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CA 2832931 A1 2011/11/21

(21) **2 832 931**

(12) **DEMANDE DE BREVET CANADIEN**
CANADIAN PATENT APPLICATION

(13) **A1**

(22) Date de dépôt/Filing Date: 2011/05/17
(41) Mise à la disp. pub./Open to Public Insp.: 2011/11/21
(62) Demande originale/Original Application: 2 797 513
(30) Priorité/Priority: 2010/05/21 (CA2,704,927)

(51) Cl.Int./Int.Cl. *C10G 1/04* (2006.01)
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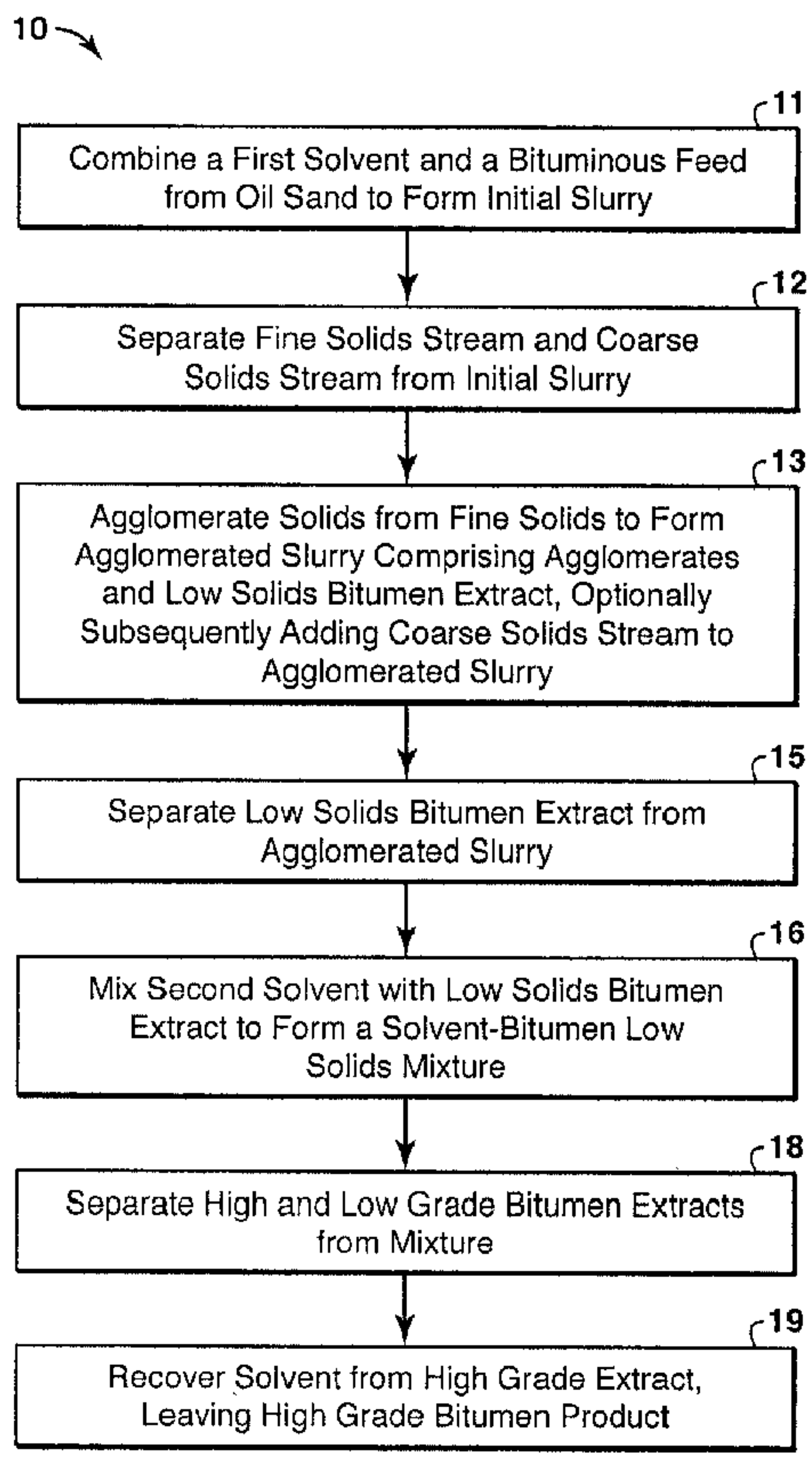
(54) Titre : PROCEDES INTEGRES POUR LA RECUPERATION DES HYDROCARBURES DANS LES SABLES BITUMINEUX
(54) Title: INTEGRATED PROCESSES FOR RECOVERY OF HYDROCARBON FROM OIL SANDS



(57) Abrégé/Abstract:
Processes are described for extracting hydrocarbon from a mineable deposit, integrating solvent-based and aqueous extraction. An exemplary process for extracting hydrocarbon from oil sands ore comprises contacting ore with a first solvent to form a first

(57) Abrégé(suite)/Abstract(continued):

slurry comprising solids and bitumen extract; separating bitumen extract from the first slurry forming solvent wet tailings comprised of the solids and the first solvent; removing the first solvent from the solvent wet tailings to form dry tailings; and combining dry tailings with water wet tailings produced from a water-based extraction process to form strengthened tailings. The dry tailings comprise less than 15 wt% water. Water wet tailings comprise more than 25 wt% water. The process permits recovery of hydrocarbon that may otherwise be too difficult to recover and thus has previously been lost. A fungible product can be formed more efficiently according to certain integrated processes described herein.

ABSTRACT

Processes are described for extracting hydrocarbon from a mineable deposit, integrating solvent-based and aqueous extraction. An exemplary process for extracting hydrocarbon from oil sands ore comprises contacting ore with a first solvent to form a first slurry comprising solids and bitumen extract; separating bitumen extract from the first slurry forming solvent wet tailings comprised of the solids and the first solvent; removing the first solvent from the solvent wet tailings to form dry tailings; and combining dry tailings with water wet tailings produced from a water-based extraction process to form strengthened tailings. The dry tailings comprise less than 15 wt% water. Water wet tailings comprise more than 25 wt% water. The process permits recovery of hydrocarbon that may otherwise be too difficult to recover and thus has previously been lost. A fungible product can be formed more efficiently according to certain integrated processes described herein.

INTEGRATED PROCESSES FOR RECOVERY OF HYDROCARBON FROM OIL SANDS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a division of application number 2,797,513, filed in Canada on November 21, 2012 which is a divisional of application number 2,740,481, filed in Canada on May 17, 2011.

FIELD

[0002] The technology described herein relates generally to recovering hydrocarbon from mineable deposits, such as bitumen from oil sands. Processes are described for recovery of hydrocarbon from oil sands which integrate solvent-based extraction technology and water-based bitumen extraction technology.

BACKGROUND

[0003] Processes for extracting hydrocarbon from oil sands require energy intensive steps to separate solids and water from hydrocarbon, to yield commercially valuable products. Increasing the efficiency of oil sands extraction in ways that reduce water utilization, reduce energy consumption, and utilize production streams or heat that may have otherwise gone to waste, will reduce the cost of production and provide environmental benefits. Such efficiencies are needed to improve upon existing processes.

[0004] In general, water-based extraction and solvent-based extraction are the two processes that have been used to extract bitumen from 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 dissolving bitumen into the solvent.

[0005] Water-based extraction processes have several advantages. Chief among them is that the process water is relatively inexpensive and environmentally benign. Another important advantage is that water-based extraction has been shown to produce a fungible bitumen product when paraffinic froth treatment is used to treat the bitumen froth. Solvent-based extraction processes also offer advantages. Solvent-based processes result in effective recovery of bitumen from streams containing large amounts of fine solids (or "fines"). Further, the volume of the tailings (or "tails") produced in solvent-based processes is less than the volume produced in water-based extraction. Additionally, the bitumen product produced by solvent-based extraction has a reduced content of fines and water when compared with bitumen froth produced in the primary separation of a water-based extraction process.

[0006] Canadian Patent Application No. 2,068,895 to NRC, describes integration of solvent extraction spherical agglomeration (SESA) technology, as described in more detail below, with the Clark Hot Water Extraction (CHWE) process for improved bitumen recovery and reduced sludge volume. A high fines conditioning drum oversize stream is processed in the SESA process while a low fines stream is processed in the Clark hot water process.

[0007] There is a need to further develop processes and systems for integrating water-based extraction processes and streams with solvent-based extraction processes and streams to capture previously unrecognized synergies between the two processes.

[0008] Processing problems associated with recovery of water and bitumen from aqueous sources, such as from conventional water-based hydrocarbon or bitumen extraction processes, are largely due to the presence of fines in the streams. Recovery of bitumen from bitumen-lean streams, or intermediate streams formed in a water-based extraction process, is environmentally prudent and would increase the efficiency of the overall extraction process. Conventional attempts at de-watering streams from a water-based extraction process have typically been undertaken only after the majority of hydrocarbon, or bitumen, has been removed.

[0009] Aqueous hydrocarbon-containing streams from a water-based extraction process which may undergo additional water-based bitumen recovery or which may be stored as waste products include middling streams from a primary separation vessel, and bitumen-lean streams from secondary flotation tails or froth treatment, among others. Such streams have a high water content, but may also have a bitumen content exceeding 15 wt% on a dry solids basis, which would be desirable to recover.

[0010] Canadian Patent No. 1,024,330 to NRC describes a process in which high fines streams, such as the middlings from a primary separation vessel of a water-based extraction process or mature fine tailings from the water-based extraction tailings ponds, may be directed to a solvent extraction solids agglomeration (SESA) process as a source of the bridging liquid.

