixed with a bituminous feed (504) from oil sands in a slurry system (506) to form an initial slurry (508). The extraction liquor (502) comprises a solvent and is used to extract bitumen from the bituminous feed (504). Contaminated water (509) is also

added to the slurry system (506) for use as the bridging liquid. The initial slurry (508) is fed into an agglomerator (510). Extraction may begin when the extraction liquor (502) is contacted with the bituminous feed (504) and a portion of the extraction may occur in the agglomerator (510). Agitation of the slurry is used to assist agglomeration.

- 5 [0049] The agglomerated slurry (514), comprising agglomerates and a low solids bitumen extract, is sent to a solid-liquid separator (516) to produce a low solids bitumen extract (518) and agglomerates (520).

[0050] The following additional steps may also be performed. The low solids bitumen extract (518) is sent to a solvent recovery unit (522) to recover solvent (524), which
10 may be re-used to wash the agglomerates (520), leaving a bitumen product (526). The agglomerates (520), along with contaminated water (534), are sent to a tailings solvent recovery unit (528) to recover solvent and water (together 530) leaving dry tailings (532).

[0051] The solvent and water (530) from the tailings solvent recovery unit (528) is sent to a liquid separator (536), which produces solvent (538) and high quality water (540).
15 Exemplary liquid separators include vertical or horizontal settling tanks that are well known in the art.

[0052] **Agglomeration.** In one embodiment, the formed agglomerates are sized on the order of 0.1-1.0 mm, or on the order of 0.1-0.3 mm. In one embodiment, at least 80 wt.% of the formed agglomerates are less than 2mm, or 0.1-1.0 mm, or 0.1 to 0.3 mm in size. The
20 rate of agglomeration may be controlled by a balance between intensity of agitation within the agglomeration vessel, shear within the vessel which can be adjusted by for example changing the shape or size of the vessel, fines content of the slurry, bridging liquid addition, and residence time of the agglomeration process. The agglomerated slurry may have a solids content of 20 to 70 wt%.

25 [0053] **Agitation.** Agglomeration is assisted by some form of agitation. The form of agitation may be mixing, shaking, rolling, or another known suitable method. The agitation of the feed need only be severe enough and of sufficient duration to intimately contact the emulsion with the solids in the feed. Exemplary rolling type vessels include rod mills and tumblers. Exemplary mixing type vessels include mixing tanks, blenders, and attrition
30 scrubbers. In the case of mixing type vessels, a sufficient amount of agitation is needed to keep the formed agglomerates in suspension. In rolling type vessels, the solids content of the feed is, in one embodiment, greater than 40 wt.% so that compaction forces assist agglomerate formation. The agitation of the slurry has an impact on the growth of the agglomerates. In the case of mixing type vessels, the mixing power can be increased in

order to limit the growth of agglomerates by attrition of said agglomerates. In the case of rolling type vessels the fill volume and rotation rate of the vessel can be adjusted in order to increase the compaction forces used in the comminution of agglomerates. These agitation parameters can be adjusted in the control system described herein.

5 **[0054] Extraction Liquor.** The extraction liquor comprises a solvent used to extract bitumen from the bituminous feed. The term "solvent" as used herein should be understood to mean either a single solvent, or a combination of solvents.

[0055] In one embodiment, the extraction liquor comprises a hydrocarbon solvent capable of dissolving the bitumen. The extraction liquor may be a solution of a hydrocarbon solvent(s) and bitumen, where the bitumen content of the extraction liquor may range
10 between 10 and 70 wt%, or 10 and 50 wt%. It may be desirable to have dissolved bitumen within the extraction liquor in order to increase the volume of the extraction liquor without an increase in the required inventory of hydrocarbon solvent(s). In cases where non-aromatic hydrocarbon solvents are used, the dissolved bitumen within the extraction liquor also
15 increases the solubility of the extraction liquor towards dissolving additional bitumen.

[0056] The extraction liquor may be mixed with the bituminous feed to form a slurry where most or all of the bitumen from the oil sands is dissolved into the extraction liquor. In one embodiment, the solids content of the slurry is in the range of 10 wt% to 75 wt%, or 50 to 65 wt%. A slurry with a higher solids content may be more suitable for agglomeration in a
20 rolling type vessel, where the compressive forces aid in the formation of compact agglomerates. For turbulent flow type vessels, such as an attrition scrubber, a slurry with a lower solids content may be more suitable.

[0057] The solvent used in the process may include low boiling point solvents such as low boiling point cycloalkanes, or a mixture of such cycloalkanes, which substantially
25 dissolve asphaltenes. The solvent may comprise a paraffinic solvent in which the solvent to bitumen ratio is maintained at a level to avoid or limit precipitation of asphaltenes.

[0058] While it is not necessary to use a low boiling point solvent, when it is used, there is the extra advantage that solvent recovery through an evaporative process proceeds at lower temperatures, and requires a lower energy consumption. When a low boiling point
30 solvent is selected, it may be one having a boiling point of less than 100 °C.

[0059] The solvent selected according to certain embodiments may comprise an organic solvent or a mixture of organic solvents. For example, the solvent may comprise a paraffinic solvent, an open chain aliphatic hydrocarbon, a cyclic aliphatic hydrocarbon, or a

mixture thereof. Should a paraffinic solvent be utilized, it may comprise an alkane, a natural gas condensate, a distillate from a fractionation unit (or diluent cut), or a combination of these containing more than 40% small chain paraffins of 5 to 10 carbon atoms. These embodiments would be considered primarily a small chain (or short chain) paraffin mixture.

5 Should an alkane be selected as the solvent, the alkane may comprise a normal alkane, an iso-alkane, or a combination thereof. The alkane may specifically comprise heptane, iso-heptane, hexane, iso-hexane, pentane, iso-pentane, or a combination thereof. Should a cyclic aliphatic hydrocarbon be selected as the solvent, it may comprise a cycloalkane of 4 to 9 carbon atoms. A mixture of C₄-C₉ cyclic and/or open chain aliphatic solvents would be

10 appropriate.

[0060] Exemplary cycloalkanes include cyclohexane, cyclopentane, or a mixture thereof.

[0061] If the solvent is selected as the distillate from a fractionation unit, it may for example be one having a final boiling point of less than 180 °C. An exemplary upper limit of

15 the final boiling point of the distillate may be less than 100 °C.

[0062] A mixture of C₄-C₁₀ cyclic and/or open chain aliphatic solvents would also be appropriate. For example, it can be a mixture of C₄-C₉ cyclic aliphatic hydrocarbons and paraffinic solvents where the percentage of the cyclic aliphatic hydrocarbons in the mixture is greater than 50%.

20 **[0063]** Extraction liquor may be recycled from a downstream step. For instance, as described below, solvent recovered in a solvent recovery unit, may be used to wash agglomerates, and the resulting stream may be used as extraction liquor. As a result, the extraction liquor may comprise residual bitumen and residual solid fines. The residual bitumen increases the volume of the extraction liquor and it may increase the solubility of the

25 extraction liquor for additional bitumen dissolution.

[0064] The solvent may also include additives. These additives may or may not be considered a solvent per se. Possible additives may be components such as de-emulsifying agents or solids aggregating agents. Having an agglomerating agent additive present in the bridging liquid and dispersed in the first solvent may be helpful in the subsequent

30 agglomeration step. Exemplary agglomerating agent additives include cements, fly ash, gypsum, lime, brine, water softening wastes (e.g. magnesium oxide and calcium carbonate), solids conditioning and anti-erosion aids such as polyvinyl acetate emulsion, commercial fertilizer, humic substances (e.g. fulvic acid), polyacrylamide based flocculants and others. Additives may also be added prior to gravity separation with the second solvent to enhance

removal of suspended solids and prevent emulsification of the two solvents. Exemplary additives include methanoic acid, ethylcellulose and polyoxyalkylate block polymers.

[0065] Bridging Liquid. A bridging liquid is a liquid with affinity for the solids particles in the bituminous feed, and which is immiscible in the solvent. Exemplary aqueous liquids may be recycled water from other aspects or steps of oil sands processing. The aqueous liquid need not be pure water, and may indeed be water containing one or more salt, a waste product from conventional aqueous oil sand extraction processes which may include additives, aqueous solutions with a range of pH, or any other acceptable aqueous solution capable of adhering to solid particles within an agglomerator in such a way that permits fines to adhere to each other.

[0066] Contaminated water is used herein as the bridging liquid or as part of the bridging liquid. The contaminated water may be, for instance, from a water-based hydrocarbon extraction process or from an in-situ thermal hydrocarbon recovery facility. The contaminated water may include solids and/or dissolved solids. Contaminated water requiring treatment prior to use within in-situ thermal hydrocarbon recovery and/or water-based extraction processes may be used. Exemplary wastewaters are concentrated brine from water treatment plants and boilers of the in-situ thermal hydrocarbon recovery processes and tailings produced from water-based hydrocarbon extraction processes.

[0067] The total amount of bridging liquid added may be controlled in order to optimize bitumen recovery and the rate of solid-liquid separation, and may also be controlled with an account of the value provided by the upgrading of the contaminated water to high quality water. By way of example, the total amount of bridging liquid added may be such that a ratio of bridging liquid plus connate water from the bituminous feed to solids within the agglomerated slurry is in the range of 0.02 to 0.25, or in the range of 0.05 to 0.11.

[0068] The bridging liquid may be added in a concentration of less than 50 wt% of the oil sands feed, or less 25 wt%.

[0069] In one embodiment, the bridging liquid may comprise fine particles (sized less than 44 μm) suspended therein. These fine particles may serve as seed particles for the agglomeration process. In one embodiment, the bridging liquid has a solids content of less than 40 wt%.

[0070] Ratio of Solvent to Bitumen for Agglomeration. The process may be adjusted to render the ratio of the solvent to bitumen in the agglomerator at a level that avoids precipitation of asphaltenes during agglomeration. Some amount of asphaltene

precipitation is unavoidable, but by adjusting the amount of solvent flowing into the system, with respect to the expected amount of bitumen in the bituminous feed, when taken together with the amount of bitumen that may be entrained in the extraction liquor used, can permit the control of a ratio of solvent to bitumen in the agglomerator. When the solvent is
5 assessed for an optimal ratio of solvent to bitumen during agglomeration, the precipitation of asphaltenes can be minimized or avoided beyond an unavoidable amount. Another advantage of selecting an optimal solvent to bitumen ratio is that when the ratio of solvent to bitumen is too high, costs of the process may be increased due to increased solvent requirements.

10 **[0071]** An exemplary ratio of solvent to bitumen to be selected as a target ratio during agglomeration is less than 2:1. A ratio of 1.5:1 or less, and a ratio of 1:1 or less, for example, a ratio of 0.75:1, would also be considered acceptable target ratios for agglomeration. For clarity, ratios may be expressed herein using a colon between two values, such as "2:1", or may equally be expressed as a single number, such as "2", which
15 carries the assumption that the denominator of the ratio is 1 and is expressed on a weight to weight basis.

[0072] Measurement of the solvent and bitumen content of the extraction liquor and/or bitumen extract could occur directly or by proxy. Direct measurement of solvent and bitumen content could involve evaporating off the solvent and measuring the mass of both
20 liquids, or use of a gas chromatograph, mass balance, spectrometer, or titration. Indirect measurement of solvent and bitumen content could include measuring: density, the index of refraction, opacity, or other properties.