[0011] Aqueous hydrocarbon-containing streams and, in particular, aqueous bitumen-lean streams from water-based extraction, contain a large proportion of water. For example, 50% or more water by weight may be found in such streams, which is higher than desired for many solvent-based extraction processes. Thus, there is a need for a process that can permit incorporation of such aqueous hydrocarbon-containing streams into a solvent-based extraction process in order recover residual bitumen within these streams.

[0012] Approximately 10% of the bitumen extracted in conventional water-based extraction processes is lost in the tailings of paraffinic froth treatment (PFT). Although a majority of these hydrocarbons are asphaltenes, there is still sufficient value to be derived from this fraction to support recovery from paraffinic froth tailings to increase the overall volume of bitumen produced. Conventional water-based extraction processes offer limited solutions for recovery of hydrocarbon from this fraction, generally requiring one or more addition extraction stages to recover residual maltenes from froth treatment tailings.

[0013] Canadian Patent Application No. 2,662,346 describes the conditioning of froth treatment tailings (both paraffinic froth treatment and naphthenic froth treatment) in order to separate the hydrocarbons from the solid mineral material. After solids removal, the hydrocarbon rich stream from the conditioning process is then directed to a solvent-based extraction process. Separating the fines from the hydrocarbons is a challenge regardless of whether it is undertaken within a conditioning stage prior to solvent extraction or within the solvent-based extraction process itself.

[0014] There is a need to develop a solvent-based extraction process for recovering hydrocarbons from paraffinic froth treatment tails without dispersing the fines into the hydrocarbon extract.

[0015] In solvent-based extraction processes, the solvent may contain dissolved (or "entrained") bitumen prior to contacting the oil sands with the solvent. Such a mixture of solvent and bitumen may be referred to interchangeably herein as a "liquor" or "extraction liquor". An exemplary level of pre-dissolved bitumen can makeup as much as 50 wt% of the liquor. Having a large amount of pre-dissolved bitumen may offer advantages. For example, using solvent with dissolved bitumen may reduce the required inventory of solvent needed for the bitumen extraction from oil sands. Further, for certain solvents, pre-dissolved bitumen may increase the ability of the liquor to dissolve additional bitumen from oil sands. Furthermore, the pre-dissolved bitumen reduces the vapor pressure of the liquor, when compared with that of the solvent, which can allow for higher operating temperatures for the solvent-based extraction process.

[0016] In previously described solvent-based extraction processes, such as those disclosed in Canadian Patent No. 2,147,943; U.S. Patent No. 4,422,209; and U.S. Patent No. 4,719,008, the pre-dissolved bitumen results from recycling bitumen from the solid-liquid separation stage to the oil sands extraction stage. The recycling of the bitumen reduces the yield of the solvent-based extraction process.

[0017] The froth treatment processes for water-based extraction, such as naphthenic froth treatment and paraffinic froth treatment, involve mixing a water extracted bitumen-rich stream with a solvent. However, the purpose of these steps within a water-based extraction process is primarily to remove residual water and solids from a bitumen-rich stream. Such froth treatment processes are conventionally conducted only within an overall water-based extraction process.

[0018] There is a need to develop alternative methods for providing pre-dissolved bitumen within the solvent of a solvent-based extraction process while reducing the amount of recycled bitumen within the solvent-based extraction process.

[0019] Solvent extracted bitumen has a much lower solids and water content than that of bitumen froth produced in the water-based extraction process. However, the residual amounts of water and solids contained in solvent extracted bitumen may nevertheless render the bitumen unsuitable for marketing. A fungible bitumen product is bitumen with a solids content of less than 300 ppm on a bitumen basis, measured as filterable solids. Further, a total bitumen solids and water (or "BS & W") content of less than 0.5% is acceptable for meeting pipeline specifications. Bitumen of such quality is termed "fungible" because it can be processed in conventional refinery processes, such as hydroprocessing, without dramatically fouling the refinery equipment. Removing contaminants from solvent extracted bitumen is difficult using conventional separation methods such as gravity settling, centrifugation or filtering.

[0020] Solvent deasphalting has previously been proposed for product cleaning of solvent extracted bitumen. Deasphalting technologies are described in U.S. Patent No. 4,572,777 issued February 25, 1986 entitled: Recovery of a carbonaceous liquid with a low fines content; and U.S. Patent No. 4,888,108 issued December 19, 1989 entitled: Separation of Fines Solids from Petroleum Oils and the Like. The solvent deasphalting processes described in these patents do not result in the formation of a fungible product in a deasphalting step. The processes described in these patents are limited by the type of deasphalting solvent used and the proper deasphalting solvent to bitumen ratio required for optimal solids removal. The deasphalting process described were not specific and relied more on conventional deasphalting technologies, such as those commonly used in refineries to produce heavy crude oils to upgrade heavy bottoms streams to deasphalt oil. However, these conventional deasphalting technologies operate at high temperatures and pressures, and at a low feed rate, compared to what would be required for a large scale production facility.

[0021] Paraffinic froth treatment (PFT) units operate under much milder conditions than deasphalting units found currently in refineries. PFT processes have generally been used only within water-based extraction processes. U.S. Patent Application No. 12/340,515 of Sury et al. (Publication No. US 2009/0200209) describes a process in which water is added to a solvent and bitumen froth mixture within a PFT process in order to enhance the deasphalting process.

[0022] U.S. Patent No. 4,634,520 and U.S. Patent No. 7,625,466 disclose methods for deasphalting a heavy oil and water emulsion. In U.S. Patent No. 4,634,520, the asphaltene and water flocs, after settling, are mixed with hot water in order to agglomerate and recover asphaltenes. In U.S. Patent No. 7,625,466, a heavy oil and water emulsion is described to mix with a deasphalting solvent and optionally with water before directing the mixture to a settling vessel.

[0023] The following references describe processes in which asphaltene-water interaction enhances deasphalting of bitumen: Fuel Processing Technology, Vol. 89 (2008) pp 933-940; and Fuel Processing Technology, Vol. 89 (2009) pp 941-948.

[0024] There is a need to develop a solvent deasphalting method for producing a fungible bitumen product from solvent extracted bitumen.

[0025] The use of hydrocarbons, such as kerosene, as process aids in water-based extraction processes has been disclosed. However, light hydrocarbons are relatively expensive as process aids, and may need to be recovered from the water extracted tailings for economic and/or environmental reasons.

[0026] Bitumen can itself act as process aid for additional bitumen recovery in a water-based extraction process. For example, U.S. Patent Application 12/163,590 filed June 27, 2008, published as Publication No US 2009/0321326 and entitled Primary Froth Recycle, reveals the possibility of using a bitumen-rich stream to enhance recovery. This document describes the recycling of primary bitumen froth in a step of the water-based extraction process upstream of the primary separation vessel, in an effort to increase overall bitumen recovery in a water-based process. This publication presents pilot plant data showing improvements in overall bitumen recovery and higher quality primary froth. For example, for oil sands ore with 10 wt% bitumen and 27 wt% fines, recycling 33% of the froth to the slurry preparation unit improved bitumen recovery from approximately 73% to approximately 91%.

[0027] The process described in US 2009/0321326 does not suggest uses for froth outside of conventional water-based extraction processes. However, an improvement in bitumen recovery is realized due to recycling of froth, illustrates that increasing the bitumen content of a water-based slurry can yield improved bitumen recovery in a water-based process.

[0028] There is a need for similar benefits to be sought within a water-based extraction process that is integrated with a solvent-based extraction process. Thus, there is a need to develop a process where solvent extracted bitumen may be used to improve the bitumen recovery within a water-based extraction process.

[0029] Wet tailings produced in water-based extraction processes are often held in a geographically contained location. Government regulations may require tailings produced from water-based extraction to achieve a set strength rating over a period of time, such as a strength rating of 5 kPa one year after production of the tailings. While such strength objectives can be met by extra dewatering, the energy intensity required to achieve an even lower water content may make the incremental dewatering inefficient. The dewatering of fine wet tailings derived from water-based extraction may involve the use of expensive flocculants. Holding areas, known as dedicated disposal areas (DDA), are required for containing the dewatered tailings. The DDAs are expected to be expensive to maintain. Furthermore, it is unclear that the thickened tailings produced from dewatering will consistently be able to meet the strength rating goal within one year of tailings production.

[0030] Treatments for solids or tailings produced by a solvent-based extraction process have been previously proposed. For example, Canadian Patent No. 1,031,712 entitled Tar Sands Separation, describes using an aqueous bridging liquid to agglomerate solids during solvent extraction. The document describes that these agglomerates can be sintered at high temperatures to produce agglomerates having concrete-like strength. The document also discloses using water with water-soluble adhesives and/or emulsion type adhesives as the bridging liquid to form the agglomerates. The adhesives would act to strengthen the agglomerates and impart water resistance when the agglomerates are dried in the tailings solvent recovery stage of the solvent-based extraction process.

[0031] The dry agglomerates produced in solvent-based extraction processes have been previously described for use in landscape construction. However, there is little suggestion of other uses for dry agglomerates. There is a need to develop processes by which these dry agglomerates from solvent-based extraction processes can be integrated within water-based extraction processes for improved overall tailings behavior.

[0032] An overview of a previously described process for recovery of hydrocarbon using solvent is provided below. This process is referred to as solvent extraction spherical agglomeration (SESA). SESA has not been commercially adopted. For a full description of the SESA process, see Sparks et al., Fuel 1992(71);1349-1353. The SESA process involved mixing a slurry of oil sands material with a hydrocarbon solvent (such as a high boiling point solvent), adding a bridging liquid (for example, water), agitating this 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. A bridging liquid (also referred to as a binding liquid) is a liquid with affinity for the solid particles (i.e. preferentially wets the solid particles) but is immiscible in the solvent. The process was conducted at about 50 – 80 °C (see also Canadian Patent Application 2,068,895 of Sparks et al.). The enlarged size of the agglomerates formed permitted easy removal of the solids by sedimentation, screening or filtration.

[0033] The proposed solvents in previously described SESA processes have a low molecular weight, high aromatic content, and low short chain paraffin content. Naphtha was the solvent proposed for the SESA process, with a final boiling point ranging between 180-220 °C, and a molecular weight of 100 – 215 g/mol.

[0034] A methodology described by Meadus et al. in U.S. Patent No. 4,057,486, involved combining solvent extraction with particle enlargement to achieve spherical agglomeration of tailings suitable for direct mine refill. Organic material was separated from oil sands by mixing the oil sands material with an organic solvent to form a slurry, after which an aqueous bridging liquid was added in small amounts. By using controlled agitation, solid particles from oil sands adhere to each other and were enlarged to form macro-agglomerates of mean diameter greater than 2 mm from which the bulk of the bitumen and solvent was excluded. This process permitted a significant decrease in water use, as compared with conventional water-based extraction processes. Solvents used in the process were of low molecular weight, having aromatic content, but only small amounts of short chain paraffins.

[0035] U.S. Patent No. 3,984,287 describes an apparatus for separating organic material from particulate tar sands, resulting in agglomeration of a particulate residue. The apparatus included a tapered rotating drum in which tar sands, water, and an organic solvent were mixed together. In this apparatus, water was intended to act as a bridging liquid to agglomerate the particulate, while the organic solvent dissolves organic materials. As the materials combined in the drum, bitumen was separated from the ore.

[0036] A device to convey agglomerated particulate solids for removal to achieve the process of Meadus et al. (U.S. Patent No. 4,057,486) within a single vessel is described in U.S. Patent No. 4,406,788.

[0037] A method for separating fine solids from a bitumen solution is described in U.S. Patent No. 4,888,108. To remove fine solids, an aqueous solution of polar organic additive as well as solvent capable of precipitating asphaltenes was added to the solution, so as to form aggregates for removal from the residual liquid.

[0038] Others have proposed sequential use of two solvents in different solvent-based extraction schemes. For example U.S. Patent No. 3,131,141 proposed the use of high boiling point solvent for oil sands extraction followed by low boiling point/volatile solvent for enhanced solvent recovery from tailings in a unique process arrangement. U.S. Patent No. 4,046,668 describes a process of bitumen recovery from oil sands using a mixture of light naphtha and methanol.

[0039] U.S. Patent No. 4,719,008 describes a method for separating micro-agglomerated solids from a high-quality hydrocarbon fraction derived from oil sands. A light milling action was imposed on a solvated oil sands mixture. After large agglomerates were formed, the milling action was used to break down the agglomerate size, but still permitted agglomerate settling and removal.

[0040] U.S. Patent No. 5,453,133 and U.S. Patent No. 5,882,429 describe soil remediation processes to remove hydrocarbon contaminants from soil. The processes employed a solvent and a bridging liquid immiscible with the solvent, and this mixture formed agglomerates when agitated with the contaminated soil. The contaminant hydrocarbon was solvated by the solvent, while soil particles agglomerated with the bridging liquid. In this way, the soil was considered to have been cleaned. Multiple extraction stages were proposed.

[0041] Govier and Sparks describe an agglomeration process in "The SESA Process for the Recovery of Bitumen from Mined Oil Sands" (Proceedings of AOSTRA Oils Sands 2000 Symposium, Edmonton 1990, Paper 5). This process is referenced herein as the Govier and Sparks process. The solvent described possessed a low molecular weight and significant aromatic content, while containing only a small amount of short chain paraffins. Exemplary solvents were described as varsol or naphtha.

[0042] Typically, a bottom sediment and water (BS&W) content, primarily comprised of fines, of between 0.2 - 0.5 wt% of solids in dry bitumen could be achieved according to the Govier and Sparks process. However, occasionally solids agglomeration would cycle unpredictably and the fines content of the agglomerator discharge stream would rise dramatically. Subsequent settling in a clarifier or bed filtration would then be required to achieve the desired product quality of 0.2 - 0.5 wt% BS&W. The BS&W component prepared by the process was comprised mostly of solids. Bitumen products with this composition are not fungible and can only be processed at a site coking facility or at an onsite upgrader.

[0043] The above-described agglomeration processes integrated solvent extraction and agglomeration within the same mixing vessel. Conventional agglomeration units are large drums designed to integrate both the extraction and agglomeration aspects of the process.

[0044] A variety of system components are known for use in bitumen extraction. The solvent-based extraction system described by Sparks et al. (Fuel 1992; 71:1349-1353) employs a direct feed of oil sand into an extraction agglomerator configured as a rotating tumbler, following which agglomerated sand is washed in a counter-current washing system using progressively cleaner solvent. Solvent is recovered from washed agglomerates using a rotating dryer.

[0045] The system described in U.S. Patent No. 4,057,486 to Meadus et al. employs an agglomerator configured as a rotating conical vessel, into which oil sands and solvent are added. This is followed by settling of agglomerates and decantation, or by screening agglomerates to separate of the organic phase from the agglomerates. Optional system components such as a fluidized bed conversion unit may be used for further processing of agglomerates, while a distillation unit or conversion unit may be used to further process the organic phase.

[0046] In Canadian Patent Application 2,068,895, a system is described which employs a rotating drum agglomerator to combine a high fines fraction from oil sands with solvent. Discharge of agglomerates through a trommel screen for removing large stones is followed by feeding effluent to a filter via a surge hopper. Countercurrent washing through a filter with progressively cleaner solvent is followed by drainage of agglomerates. A rotary dryer is employed for drying agglomerates and for solvent recovery.

[0047] It is desirable to provide processes and systems that increase the efficiency of oil sands extraction, reduce water use, utilize waste products of extraction processes, and/or reduce energy intensity required to produce a commercially desirable bitumen product from oil sands. Producing a product that is capable of meeting or exceeding requirements for downstream processing or pipeline transport is desirable.

SUMMARY

[0048] It is an object of the present disclosure to obviate or mitigate at least one disadvantage of previous processes or systems for hydrocarbon extraction from mineable deposits such as oil sands.

[0049] There are described herein processes and/or systems for integrating a water-based extraction processes and streams with solvent-based extraction processes and streams in order to capture previously unrecognized synergies between the two processes.

[0050] ***(A) Integration of Water-Based Extraction and Solvent-Based Extraction Processes and Systems***

[0051] It is desirable to optimize efficiencies of geographically proximal water-based extraction and solvent-based extraction systems by integrating streams from one system into the other, in situations where such streams may be used effectively, for example to increase bitumen recovery, produce a cleaner product, and/or increase thermal efficiencies.

[0052] There is described herein a process for extracting bitumen from oil sands into a bitumen-rich stream, the process comprising: (a) separating bitumen from oil sands by addition of water to form a bitumen-enhanced stream and a bitumen-lean stream; (b) mixing the bitumen-lean stream with additional oil sands to form a mixed stream; (c) adding solvent to the mixed stream to extract bitumen from the mixed stream into the solvent, thereby forming a bitumen-depleted stream and an extracted bitumen stream; and (d) mixing the extracted bitumen stream with the bitumen-enhanced stream to form a bitumen-rich stream.

[0053] Processes are described herein which integrate solvent-based extraction procedures with certain aspects of water-based extraction procedures for extraction of hydrocarbon from mineable deposits. Hydrocarbon-containing streams from water-based extraction processes can be directed to solvent-based extraction processes, and/or streams from solvent-based extraction processes can be directed to water-based processes. This may have the possible advantages of reducing and/or eliminating process equipment currently used in either the water-based extraction process or solvent-based extraction process.

[0054] Furthermore, the integration of these extraction processes may also lead to an overall reduction in water use in the water-based extraction process per unit of bitumen produced. Other benefits may include reduced tailings volumes, improved operation of both the water-based and solvent-based extraction processes, and increased overall bitumen recovery from oil sands. Other possible integration opportunities include directing the bitumen product derived from solvent-based extraction to the water-based extraction process. For example, solvent extracted bitumen product may be directed to the froth treatment stage of water-based extraction process for further processing. This integration may result in the advantage of producing a cleaner pipelineable product from the solvent extracted bitumen, which is optimally fungible, with 300 ppm or less of total solids content.

[0055] A reduction in fresh water withdrawal from nearby rivers may be realized. Improved tailings management versus currently practiced water-based extraction process could also be an advantage of the processes and systems described herein. Further, the integration of water-based extraction and solvent-based extraction processes may have the advantage of reduced energy intensity, and commensurate cost reductions. Heat generated during solvent-based extraction may be captured to heat water used in the water-based extraction process and vise versa. Further, heated streams may be combined with cold streams to achieve process efficiencies.

[0056] ***(B) Recovery of Bitumen from Aqueous Sources***

[0057] Further, it is desirable to provide techniques to recover bitumen from aqueous hydrocarbon-containing streams arising from water-based extraction, that can operate efficiently in the presence of fines, or which are largely unaffected by the presence of fines.

[0058] There is described herein a process for pre-treating an aqueous hydrocarbon-containing feed for a downstream solvent-based extraction process for bitumen recovery, said aqueous hydrocarbon-containing feed comprising from 50 wt% to 95 wt% water, from 0.1 wt% to 10 wt% bitumen, and from 5 wt% to 50 wt% solids, wherein said solids comprise fines, the process comprising: removing water from the aqueous hydrocarbon-containing feed to produce an effluent comprising 40 wt% water or less; and providing the effluent to the downstream solvent-based extraction process for bitumen recovery, wherein said downstream solvent-based extraction process comprises fines agglomeration.

[0059] Certain embodiments described herein advantageously permit recovery of hydrocarbon from aqueous hydrocarbon-containing streams that were previously considered too dilute for recovery, in part due to a high fines content combined together with a high water content of over 50% by weight. By de-watering such aqueous streams containing bitumen to the point that the effluent contains less than 40% water, the streams can then be used in a process that employs agglomeration of fines.