[0073] Slurry System. The slurry system may optionally be a mix box, a pump, or a combination of these. By slurrying the extraction liquor together with the bituminous feed, and optionally with additional additives, the bitumen entrained within the feed is given an
25 opportunity to become extracted into the solvent phase prior to agglomeration within the agglomerator.

[0074] The resulting slurry from the slurry system may have a solid content in the range of 20 to 65 wt%. In another embodiment, the slurry may have a solid content in the
30 range of 20 to 50 wt%. In another embodiment, the slurry may have a solid content in the range of 40 to 65 wt%. In the case of mixing type vessels, a lower solid content may be preferred since that will assist in the proper mixing of the bridging liquid and reduce the mixing energy needed to keep the slurry well mixed. In the case of rolling type vessels, a higher solid content may be preferred since that will increase the compaction forces used in

the comminution of agglomerates. Additionally, the increased compaction forces may reduce the amount of hydrocarbons that remain in the agglomerates and produce stronger agglomerates.

5 [0075] The preferred temperature of the slurry is in the range of 20-60 °C. An elevated slurry temperature is desired in order to increase the bitumen dissolution rate and reduce the viscosity of the slurry to promote more effective sand digestion and agglomerate formation. Temperatures above 60 °C are generally avoided due to the complications resulting from high vapor pressures.

10 [0076] **Residence Time.** The residence time of the extraction process may be greater than 5 minutes, or may be greater than 10 minutes, or may be greater than 15 minutes, or may be greater than 30 minutes. Depending on the desired level of agglomeration, the residence time of the agglomeration process may be in the range of 15 seconds to 10 minutes. In order to maximize bitumen recovery, the residence time of the agglomeration process may be in the range of 1 to 5 minutes.

15 [0077] **Solid-Liquid Separator.** As described above, the agglomerated slurry may be separated into a low solids bitumen extract and agglomerates in a solid-liquid separator. The solid-liquid separator may comprise any type of unit capable of separating solids from liquids, so as to remove agglomerates. Exemplary types of units include a gravity separator, a clarifier, a cyclone, a screen, a belt filter or a combination thereof.

20 [0078] The system may contain a solid-liquid separator but may alternatively contain more than one. When more than one solid-liquid separation step is employed at this stage of the process, it may be said that both steps are conducted within one solid-liquid separator, or if such steps are dissimilar, or not proximal to each other, it may be said that a primary solid-liquid separator is employed together with a secondary solid-liquid separator. When a
25 primary and secondary unit are both employed, generally, the primary unit separates agglomerates, while the secondary unit involves washing agglomerates.

[0079] Non-limiting methods of solid-liquid separation of an agglomerated slurry are described in Canadian Patent Application Serial No. 2,724,806 (Adeyinka et al.), filed December 10, 2010.

30 [0080] **Secondary Stage of Solid-Liquid Separation to Wash Agglomerates.** As a component of the solid-liquid separator, a secondary stage of separation may be introduced for counter currently washing the agglomerates separated from the agglomerated slurry. The initial separation of agglomerates may be said to occur in a primary solid-liquid

separator, while the secondary stage may occur within the primary unit, or may be conducted completely separately in a secondary solid-liquid separator. By “counter currently washing”, it is meant that a progressively cleaner solvent is used to wash bitumen from the agglomerates. Solvent involved in the final wash of agglomerates may be re-used for one or more upstream washes of agglomerates, so that the more bitumen entrained on the agglomerates, the less clean will be the solvent used to wash agglomerates at that stage. The result being that the cleanest wash of agglomerates is conducted using the cleanest solvent.

5
10
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[0081] A secondary solid-liquid separator for counter currently washing agglomerates may be included in the system or may be included as a component of a system described herein. The secondary solid-liquid separator may be separate or incorporated within the primary solid-liquid separator. The secondary solid-liquid separator may optionally be a gravity separator, a cyclone, a screen or belt filter. Further, a secondary solvent recovery unit for recovering solvent arising from the solid-liquid separator can be included. The secondary solvent recovery unit may be a conventional fractionation tower or a distillation unit.

[0082] When conducted in the process, the secondary stage for counter currently washing the agglomerates may comprise a gravity separator, a cyclone, a screen, a belt filter, or a combination thereof.

20
[0083] The solvent used for washing the agglomerates may be solvent recovered from the low solids bitumen extract, as described in Canadian Patent Application Serial No. 2,724,806 (Adeyinka et al.). A second solvent may alternatively or additionally be used as described in Canadian Patent Application Serial No. 2,724,806 (Adeyinka et al.) for additional bitumen extraction downstream of the agglomerator.

25
[0084] **Recycle and Recovery of Solvent.** The process may involve removal and recovery of solvent used in the process.

[0085] In this way, solvent is used and re-used, even when a good deal of bitumen is entrained therein. Because an exemplary solvent:bitumen ratio in the agglomerator may be 2:1 or lower, it is acceptable to use recycled solvent containing bitumen to achieve this ratio.
30 The amount of make-up solvent required for the process may depend solely on solvent losses, as there is no requirement to store and/or not re-use solvent that has been used in a previous extraction step. When solvent is said to be “removed”, or “recovered”, this does not require removal or recovery of all solvent, as it is understood that some solvent will be retained with the bitumen even when the majority of the solvent is removed.

[0086] The system may contain a single solvent recovery unit for recovering the solvent(s) arising from the gravity separator. The system may alternatively contain more than one solvent recovery unit.

5 [0087] Solvent may be recovered by conventional means. For example, typical solvent recovery units may comprise a fractionation tower or a distillation unit. The solvent recovered in this fashion will not contain bitumen entrained therein. This clean solvent is preferably used in the last wash stage of the agglomerate washing process in order that the cleanest wash of the agglomerates is conducted using the cleanest solvent.

10 [0088] The solvent recovered in the process may comprise entrained bitumen therein, and can thus be re-used as the extraction liquor for combining with the bituminous feed. Other optional steps of the process may incorporate the solvent having bitumen entrained therein, for example in countercurrent washing of agglomerates, or for adjusting the solvent and bitumen content prior to agglomeration to achieve the selected ratio within the agglomerator that avoids precipitation of asphaltenes.

15 [0089] **Dilution of Agglomerator Discharge to Improve Product Quality.** Solvent may be added to the agglomerated slurry for dilution of the slurry before discharge into the primary solid-liquid separator, which may be for example a deep cone settler. This dilution can be carried out in a staged manner to pre-condition the primary solid-liquid separator feed to promote higher solids settling rates and lower solids content in the solid-liquid separator's
20 overflow. The solvent with which the slurry is diluted may be derived from recycled liquids from the liquid-solid separation stage or from other sources within the process.

[0090] When dilution of agglomerator discharge is employed in this embodiment, the solvent to bitumen ratio of the feed into the agglomerator is set to obtain from about 10 to about 90 wt% bitumen in the discharge, and a workable viscosity at a given temperature. In
25 certain cases, these viscosities may not be optimal for the solid-liquid separation (or settling) step. In such an instance, a dilution solvent of equal or lower viscosity may be added to enhance the separation of the agglomerated solids in the clarifier, while improving the quality of the clarifier overflow by reducing viscosity to permit more solids to settle. Thus, dilution of agglomerator discharge may involve adding the solvent, or a separate dilution solvent, which
30 may, for example, comprise an alkane.

Potential Advantages of Certain Embodiments Described Herein

[0091] The integration of solvent-based extraction with water-based extraction or thermal oil recovery methods may have the potential to capture synergies related to water

quality between these processes. Some of these potential advantages are described below.

[0092] In solvent-based extraction processes that use water to help in the solid-liquid separation processes, both water and solvent are evaporated within the tailings solvent recovery process. In some processes, a significant amount of the water must be evaporated
5 in order to recover the necessary amount of solvent from the tailings. The large expenditure of energy due to the evaporation of water in the tailings solvent recovery unit has been typically seen as a major disadvantage of solvent-extraction processes. However, in embodiments described herein, the high quality water produced within the tailings solvent recovery unit is directed to thermal oil recovery or water-based extraction processes where
10 high quality water is a premium. For these reasons, the energy used in the tailings solvent recovery unit has a reduced negative impact because it produces outputs of greater value.

[0093] The produced water of thermal oil recovery processes and the tailings of water-based extraction processes comprise residual bitumen that is desirable to recover. In the case of thermal oil recovery, the conventional method of recovering the residual bitumen
15 is gravity separation. It is difficult to separate emulsified bitumen or bitumen of small droplet size by gravity. For this reason, a number of processing stages and pieces of equipment are required for the necessary oil-water separation, which results in a process that is both expensive in capital cost and operating cost. Similar limitations exist for the residual bitumen in the tailings produced from water-based extraction. In embodiments described herein,
20 residual bitumen can be recovered and high quality water can be produced from the solvent-based extraction process.

[0094] In the circumstances where the wastewater and blowdown streams from the thermal oil recovery processes cannot be disposed of by injection into deep wells, the streams are concentrated to produce solids. The precipitated solids from units such as a
25 crystallizer are difficult to separate from the liquid since separation equipment such as centrifuges and filter presses are prone to plugging and other failures. These problematic pieces of separation equipment can be avoided in cases where a forced circulation crystallizer is used to concentrate the brine to a 50 to 60% solids content. The concentrated brine is then treated in a rotary dryer to produce dried solids. The operation of the rotary
30 dryer is difficult since a large recycle stream, which returns dried solids back to the dryer feed stream, is required to maintain a 90% or greater solids content for the feed going into the rotary dryer. Embodiments described herein may eliminate or reduce the need for the recycle loop. For example, the concentrated brine can mix with the solids of the solvent-based extraction process and the mixture can be dried in tailings solvent recovery unit such
35 as a rotary dryer.

[0095] The wastewater from in-situ thermal water treatment plants is generally of a pH > 8.5. For water based extraction, it has been found that such a pH enhances recovery. Using contaminated water with a high pH as the bridging liquid in the solvent extraction process may enhance the separation of bitumen from the sand grains, reduce bitumen inclusion and thereby increase recovery.

5

[0096] In the preceding description, for purposes of explanation, numerous details are set forth in order to provide a thorough understanding of the embodiments. However, it will be apparent to one skilled in the art that these specific details are not required.

[0097] The above-described embodiments are intended to be examples only. Alterations, modifications and variations can be effected to the particular embodiments by those of skill in the art without departing from the scope.

10

CLAIMS

What is claimed is:

1. A method of processing a bituminous feed and contaminated water, the method comprising:
 - 5 a) contacting the bituminous feed with an extraction liquor and the contaminated water to form an initial slurry, wherein the extraction liquor comprises a solvent;
 - b) solvent extracting the initial slurry to extract bitumen from the bituminous feed to form an extracted slurry comprising solids, the contaminated water, and a bitumen extract;
 - c) separating the solids and the contaminated water from the bitumen extract;
 - 10 d) recovering solvent from the bitumen extract to form a bitumen product;
 - e) recovering solvent and high quality water from the solids to form dry tailings; and
 - f) separating the high quality water from the solvent.
2. The method of claim 1, wherein:
 - 15 the extracted slurry is an agglomerated slurry;
 - the bitumen extract is a low solids bitumen extract;
 - step b) comprises agitation solids within the initial slurry to form the agglomerated slurry comprising agglomerates and the low solids bitumen extract, the agglomerates comprising the solids and the contaminated water;
 - 20 step c) comprises separating the agglomerates from the low solids bitumen extract;
 - step d) comprises recovering solvent from the low solids bitumen extract to form the bitumen product; and
 - step e) comprises recovering solvent and high quality water from the agglomerates to form the dry tailings.
- 25 3. The method of claim 2, further comprising washing the agglomerates with the solvent recovered from the low solids bitumen extract.