[0060] Recycling conventionally discarded aqueous hydrocarbon-containing streams is important from an environmental perspective as well as from an efficiency perspective. By decreasing water content of an aqueous hydrocarbon-containing stream to a desirable level, the stream would become more desirable for use in solvent-based extraction processes. Recovered water may advantageously be put to use in any aspect of bitumen production that may incorporate recycled water. By de-watering an aqueous hydrocarbon-containing stream prior to attempts to remove all hydrocarbon or bitumen, steps in a conventional water-based extraction process can be omitted, thereby introducing efficiencies at certain steps in the process.

[0061] ***(C) Extracting Hydrocarbons from PFT Tailings by Directing Tailings into a Solvent-Based Extraction Process***

[0062] Further, it is desirable to increase recovery of hydrocarbon from paraffinic froth treatment tailings by directing such tailings into a solvent-based extraction process for further bitumen recovery.

[0063] There is described herein a process for recovering hydrocarbon from a tailings stream from a paraffinic froth treatment process, the process comprising: (a) accessing a hydrocarbon-containing froth treatment tailings stream from a paraffinic froth treatment process; (b) combining the froth treatment tailings stream with a solvent and additional oil sands to form a slurry; (c) agitating the slurry to dissolve hydrocarbon into the solvent and to agglomerate fines within the slurry; (d) separating the extracted hydrocarbon from the agglomerated fines to form a low solids extracted hydrocarbon stream and an extracted tailings stream; and (e) recovering the solvent from the extracted tailings stream.

[0064] Advantageously, according to an embodiment in which froth treatment tailings are directed into a solvent-based extraction process involving fines agglomeration, the extraction of residual bitumen from the tailings and the formation of agglomerates occur simultaneously during the agglomeration step. In this way, most of the hydrocarbons are recovered and most of the fines solids are captured within the formed agglomerates for easy separation from the hydrocarbon extract.

[0065] ***(D) Directing a Bitumen-Rich Stream into a Solvent-Based Extraction Process***

[0066] It is desirable to direct bitumen-rich aqueous streams, derived from water-based extraction, into a solvent-based extraction process, as a source of dissolved bitumen for the solvent used in an extraction liquor. In this way, the amount of bitumen recycled within the solvent-based extraction process can be reduced or eliminated while maintaining the advantages provided by having pre-dissolved bitumen within the solvent used in the solvent-based extraction process. Further, the increased bitumen yield (lower recycle bitumen) of the solvent-based extraction process translates to a significant reduction in the energy requirement, on a production basis, of the tailing solvent recovery unit.

[0067] There is described herein a process for recovering bitumen from oil sands, the process comprising: (a) extracting bitumen from oil sands in a water-based extraction process to form a bitumen-enhanced stream and a bitumen-lean stream; (b) mixing the bitumen-enhanced stream with a solvent to form an extraction liquor; (c) mixing the extraction liquor with additional oil sands to form a slurry comprising solids and bitumen extract; (d) separating the solids from the slurry to form a low solids bitumen extract; and (e) recovering solvent from the low solids bitumen extract to form a solvent extracted bitumen product.

[0068] Bitumen-rich streams derived from the water-based extraction process can be used to replace recycled bitumen. In this way, most or all of the bitumen processed in the solvent-based extraction process will add to the bitumen yield of the process. Additionally, fewer solids will be processed in the solvent-based extraction process per unit of bitumen produced.

[0069] The bitumen-rich aqueous streams can also provide the water needed for solvent-based extraction, for example when a solids agglomeration step employs a bridging liquid. Additionally, the solvent-based extraction process may also act to separate most of the solids and water associated with the bitumen-rich aqueous streams from the resulting bitumen extract. In this way, the solvent-based extraction process can act in place of the froth treatment unit of a conventional water-based extraction process.

[0070] ***(E) Water-Assisted Deasphalting Technologies for Streams Derived from Solvent-Based Extraction***

[0071] It is desirable to provide processes through which residual fine solids and water can be removed from a stream derived from a solvent-based extraction process, by a deasphalting process such as paraffinic froth treatment associated with a water-based extraction process or a process similar to paraffinic froth treatment. In this way, advantages associated with paraffinic froth treatment, such as enhanced settling rates, higher product yields, and reduced operating temperatures, can be realized.

[0072] There is described herein a process for removing solids from oil sands, the process comprising: (a) forming an oil sands slurry by mixing the oil sands with a first solvent, wherein the amount of first solvent added is greater than 10 wt% of the oil sands; (b) separating a majority of the solids from the oil sands slurry, forming a solids-rich stream and a bitumen-rich stream, wherein the bitumen-rich stream comprises residual solids; (c) emulsifying the bitumen-rich stream with a water-containing stream to form a hydrocarbon-external emulsion, wherein hydrocarbons form an external phase of the emulsion; (d) mixing the hydrocarbon-external emulsion with a deasphalting solvent in sufficient quantity to cause some asphaltene precipitation, wherein precipitated asphaltenes adhere to at least a portion of the residual solids and to water droplets; and (e) separating the precipitated asphaltenes from the hydrocarbon-external emulsion, thereby removing residual solids and water droplets adhering to the precipitated asphaltenes and forming a cleaned hydrocarbon product.

[0073] Further, there is described herein a process for removing solids from oil sands comprising bitumen and solids, the process comprising: (a) mixing oil sands with a first solvent to form an oil sands slurry, wherein the amount of the first solvent added is greater than 10 wt% of the oil sands; (b) separating a majority of the solids from the oil sands slurry to form a solids-rich stream and an initial bitumen-rich stream, wherein the initial bitumen-rich stream comprises residual solids; (c) removing the first solvent from the initial bitumen-rich stream to form a solvent depleted bitumen-rich stream; (d) directing at least a portion of the solvent-depleted bitumen-rich stream to a paraffinic froth treatment process of a water-based extraction process; and (e) deriving a fungible bitumen product from the paraffinic froth treatment process.

[0074] Solvent deasphalting assisted by the addition of water to the solvent extracted bitumen will allow for a deasphalting process similar to PFT, bringing about some of the advantages of the PFT process within solvent-based bitumen extraction process.

[0075] ***(F) Directing Solvent Extracted Bitumen Product to Water-based Extraction Processes***

[0076] It is desirable to utilize integration of bitumen-containing streams from solvent-based extraction processes for preparing an input feed for water-based extraction process so as to achieve a bitumen enriched stream within the water-based extraction process.

[0077] There is described herein a process for recovering hydrocarbon from oil sands, the process comprising: (a) contacting a first oil sands ore with a solvent to form a solvent-based slurry comprising solids and a bitumen extract; (b) separating the solids from the solvent-based slurry to produce a low solids bitumen extract; (c) removing solvent from the low solids bitumen extract to form a solvent extracted bitumen product; (d) contacting a second oil sands ore with water to form an aqueous slurry; (e) mixing the solvent extracted bitumen product with the aqueous slurry to form a bitumen enriched slurry; and (f) recovering bitumen from the bitumen enriched second slurry.

[0078] The enriched bitumen stream may lead to an increase in overall bitumen recovery and bitumen froth quality. Furthermore, since recovered bitumen from the water-based extraction process may undergo paraffinic froth treatment to produce a fungible bitumen product, this integration of extraction processes permits further cleaning of the streams derived from solvent-based extraction which may not yet be of a fungible quality, or adequately pure to meet pipeline specifications.

[0079] ***(G) Directing Solvent Extracted Tailings to Water-Based Extraction Process***

[0080] It is desirable to combine nominally dry tailings from a solvent-based extraction process with tailings or partially dewatered tailings from a water-based extraction process in order to yield a combined higher volume of reclaimable material.

[0081] There is described herein a process for extracting hydrocarbon from oil sands ore, the process comprising: (a) contacting the ore with a first solvent to form a first slurry comprising solids and a bitumen extract; (b) separating the bitumen extract from the first slurry to form solvent wet tailings comprised of the solids and the first solvent; (c) removing the first solvent from the solvent wet tailings to form dry tailings; (d) combining said dry tailings with water wet tailings produced from a water-based extraction process to form strengthened tailings, wherein the dry tailings comprise a water content of less than 15 wt% and the water wet tailings comprise a water content of more than 25 wt%.

[0082] For example, the agglomerated fines produced in a solvent-based extraction process that employs solids agglomeration may be treated using heat or chemicals to reduce the likelihood of the agglomerates disintegrating in the presence of water. Such agglomerated fines can be directed to the water-based extraction process where they may serve as coarse tailings substitutes in a process such as non-segregating tailings formation. The integration of water extracted wet tailings with solvent extracted dry tailings in order to produce a mixture of tailings with higher yield strength than the water extracted wet tailings alone offers advantages in meeting stringent requirements for tailings characteristics.

[0083] Other aspects and features described herein will become apparent to 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

[0084] Embodiments of the present disclosure will now be described, by way of example only, with reference to the attached Figures.

[0085] **Figure 1** is a schematic representation of process within the scope of the present disclosure.

[0086] **Figure 2** illustrates an exemplary embodiment of processes consistent with the representation shown in **Figure 1**.

[0087] **Figure 3** is a schematic representation of processes within the scope of the present disclosure.

[0088] **Figure 4** illustrates an exemplary embodiment of processes consistent with the representation shown in **Figure 3**.

[0089] **Figure 5** is a schematic representation of process within the scope of the present disclosure.

[0090] **Figure 6** illustrates an exemplary embodiment of processes consistent with the representation shown in **Figure 5**.

[0091] **Figure 7** provides a schematic representation of systems within the scope of the present disclosure.

[0092] **Figure 8** is a schematic representation of an embodiment of the process described herein.