4. The method of claim 2, wherein a ratio of the solvent to bitumen in the agglomerated slurry is less than 2:1.
5. The method of claim 1, wherein the high quality has a solids content of less than 1 wt%.
- 5 6 The method of claim 1, wherein the high quality water has a monovalent cation concentration of less than 2,000 wppm.
7. The method of claim 1, wherein the contaminated water comprises surface, subterranean, or process affected water.
8. The method of claim 1, wherein the contaminated water is from an in-situ thermal
10 hydrocarbon recovery process facility.
9. The method of claim 1, wherein the contaminated water comprises produced water from a primary liquid-liquid separation vessel or a separation vessel downstream of the primary separation vessel, wastewater from a water treatment plant, or a blowdown stream from a steam generator.
- 15 10. The method of claim 8, further comprising passing the high quality water to a boiler in the in-situ thermal hydrocarbon recovery process facility.
11. The method of claim 1, wherein the contaminated water is from an aqueous-based hydrocarbon extraction process.
12. The method of claim 11, wherein the contaminated water comprises middlings from
20 primary separation, secondary separation tailings, tertiary separation tailings, froth treatment tailings, or mature fine tailings.
13. The method of claim 1, further comprising preheating the bituminous feed to at least partially evaporate connate water producing evaporated connate water.
14. The method of claim 13, further comprising recovering the evaporated connate water
25 as high quality water.
15. The method of claim 1, wherein the contaminated water has a solids content of less than or equal to 40 wt%.
16. The method of claim 1, wherein the dry tailings have a water:solids mass ratio of less than 0.15:1.

17. The method of claim 1, wherein step e) is effected by evaporation, by indirectly heating the solvent and high quality water, or by applying direct heat to the solvent and high quality water using natural gas.
18. The method of claim 1, further comprising passing the high quality water to a utility
5 system, a surface disposal area, an aqueous-based hydrocarbon extraction process, or a in-situ thermal hydrocarbon recovery process.
19. The method of claim 1, further comprising combining the high quality water with additional contaminated water to form an aqueous blend, and using the aqueous blend in an water-based hydrocarbon extraction process.
- 10 20. The method of claim 1, wherein step e) is effected in a tailings solvent recovery unit into which additional contaminated water is added for maintaining a certain level of water within the dry tailings or for recovering additional heat and additional high quality water.
21. The method of claim 1, wherein the contaminated water has a pH of greater than 7.
22. The method of claim 1, wherein step a) comprising contacting the bituminous feed
15 with the extraction liquor, and then adding the contaminated water, or contacting the bituminous feed with the extraction liquor after, or at the same time, as the contaminated water.
23. The method of claim 1, wherein the contaminated water is added in a concentration of between 1 and 20 wt% of the initial slurry.
- 20 24. The method of claim 1, wherein the extraction liquor comprises bitumen in an amount of 10 to 70 wt% and the solvent of step a).
25. The method of claim 1, wherein the solvent comprises an organic solvent or a mixture of organic solvents.
26. The method of claim 25, wherein the solvent comprises a paraffinic solvent, a cyclic
25 aliphatic hydrocarbon, or a mixture thereof.
27. The method of claim 1, wherein the solvent comprises at least 50 wt% cyclohexane.
28. The method of claim 1, wherein the bituminous feed is derived from oil sands.