[0093] **Figure 9** illustrates an integrated process in which streams from a water-based process are directed to a solvent-based extraction process.

[0094] **Figure 10** is a schematic representation of processes for preparation of an aqueous stream for downstream bitumen extraction, within the scope of the present disclosure.

[0095] **Figure 11** depicts an embodiment of processes according to **Figure 10**, which employ primary and secondary water separation.

[0096] **Figure 12** is a schematic illustration of processes incorporating the preparation of an aqueous stream according to **Figure 10** together with downstream steps for recovery of bitumen using a solvent-based extraction process.

[0097] **Figure 13** is a schematic representation of an exemplary process in which froth tailings are directed to a solvent-based extraction process to recover bitumen.

[0098] **Figure 14** is a schematic representation of an embodiment of the process depicted in **Figure 13**, in which hydrocarbon from paraffinic froth treatment tailings is extracted in a water-based process involving agglomeration.

[0099] **Figure 15** is a schematic representation of a process for utilizing bitumen entrained in froth from a water-based process in a solvent-based process.

[00100] **Figure 16** illustrates an exemplary process for utilizing an extraction liquor spiked with bitumen froth from water-based extraction.

[00101] **Figure 17** is a schematic representation of a process in which fine solids are removed from a solvent extracted bitumen product by water-assisted partial deasphalting.

[00102] **Figure 18** illustrates a process according to **Figure 17** in which water-assisted deasphalting is used to create a fungible product from solvent extracted oil sands.

[00103] **Figure 19** is a schematic representation of a process in which paraffinic froth treatment is used to remove residual solids within a product stream derived from solvent extraction.

[00104] **Figure 20** illustrates a process according to **Figure 19** in which the bitumen product produced by PFT is below the threshold of fungible standards to permit the product of a solvent-based extraction process, that does not meet the fungible standards, to be combined directly, resulting in a net fungible product.

[00105] **Figure 21** is a schematic diagram of a process in which a solvent-based extraction product is further processed as an input feed into a water-based extraction process.

[00106] **Figure 22** illustrates a process in which a stream derived from solvent-based extraction is processed in a water-based extraction process.

[00107] **Figure 23** is a schematic diagram of a process in which dry tailings from a solvent-based extraction process are integrated in a water-based extraction process.

[00108] **Figure 24** illustrates a process in which integration of dry agglomerated tailings with tailings derived from a water-based extraction process, results in strengthened tailings for use in reclaimed land.

DETAILED DESCRIPTION

[00109] Generally, there are described herein processes and systems for extraction of bitumen from oil sands. Processing oil sands according to the processes described herein can permit high throughput, efficiencies, increased bitumen recovery, and/or improved product quality and value.

[00110] The term "bituminous feed" from oil sands refers to a stream derived from oil sands that requires downstream processing in order to realize valuable bitumen products or fractions. The bituminous feed from oil sands is one that contains bitumen along with other undesirable components, which are removed in the process described herein. 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 but nevertheless requires further processing according to the process described herein. Also, recycled streams that contain bitumen in combination with other components for removal in the described process 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 contains 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.

[00111] As used herein, "agglomerate" refers to conditions that produce a cluster, aggregate, collection or mass, such as nucleation, coalescence, layering, sticking, clumping, fusing and sintering, as examples.

[00112] Certain extraction processes for separation of bitumen from oil sands involving aqueous extraction are referred to herein as "water-based" extraction processes. Bitumen extraction processes that primarily involve water may also include solvent additions at different stages in various steps in combination with water. However, in such cases, water remains the dominant liquid by volume in the extraction process. Certain extraction processes for separation of bitumen from oil sands involving solvent extraction are referred to herein as "solvent-based" extraction processes. Bitumen extraction processes that primarily involve solvent may also include water additions at different stages in various steps in combination with solvent. However, in such cases, solvent remains the dominant liquid by volume in the extraction process.

[00113] ***(A) Integration of Water-Based Extraction and Solvent-Based Extraction Processes and Systems***

[00114] A process is described herein for extracting bitumen from oil sands into a bitumen-rich stream. The process involves separating bitumen from oil sands by addition of water to form a bitumen-enhanced stream and a bitumen-lean stream. This may be done, for example, using a water-based extraction process, and the bitumen-enhanced stream may be, for example froth, sales bitumen product, FSU overflow, or SRU underflow.

[00115] The bitumen-lean stream is mixed with additional oil sands to form a mixed stream. The bitumen-lean stream may be partially dewatered before mixing with additional oil sands, for example, to a level of 40% water by weight or less.

[00116] Solvent is added to the mixed stream to extract bitumen from the mixed stream into the solvent, thereby forming a bitumen-depleted stream and an extracted bitumen stream. This may be done, for example, in a solvent-based extraction process, and the bitumen-lean stream may be derived from, middlings, primary separation tailings, flotation tailings, mature fine tailings, froth treatment tailings (such as from FSU underflow or TSRU), or other streams derived from water-based extraction, such as a reject stream from a slurry preparation system of a water-based extraction process.

[00117] The extracted bitumen stream is then mixed with the bitumen-enhanced stream to form a bitumen-rich stream. Optionally, solvent can be removed from the extracted bitumen stream before mixing with the bitumen-enhanced stream. Once formed, the bitumen-rich stream may be subsequently processed to remove residual solids and water therefrom to produce a product cleaned bitumen, which may optionally be upgraded on sit. Such processing may occur for example in a froth treatment unit of a water-based extraction process to produce a product cleaned bitumen. The bitumen-rich stream may be processed to meet fungible specifications so as to produce a fungible bitumen product. An exemplary mode of treatment for the bitumen-rich stream is within paraffinic froth treatment, which can achieve a fungible bitumen product. Advantageously, the bitumen-rich stream can be mixed with the bitumen-lean stream before being directed to paraffinic froth treatment, and optionally, the bitumen-lean stream can be partially dewatered before being mixed in this way.

[00118] The bitumen-enhanced stream may be referred to as "sales bitumen product", in instances wherein mixing the extracted bitumen stream yields a bitumen-rich stream that is fungible.

[00119] The bitumen-depleted stream may be one comprising agglomerated fines, optionally derived from the mixed stream after adding solvent to the mixed stream, forming agglomerates in a solvent-based extraction process. Such agglomerates may be washed on a belt filter using countercurrent washing.

[00120] In this process, heat may be recovered from a solvent recovery unit of the solvent-based extraction process.

[00121] According to certain embodiments wherein a water-based extraction process is used to form the bitumen-enhanced stream, and a solvent-based extraction process is used to form the bitumen-depleted and extracted bitumen streams, it is possible to consolidate a solvent recovery step of the water-based extraction process with a solvent recovery step of the solvent-based extraction process to realize efficiency in the process. Optionally, the water-based extraction process may employ a primary separation vessel for recovering bitumen froth and a froth separation unit for producing the bitumen-enhanced stream. When solvent-based extraction is employed, it may be a solvent-based extraction and solids agglomeration process (SESA).

[00122] ***(B) Recovery of Bitumen from Aqueous Sources***

[00123] A process is described herein for pre-treating an aqueous hydrocarbon-containing feed for a downstream solvent-based extraction process for bitumen recovery. The feed may include from 50 wt% to 95 wt% water, from 0.1 wt% to 10 wt% bitumen, and from 5 wt% to 50 wt% solids, wherein said solids comprise fines. The process involves removing water from the feed to produce an effluent comprising 40 wt% water or less; and subsequently providing the effluent to the downstream solvent-based extraction process for bitumen recovery. The downstream solvent-based extraction process may comprise fines agglomeration. Removing water from the aqueous hydrocarbon-containing feed may entail flowing the feed into a primary water separation system to remove water therefrom, such as a clarifier, a settler, a thickener or a cyclone. A solvent and/or flocculant may be added, for example mixed in with the feed prior to separation within a clarifier . This step of water removal produces a reduced-water stream of from 30 wt% to 60 wt% solids, and recycled water. Further, water may removed from the reduced-water stream using a secondary water separation system to produce an effluent comprising 40 wt% water or less.

[00124] The feed may be one that is produced from a water-based extraction process wherein a flocculants or coagulant is used to induce aggregation of fines and hydrocarbons within the water-based extraction process.

[00125] If solvent is mixed with the feed, the solvent may havie bitumen entrained therein for a solvent:bitumen ratio of less than about 2:1. Such a solvent may be a low boiling point cycloalkane.

[00126] For embodiments in which a secondary water separation system is employed, this may comprise a centrifuge with filtering capacity, a shale shaker, a vacuum belt filter, or one or more clarifiers.

[00127] The aqueous hydrocarbon-containing feed may be the effluent of a froth separation unit, for example, or may be derived from tailings from a tailings solvent recovery unit.

[00128] Embodiments of the process may additionally comprise recovery of bitumen, wherein the downstream solvent-based extraction process comprises: combining a first solvent with the effluent and a bituminous feed from oil sands to form an initial slurry; separating the initial slurry into a fine solids stream and a coarse solids stream; agglomerating solids from the fine solids stream to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract; separating the low solids bitumen extract from the agglomerated slurry; mixing a second solvent with the low solids bitumen extract to form a solvent-bitumen low solids mixture, the second solvent having a similar or lower boiling point than the first solvent; subjecting the mixture to gravity separation to produce a high grade bitumen extract and a low grade bitumen extract; and recovering the first and second solvent from the high grade bitumen extract, leaving a high grade bitumen product.

[00129] The downstream solvent-based extraction process may alternatively include: combining a first solvent with the effluent and a bituminous feed from oil sands to form an initial slurry; agglomerating solids from the initial slurry to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract; separating the low solids bitumen extract from the agglomerated slurry; mixing a second solvent with the low solids bitumen extract to form a solvent-bitumen low solids mixture, the second solvent having a similar or lower boiling point than the first solvent, subjecting the mixture to gravity separation to produce a high grade bitumen extract and a low grade bitumen extract; and recovering the first and second solvent from the high grade bitumen extract, leaving a high grade bitumen product; wherein the ratio of first solvent to bitumen in the initial slurry is selected to avoid precipitation of asphaltenes during agglomeration.