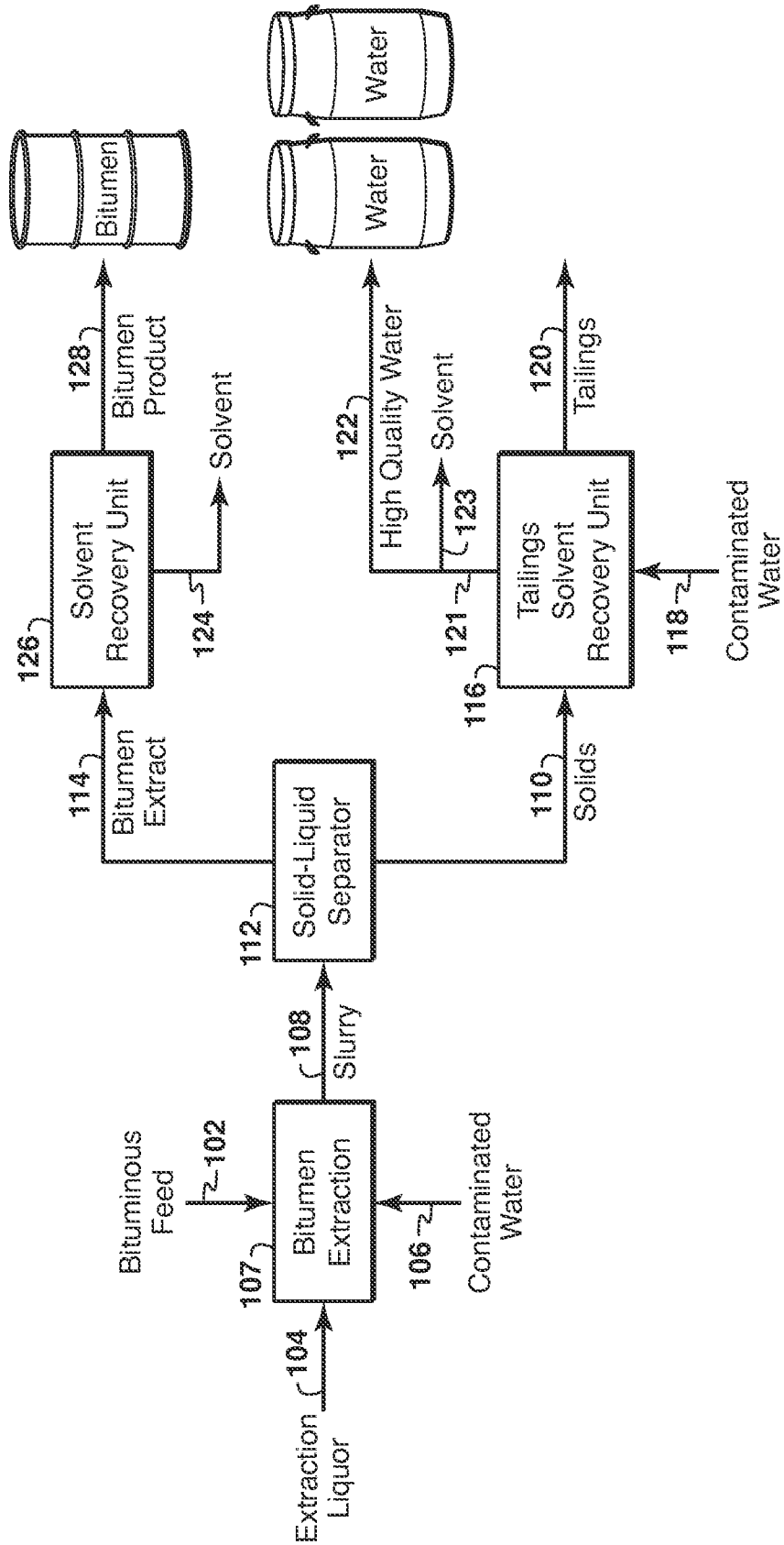


FIG. 1

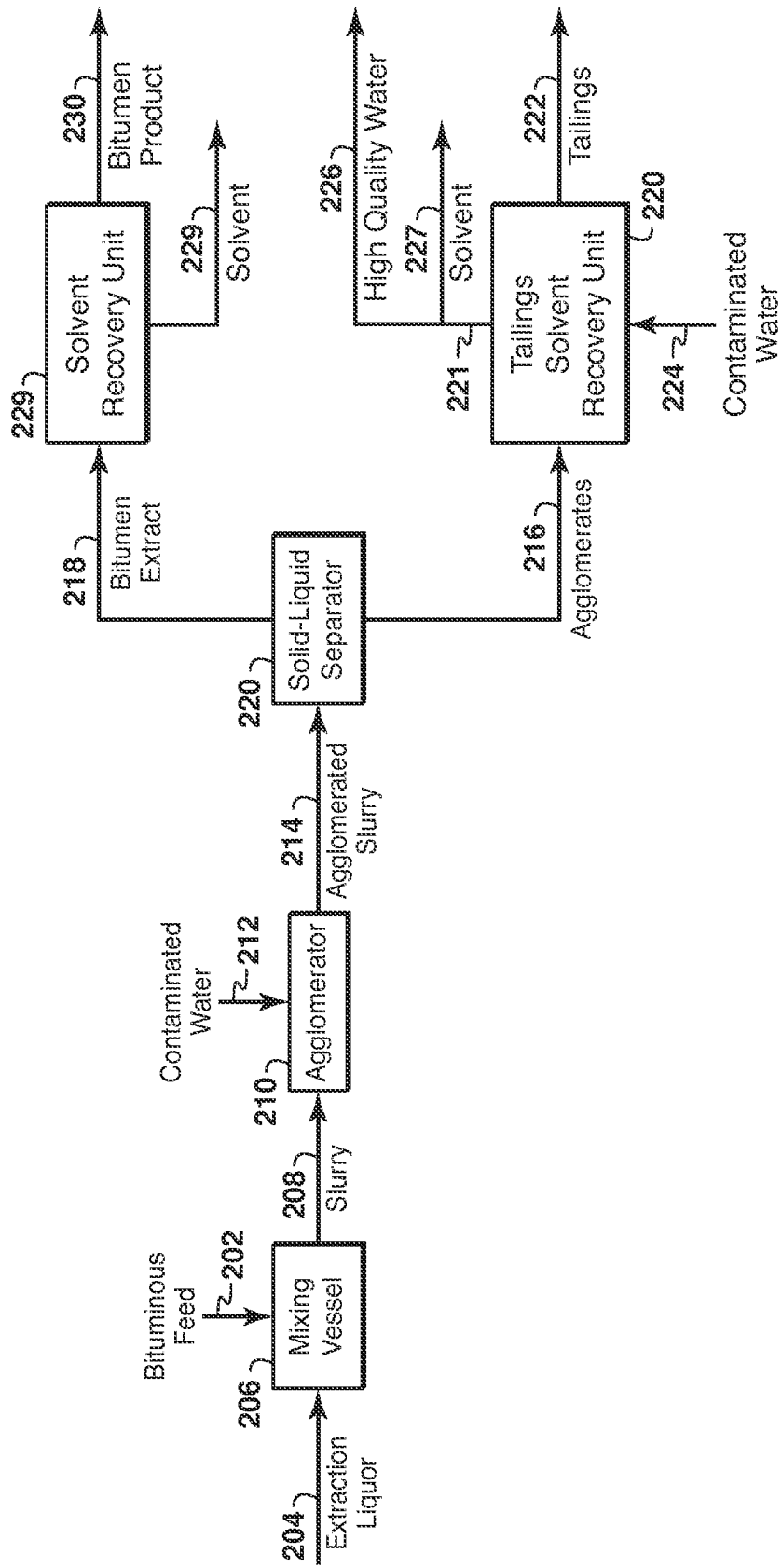