[00130] A system is described herein for pre-treating an aqueous hydrocarbon-containing feed for a downstream solvent-based extraction process for bitumen recovery, wherein the feed contains from 50 wt% to 95 wt% water, from 0.1 wt% to 10 wt% bitumen, and from 5 wt% to 50 wt% solids, wherein said solids are fines. The system comprises a dewatering unit for removing water from the aqueous hydrocarbon-containing feed to produce an effluent comprising 40 wt% water or less; and a conduit for providing the effluent to a downstream solvent-based extraction process comprising fines agglomeration to recover bitumen.

[00131] In such a system, the dewatering unit may include a primary water separation system to remove water from the aqueous hydrocarbon-containing feed, producing a reduced-water stream and recycled; and a secondary water separation system for receiving the reduced-water stream and removing water therefrom to produce an effluent comprising 40 wt% water or less. The system may additionally comprise components for recovery of bitumen in the downstream solvent-based extraction process. For example, such components may be: a slurry system wherein a bituminous feed is mixed with effluent from the de-watering system and a first solvent to form an initial slurry; a fine/coarse solids separator in fluid communication with the slurry system for receiving the initial slurry and separating a fine solids stream therefrom; an agglomerator for receiving a fine solids stream from the fine/coarse solids separator, for agglomerating solids and producing an agglomerated slurry; a primary solid-liquid separator for separating the agglomerated slurry into agglomerates and a low solids bitumen extract; a gravity separator for receiving the low solids bitumen extract and a second solvent; and a primary solvent recovery unit for recovering the first solvent or the second solvent in a high grade bitumen extract arising from the gravity separator and for separating bitumen therefrom.

[00132] Further, the components for recovery of bitumen in the downstream solvent-based extraction process could alternatively include: a slurry system wherein a bituminous feed is mixed with a first solvent to form an initial slurry; an agglomerator for receiving the initial slurry, for agglomerating solids and producing an agglomerated slurry; a primary solid-liquid separator for separating the agglomerated slurry into agglomerates and a low solids bitumen extract; a gravity separator for receiving the low solids bitumen extract and a second solvent; and a primary solvent recovery unit for recovering the first solvent or the second solvent in a high grade bitumen extract arising from the gravity separator and for separating bitumen therefrom.

[00133] ***(C) Extracting Hydrocarbons from PFT Tailings by Directing Tailings into a Solvent-Based Extraction Process***

[00134] Described herein is a process for recovering hydrocarbon from a tailings stream from a paraffinic froth treatment process. An exemplary embodiment of the process includes accessing a hydrocarbon-containing froth treatment tailings stream from a paraffinic froth treatment process; combining the froth treatment tailings stream with a solvent and additional oil sands to form a slurry; agitating the slurry to dissolve hydrocarbon into the solvent and to agglomerate fines within the slurry; separating the extracted hydrocarbon from the agglomerated fines to form a low solids extracted hydrocarbon stream and an extracted tailings stream; and recovering the solvent from the extracted tailings stream. The froth treatment tailings stream may be derived from a froth separation unit underflow of the paraffinic froth treatment (PFT) process, or from a tailings solvent recovery unit of PFT. Further, the froth treatment tailings stream may be partially dewatered to form a dewatered tailings stream before combining with the solvent, for example, the stream can be dewatered to less than 40 wt% water.

[00135] The slurry formed may have a water content of from 5 wt% to 25 wt%.

[00136] The solvent may be an aromatic solvent, such as toluene or benzene, and may have bitumen entrained therein, for example at an initial level in the solvent of 10 wt% or greater. For example, the solvent may be a cycloalkane with entrained bitumen.

[00137] In certain embodiments, the extracted tailings stream may comprise agglomerated fines. The process may further entail removal of the solvent from the low solids extracted hydrocarbon stream to form a bitumen product.

[00138] Optionally, separating the extracted hydrocarbon from the agglomerated fines may comprise washing agglomerated fines on a belt filter, for example with countercurrent washing with progressively cleaner solvent.

[00139] ***(D) Directing a Bitumen-Rich Stream into a Solvent-Based Extraction Process***

[00140] A process for recovering bitumen from oil sands is described herein, which includes extracting bitumen from oil sands in a water-based extraction process to form a bitumen-enhanced stream and a bitumen-lean stream; mixing the bitumen-enhanced stream with a solvent to form an extraction liquor; mixing the extraction liquor with additional oil sands to form a slurry comprising solids and bitumen extract; separating the solids from the slurry to form a low solids bitumen extract; and recovering solvent from the low solids bitumen extract to form a solvent extracted bitumen product.

[00141] The oil sands initially extracted in the process may be of a high to medium bitumen content and a low to medium fines content. Further, the additional oil sands mixed with the extraction liquor for extraction may be of low to medium bitumen content and of high to medium fines content. The water-based extraction process used to produce the bitumen-enhanced stream may optionally employ a flocculant or a coagulant to induce aggregation of fines and hydrocarbon within the water-based extraction process. The water used in the water-based extraction process may have a sodium ion content of 1000 wppm or greater, on a weight basis, and/or may have a calcium ion content of 100 wppm or greater (also on a weight basis). Further, the water may have a pH of less than 8.

[00142] The bitumen-enhanced stream may have bitumen to solids ratio greater than the oil sands, for example, a bitumen:solids ratio of greater than 0.5:1. The bitumen-enhanced stream may have a bitumen content of 50 wt% or greater, and/or may have a water content of 30 wt% or less. The bitumen-enhanced stream may be bitumen froth derived from the water-based extraction process. Optionally, the bitumen-enhanced stream may be partially dewatered prior to mixing with the solvent. The extraction liquor may also be partially dewatered prior to mixing with additional oil sands. The bitumen-lean stream may also be partially dewatered.

[00143] The solvent mixed with the bitumen-enhanced stream may comprise dissolved bitumen. The extraction liquor may have a bitumen content of 40 wt% or less.

[00144] In embodiments of the process fines may be agglomerated within the slurry.

[00145] In the solvent extracted bitumen product, there may be, for example, from between 0.1 to about 2 wt% solids on a bitumen basis. The process may optionally direct the solvent extracted bitumen product to a product cleaning step to produce a fungible bitumen product. Exemplary cleaning steps may include gas flotation, membrane filtration, or a combination thereof. A fungible bitumen product so formed may have less than 300 wppm solids on a bitumen basis. The solvent extracted bitumen product may be forwarded to an upgrader for further processing.

[00146] ***(E) Water-Assisted Deasphalting Technologies for Streams Derived from Solvent-Based Extraction***

[00147] A process is described herein for removing solids from oil sands. The process involves forming an oil sands slurry by mixing the oil sands with a first solvent, wherein the amount of first solvent added is greater than 10 wt% of the oil sands; separating a majority of the solids from the oil sands slurry, forming a solids-rich stream and a bitumen-rich stream, wherein the bitumen-rich stream comprises residual solids; emulsifying the bitumen-rich stream with a water-containing stream to form a hydrocarbon-external emulsion, wherein hydrocarbons form an external phase of the emulsion; mixing the hydrocarbon-external emulsion with a deasphalting solvent in sufficient quantity to cause some asphaltene precipitation, wherein precipitated asphaltenes adhere to at least a portion of the residual solids and to water droplets; and separating the precipitated asphaltenes from the hydrocarbon-external emulsion, thereby removing residual solids and water droplets adhering to the precipitated asphaltenes and forming a cleaned hydrocarbon product.

[00148] The solvents may be removed from the cleaned hydrocarbon product to form a fungible bitumen product, such as one comprising 300 wppm solids or less on a bitumen basis.

[00149] In one embodiment, the majority of the deasphalting solvent comprises C3-C6 components, on a weight basis. In certain embodiments, the first solvent and deasphalting solvent are the same.

[00150] The water-containing stream may be process water, bitumen froth, middlings, flotation tailings, froth treatment tailings, deasphalting unit tailings, or mixtures thereof.

[00151] The hydrocarbon-external emulsion formed in the process may comprise a hydrocarbon dominated phase as overflow and an underflow with water as the dominant fluid.

[00152] The first solvent may be removed from the bitumen-rich stream prior to emulsifying the bitumen-rich stream with the water-containing stream. Optionally, adding the deasphalting solvent to the bitumen-rich stream may occur prior to emulsifying the bitumen-rich stream with the water-containing stream. Advantageously, the deasphalting solvent can be added to the bitumen-rich stream in an amount that is not sufficient to precipitate asphaltenes.

[00153] The process may comprise removing the first solvent from the hydrocarbon-external emulsion prior to mixing the hydrocarbon-external emulsion with the deasphalting solvent.

[00154] Agglomeration of fines may be employed in order to separate a majority of the solids from the oil sands slurry.

[00155] The bitumen-rich stream may be one containing between 0.1 to about 2 wt% solids on a bitumen basis.

[00156] Mixing the emulsion with the deasphalting solvent may occur in a deasphalting unit, for example, a paraffinic forth treatment unit of a water-based extraction process. In certain embodiments, the water-containing stream may provide a sufficient amount of water to allow water to be the dominant fluid in a settling phase when the emulsion is deasphalted. Alternatively, the deasphalting unit may comprise primary separation and secondary separation. Deasphalting may occur within the deasphalting unit by mixing the deasphalting solvent with the hydrocarbon-external emulsion and directing the mixture into a primary settling vessel to produce a primary overflow and a primary underflow; introducing the primary overflow into a solvent recovery unit to produce the cleaned bitumen product and to recover the deasphalting solvent. Optionally, the primary underflow may be introduced into a secondary settling vessel with the deasphalting solvent from the solvent recovery unit, to recovery deasphalting solvent and a secondary underflow. Deasphalting solvent derived from the secondary settling vessel may be used as the deasphalting solvent for mixing with the hydrocarbon-external emulsion.