FIG. 2

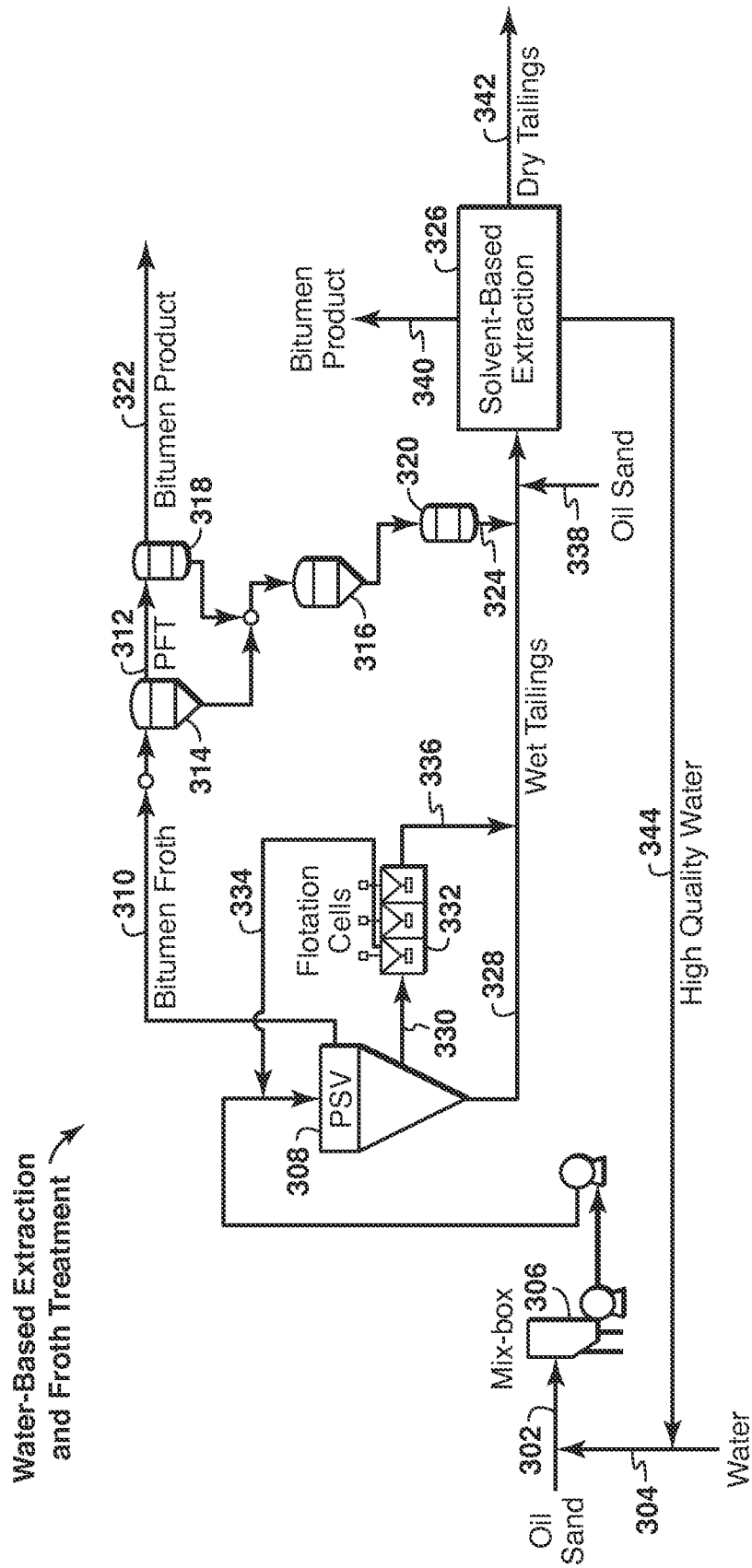
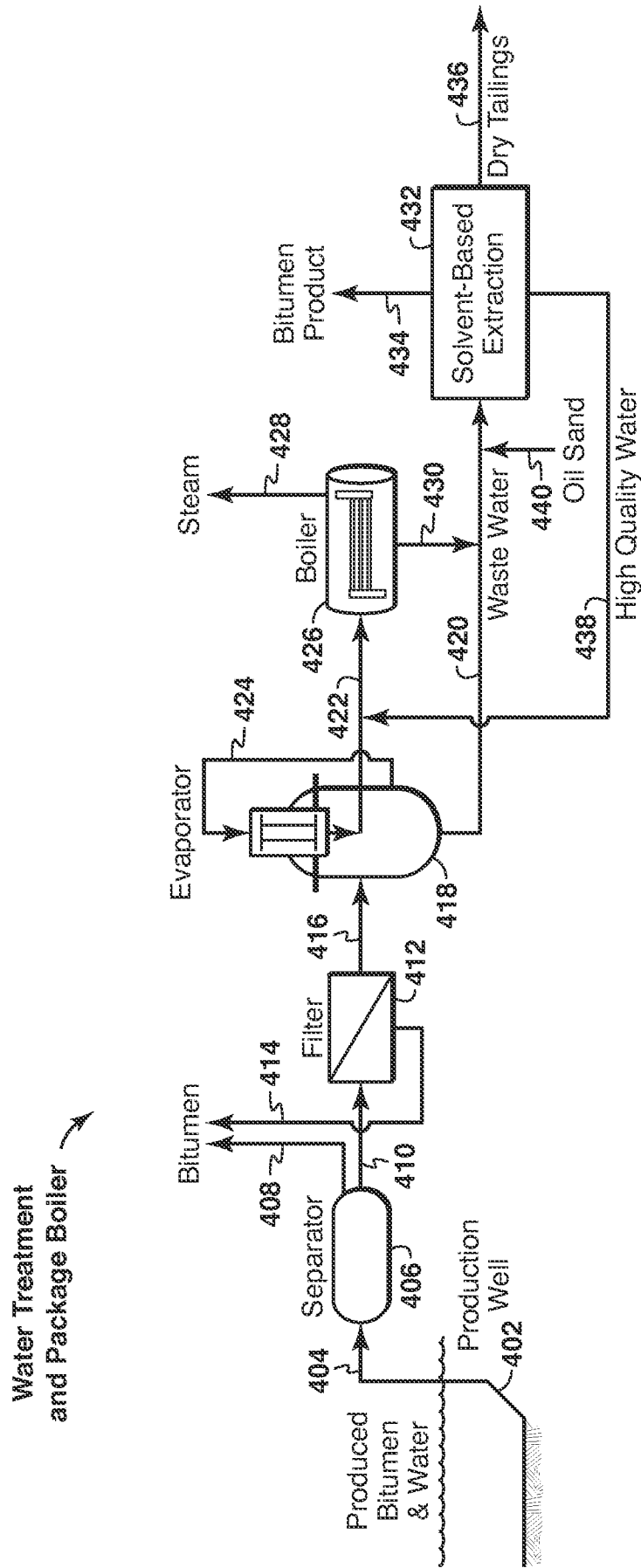