[00157] The process may additionally comprise adding water, additives, or a combination thereof, to the primary settling vessel. Further, the secondary underflow may be introduced into a tailings solvent recovery unit to produce tailings and to recover deasphalting solvent. The deasphalting solvent from the tailings solvent recovery unit may be recycled into the secondary settling vessel.

[00158] In embodiments of the process, the ratio of the deasphalting solvent to bitumen of the secondary settling vessel may be about 10:1 or greater, which minimizes bitumen lost in the secondary underflow. The deasphalting solvent may be a paraffinic solvent.

[00159] There is also described herein a further process for removing solids from oil sands comprising bitumen and solids which involves mixing oil sands with a first solvent to form an oil sands slurry, wherein the amount of the first solvent added is greater than 10 wt% of the oil sands. A majority of the solids are then separated from the oil sands slurry to form a solids-rich stream and an initial bitumen-rich stream, wherein the initial bitumen-rich stream comprises residual solids. The first solvent is then removed from the initial bitumen-rich stream to form a solvent depleted bitumen-rich stream; and at least a portion of the solvent-depleted bitumen-rich stream is directed to a paraffinic froth treatment process of a water-based extraction process. A fungible bitumen product can then be derived from the paraffinic froth treatment process. Optionally, the process may comprise mixing oil sands with water, wherein the amount of water added is greater than 50 wt% of the oil sands, and forming bitumen froth, wherein the bitumen froth comprises bitumen, solids and water; and

directing the bitumen froth and a second solvent to paraffinic froth treatment.

[00160] The residual solids within the initial bitumen-rich stream may be less than 2 wt% of the mass content of the initial bitumen-rich stream. Further, the second solvent may be a paraffinic solvent or a mixture thereof.

[00161] According to one embodiment, the paraffinic froth treatment process may occur within a first froth settling unit (FSU 1) and a second froth settling unit (FSU 2). The solvent-depleted bitumen-rich stream may be mixed with the bitumen froth before being directed to the FSU 1. The solvent-depleted bitumen-rich stream may be mixed with overflow of FSU 1. Optionally, the second solvent can be removed from the overflow of FSU 1 prior to mixing with the solvent-depleted bitumen-rich stream. Further, the solvent-depleted bitumen-rich stream can be mixed with the underflow of FSU 1. The solvent-depleted bitumen-rich stream can optionally be mixed with the overflow of FSU 2.

[00162] A fungible bitumen product so formed may have a solids content of less than 300 wppm on a bitumen basis.

[00163] A bridging liquid, such as for example water, may be added to the oil sands slurry to agglomerate fines within the oil sands slurry.

[00164] According to certain embodiments, the first solvent and the second solvent can be the same.

[00165] ***(F) Directing Solvent Extracted Bitumen Product to Water-based Extraction Processes***

[00166] A process is described herein for recovering hydrocarbon from oil sands. The process includes contacting a first oil sands ore with a solvent to form a solvent-based slurry comprising solids and a bitumen extract; separating the solids from the solvent-based slurry to produce a low solids bitumen extract; removing solvent from the low solids bitumen extract to form a solvent extracted bitumen product; contacting a second oil sands ore with water to form an aqueous slurry; mixing the solvent extracted bitumen product with the aqueous slurry to form a bitumen enriched slurry; and recovering bitumen from the bitumen enriched second slurry.

[00167] Optionally, the aqueous slurry comprises a water-based extraction stream upstream of primary separation in a water-based extraction process, for example a middlings stream of primary separation in a water-based extraction process. Alternatively, the aqueous slurry may comprise a tailings stream of primary, secondary or tertiary separation in a water-based extraction process.

[00168] The solvent extracted bitumen product may be mixed with process water prior to mixing with the aqueous slurry.

[00169] The solvent-based slurry may be mixed with a bridging liquid, such as process water, to agglomerate solids within the solvent-based slurry.

[00170] Recovery of bitumen may occur within a settling vessel, or within flotation cells.

[00171] The step of mixing the solvent extracted bitumen product with the aqueous slurry may occur upstream of froth treatment. Optionally, the step of mixing the solvent extracted bitumen product with the aqueous slurry can occur within a hydrotransport pipeline.

[00172] ***(G) Directing Solvent Extracted Tailings to Water-Based Extraction Process***

[00173] There is described herein a process for extracting hydrocarbon from oil sands ore, the process comprising contacting the ore with a first solvent to form a first slurry comprising solids and a bitumen extract; separating the bitumen extract from the first slurry to form solvent wet tailings comprised of the solids and the first solvent; removing the first solvent from the solvent wet tailings to form dry tailings; and combining said dry tailings with water wet tailings produced from a water-based extraction process to form strengthened tailings. In this process, the dry tailings comprise a water content of less than 15 wt% and the water wet tailings comprise a water content of more than 25 wt%.

[00174] The solvent wet tailings may be washed with a second solvent producing washed solids. The first solvent and second solvent may be removed from the washed solids to form the dry tailings. The second solvent is a paraffinic solvent of carbon number C7 or less.

[00175] A bridging liquid, such as process water optionally including dissolve salts, can be added to the first slurry so as to agglomerate some or all the solids within the first slurry to form an agglomerated slurry comprising agglomerated solids and a bitumen extract. According to one optional embodiment, the bridging liquid may be water with water-soluble adhesives and/or emulsion type adhesives.

[00176] The dry tailings may comprise precipitated asphaltenes.

[00177] The process may further comprise adding water-soluble adhesives and/or emulsion type adhesives to the solvent wet tailings. Also, the process may include adding water-soluble adhesives and/or emulsion type adhesives to the dry tailings.

[00178] Optionally, the dry tailings are sintered at a high temperature prior to forming strengthened tailings. Dry tailings may be heat treated at a temperatures greater than 500 °C.

[00179] The water wet tailings may optionally be thickened fine tailings from a water-based extraction process, such as for example, the underflow from a high rate or paste thickener. Alternatively, the water wet tailings may be mature fine tailings from a water-based extraction process, or may be non-segregating tailings from a water-based extraction process. The non-segregating tailings, if utilized, may comprise a mixture of thickened fine tailings and coarse tailings produced within a water-based extraction process. Further, the non-segregating tailings may comprise a mixture of mature fine tailings and coarse tailings produced within a water-based extraction process. The water wet tailings may be partially dewatered prior to mixing with dry tailings. Such dry tailings may be sintered at a temperature greater than 500 °C.

[00180] Strengthened tailings may be ones having, for example, a strength of 5 kPa or greater. The strengthened tailings may be treated with a coagulant, and/or may also be treated so as to lower the pH of the strengthened tailings.

[00181] The water wet tailings may optionally be sprayed onto the dry tailings to combine the dry and wet tailings. Further the dry tailings and water wet tailings may be mixed to form agglomerates comprising solids from the water wet tailings.

[00182] The dry tailings may be used as mine construction material, in mine refill, and/or in direct reclamation of land.

[00183] In the process described, the oil sands ore may be a low grade of oil sands ore with high fines content.

[00184] Before discussing additional details, under sections **(A)** to **(G)** below, the ways in which integration of solvent-based extraction processes with water-based extraction processes can be achieved, exemplary non-limiting solvent-based extraction processes will be described.

[00185] **Overview of Exemplary Solvent-Based Extraction Processes Involving Agglomeration**

[00186] Exemplary processes of solvent-based extraction are described in Canadian Patent Application No. 2,724,806, filed December 10, 2010 and entitled: "Processes and Systems for Solvent Extraction of Bitumen from Oil Sands". Processes for solvent-based extraction of a bituminous feed, as described in this document, employing fines agglomeration are briefly described below. Solvent-based extraction processes which may be integrated with water-based extraction processes according to the processes described herein are not limited to the process described below, but may also extend to solvent-based processes described above in the background section, or any other process that relies upon solvent, as opposed to water, as a basis for extracting bitumen from oil sands.

[00187] As described in Canadian Patent Application No. 2,724,806, to extract bitumen from oil sands in a manner that employs solvent, a solvent is combined with a bituminous feed derived from oil sand to form initial slurry. Separation of the initial slurry into a fine solids stream and coarse solids stream may be followed by 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 low solids bitumen extract to extract bitumen may take place, forming a solvent-bitumen low solids mixture, which can then be separated further into a 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.

[00188] In an exemplary embodiment of solvent-based extraction, a bituminous feed is combined with a first solvent having entrained bitumen. A slurry system is employed to form the initial slurry, which system may include a mixing vessel, such as a mix box, a pump or a combination thereof, having a feed section with gas blanket that provides a low oxygen environment. Steam can be added to the slurry system to heat the initial slurry to a level of, for example, 0 to 60 °C. The initial slurry can be separated in a fine/coarse solids separator to form a fine solids stream that is directed into an agglomerator, as well as a coarse solids stream which may optionally join with the agglomerated slurry arising from the agglomerator for further processing.

[00189] The first solvent, having bitumen entrained therein, may be derived from downstream recycling of the first solvent. This solvent can be added to the agglomerator in order to achieve a desired ratio of solvent:bitumen within the agglomerator. A desirable ratio may be one that limits precipitation of asphaltenes within the agglomerator, such as less than 2:1.