FIG. 3



Water Treatment and Package Boiler

FIG. 4

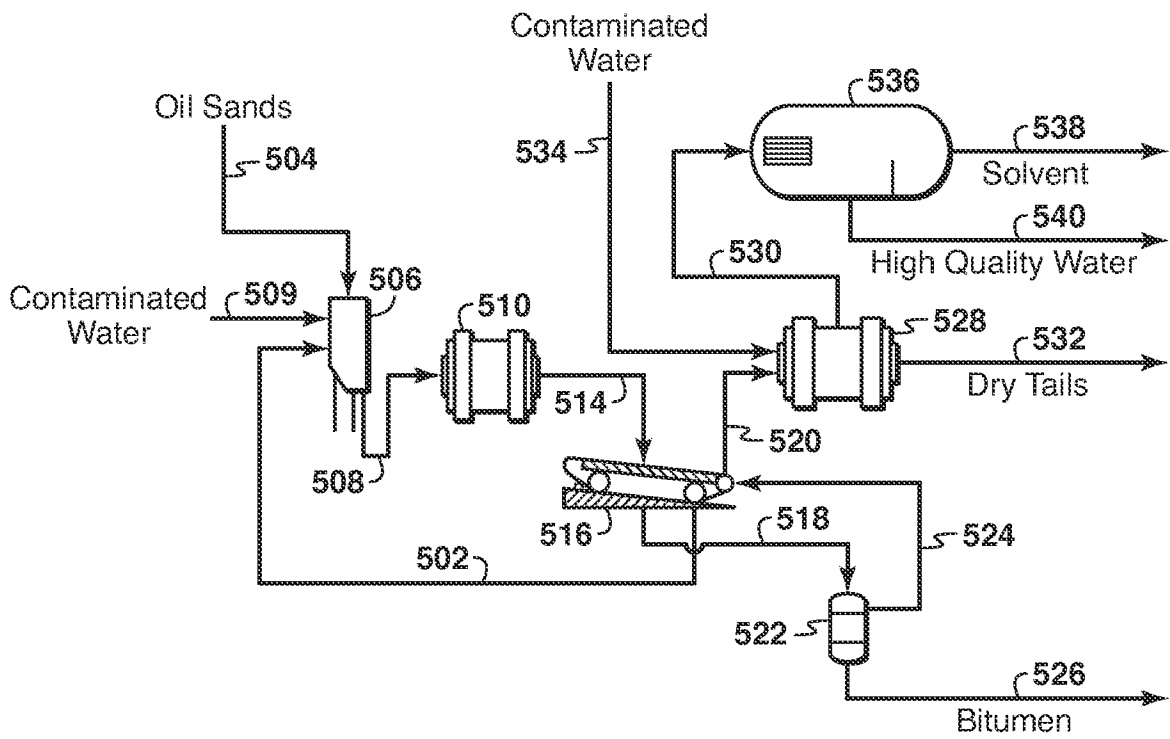


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 12/43577

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - C10G 1/04 (2012.01)

USPC - 208/390; 208/45;208/424

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)

IPC(8)- C10G 1/04 (2012.01);

USPC- 208/390; 208/45;208/424

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Patents and NPL (classification, keyword; search terms below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWest (US Pat, PgPub, EPO, JPO), GoogleScholar (PL, NPL), FreePatentsOnline (US Pat, PgPub, EPO, JPO, WIPO, NPL);
search terms: bitumen, extract, separate, solvent, water, recover, dry, tail, purity, quality, filter, distill, agglomerate, connate, cyclohexane

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2011/0180458 A1 (DUYVESTEYN et al.) 28 July 2011 (28.07.2011), para [0011], [0012], [0024], [0025], [0030], [0032], [0040], [0045], [0054], [0062], [0064], [0106], [0111], [0114]	1-28
Y	US 2011/0061610 A1 (SPEIRS et al.) 17 March 2011 (17.03.2011), para [0011], [0014], [0021], [0025]-[0031], [0039]	1-28
Y	US 4,225,433 A (LIU et al.) 30 September 1980 (30.09.1980), col 2, ln 39-68; col 3, ln 16-44; col 3, ln 57-66	2-4
Y	US 4,596,651 A (WOLFF et al.) 24 June 1986 (24.06.1986), col 3, ln 1-23; col 3, ln 47-65; col 7, ln 21-34	13, 14
Y	US 4,722,782 A (GRAHAM et al.) 02 February 1988 (02.02.1988), Tables I, II; col 2, ln 41-62; col 3, ln 4-22; col 3, ln 63 to col 4, ln 15; col 9, ln 41-49	26, 27

Further documents are listed in the continuation of Box C.

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Date of the actual completion of the international search

13 August 2012 (13.08.2012)

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