[00190] For fine/coarse solids separation, a settling vessel, cyclone or screen may be used, or any other suitable separation device. An aqueous bridging liquid, such as water, may optionally be added during agglomeration in the interests of achieving good adherence of fines into larger particles while agitation occurs. The agglomerated slurry formed comprises agglomerates that can be separated from a low solids bitumen extract. In the instance where coarse solids stream is combined with the agglomerated slurry, some residual bitumen adhering to the coarse solids may become entrained in the low solids bitumen extract, and thus can be recovered. In order to separate solids from the low solids bitumen extract, the slurry can be sent to solid-liquid separation. Primary means of separation may involve deep cone settlers, incline plate (lamella) settlers, or other clarification devices.

[00191] Once separated from the solids, the low solids bitumen extract can be combined in a mixer with a solvent that can be the same or different from the solvent used in forming the initial slurry. Optionally, the low solids bitumen extract can be sent to a solvent recovery unit, to recover solvent therefrom, before any subsequent mixing with a different solvent is undertaken within the mixer. In instances where the solvent used in the mixer used is different from the earlier (or “first”) solvent, the different (or “second”) solvent may be one having a low boiling point. The bitumen-containing mixture derived from the mixer may be separated using a gravity separator such as a clarifier or other separator capable of separating solids and water. Streams arising from the gravity separator are directed to a solvent recovery unit, following which a high grade bitumen product can be formed. Further, underflow of the gravity separator, from which solvent is recovered, forms a low grade bitumen product. The solvent recovered can be re-used in the process, with or without bitumen entrained therein. When the second solvent differs from the first due to its volatility and low boiling point, it can readily be recovered according to these characteristics.

[00192] The agglomerates separated from the agglomerated slurry can also be utilized, and subjected to subsequent solid-liquid separator, permitting recovery of solvent and bitumen therefrom. Solvent derived agglomerates may also be recycled. Washing of agglomerates may be conducted using a belt filter with countercurrent washing using progressively cleaner solvent. Additional quantities of solvent can be used if needed. Tailings may be recovered in a tailings solvent recovery unit (TSRU) so that agglomerated tailings can be separated from solvent or any recoverable water present.

[00193] A stream containing solvent plus bitumen, arising from the secondary solid-liquid separation of agglomerates can be processed with the intent of achieving a bottom sediment and water (BS&W) content lower than about 0.5 wt% solid in dry bitumen. For example, the product could have less than 400 wppm solids. This stream may be utilized commercially, or recycled back into the solvent-based extraction process by including it in the agglomerator or slurry system as a way of providing solvent while maintaining the desired solvent:bitumen ratio within the agglomerator, in efforts to avoid precipitation of asphaltenes.

[00194] Solvents used in the process include low boiling point solvents such as low boiling point cycloalkanes, or a mixture of such cycloalkanes, which substantially dissolve asphaltenes. The solvent may comprise a paraffinic solvent in which the solvent to bitumen ratio is maintained at a level to avoid precipitation of asphaltenes. In the case where a second solvent is used that differs from the first solvent added to the slurry system, the second solvent may comprise low boiling point n- or iso-alkanes and alcohols or blends of these.

[00195] Solvent-based extraction processes to recover bitumen from oil sands are described, employing solvent extraction and sequential agglomeration of fines to advantageously simplify subsequent solid-liquid separation. The processes can produce at least one bitumen product with a quality specification of water and solids that exceeds downstream processing and pipeline transportation requirements and contains low levels of solids and water. Further, systems for implementing such processes are described.

[00196] The use of low boiling point solvents advantageously permits recovery of solvent with a lower energy requirement than would be expended for recovery of high boiling point solvents. By conducting solvent extraction and agglomeration steps independently, shorter residence times in the agglomeration unit can be achieved. The sequential nature of the process allows for flexible design of a slurry feed system which permits high throughput from a smaller sized agglomeration unit, as well as faster bitumen production.

[00197] When the optional step of steam pre-conditioning is employed in the process, this realizes the further advantage that steam not only heats the slurry or oil sands, but adds the water necessary for the later agglomeration process.

[00198] Advantageously, the described processes permit formation of bitumen products with an acceptable composition for sale or processing at a remote refinery, and thus these products need not be processed by an onsite upgrader.

[00199] The bitumen product formed can be utilized in its current form, or further processed as necessary to meet and/or exceed quality specifications of low water content and low solids content required for pipeline transport and downstream processing. The processes described herein permit different levels and qualities of bitumen to be formed. Premium, dry and clean bitumen to be obtained as well as a lower grade bitumen (which in certain cases may comprise primarily of asphaltenes) for various commercial uses.

[00200] A bitumen product could be formed containing less than about 400 wppm solids on a bitumen basis, for example less than about 300 wppm solids, less than about 200 wppm solids, or less than about 100 wppm solids, according to the processes described. Further, a product formed by the process described herein may contain about 0.5 wt% or less of combined water plus solids of the dry weight of bitumen product. For example, a bitumen product containing 0.4 wt% or less, 0.3 wt% or less, 0.2 wt% or less, or 0.1 wt% or less of combined water and solids can be produced. Water content, if evaluated alone, may be less than or equal to 200 wppm in the final bitumen product. This is an improved result compared with the 0.2 - 0.5 wt% of solids in dry bitumen that can be achieved according to the previously described SESA process of Govier and Sparks. A bitumen product having 300 wppm solids or less, is considered to be a high grade fungible bitumen product. As used herein, wppm may be found to be interchangeable with the abbreviation ppm, which can be assumed to be parts per million when evaluated on a weight basis.

[00201] There are a variety of ways in which the solvent extraction and agglomeration can be conducted according to the process described in Canadian Patent Application No. 2,724,806. For example, in one embodiment, a first solvent is added prior to agglomeration, an initial slurry is formed, which is then agglomerated through mixing to form an agglomerated slurry. A low solids bitumen extract is separated from the agglomerated slurry, and is subsequently mixed with a second solvent to further extract bitumen. While the second solvent is one having a similar or lower boiling point than the first solvent. Gravity separation and other downstream processes may be used to separate bitumen and recycle solvent. Agglomerates can be washed using counter current washing, for example on a belt filter, with progressively cleaner solvent (having dissolved bitumen therein). In another embodiment the second solvent may be added prior to separating low solids bitumen extract from the agglomerated slurry. Coarse solids may be removed from the initial slurry prior to agglomeration and can then be processed separately, or reintroduced and mixed with agglomerates for further processing. Alternatively the initial slurry may simply be directed to agglomeration without removal of coarse solids.

[00202] Systems described in Canadian Patent Application No. 2,724,806 comprise a variety of components, such as a fine/coarse solids separator and a gravity separator. Specifically, such a system includes a slurry system for mixing the bituminous feed with a first solvent to form the initial slurry. Optionally, a fine/coarse solids separator, in fluid communication with the slurry system, receives the initial slurry and separates fine solids and coarse solids. However, it is possible to allow fine and coarse solids to proceed to agglomeration without separation. The system includes an agglomerator for receiving the fine solids stream from the fine/coarse solids separator (when present), for agglomerating solids and producing an agglomerated slurry. A primary solid-liquid separator is present in the system for separating the agglomerated slurry into agglomerates and a low solids bitumen extract. A gravity separator is present in the system for receiving the low solids bitumen extract and a second solvent. A primary solvent recovery unit is included, for recovering solvent.

[00203] ***Ratio of Solvent to Bitumen in Initial Slurry.*** The process may be adjusted to render the ratio of the first solvent to bitumen in the initial slurry at a level that avoids precipitation of asphaltenes during agglomeration.

[00204] 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 solvent used, can permit the control of a ratio of solvent to bitumen in the slurry system and agglomerator. When the solvent is 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.

[00205] Solvent used in extraction processes described herein containing dissolved or entrained bitumen may be referenced interchangeably as “liquor” or “extraction liquor”. which is a term that encompasses the solvent together with any bitumen entrained or dissolved therein, regardless of the quantity or ratio of solvent to bitumen.

[00206] 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 carries the assumption that the denominator of the ratio is 1 and is expressed on a weight to weight basis.

[00207] ***Slurry System.*** The slurry system in which the slurry is prepared in the system may optionally be a mix box, a pump, or a combination of these. By slurrying the first solvent together with the bituminous feed, and optionally with additional additives, the bitumen entrained within the feed is given an opportunity to become extracted into the solvent phase prior to the downstream separation of fine and coarse solid streams and prior to agglomeration within the agglomeration. In some prior art processes, solvent is introduced at the time of agglomeration, which may require more residence time within the agglomerator, and may lead to incomplete bitumen dissolution and lower overall bitumen recovery. The slurry system advantageously permits contact and extraction of bitumen from solids within the initial slurry, prior to agglomeration. Forming an initial slurry prior to agglomeration advantageously permit flexible design of the slurry system and simplifies means of feeding materials into the agglomerator.

[00208] ***Bridging Liquid.*** A bridging liquid is a liquid with affinity for the solids particles in the bituminous feed, and which is immiscible in the first solvent. In some embodiments, the agglomerating of solids comprises adding an aqueous bridging liquid to the fine solids stream and providing agitation. 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 solution 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. An exemplary bridging liquid is water. The bridging liquid may be referred to interchangeably herein as a "binding liquid".

[00209] ***Heating Bituminous Feed With Steam.*** According to an embodiment of the process, steam may be added to the bituminous feed before combining with the first solvent, to increase the temperature of the bituminous feed to a temperature of from about 0 °C to about 60 °C. Steam may be of particular benefit when oil sands are mined in cold conditions, such as during winter time. The steam may be added to heat the oil sands or other bituminous feed to a temperature of from about 0 °C to about 30 °C. The temperatures recited here are simply approximate upper and lower values. Because these are exemplary ranges, provided here primarily for illustration purposes, it is emphasized that values outside of these ranges may also be acceptable. A steam source for pre-conditioning the initial slurry entering the separator may be an optional component of the system. Other methods of heating the bituminous feed or the solvent (or solvent/bitumen combination) used to form the initial slurry may be incorporated into the process.

[00210] During the winter, a bituminous feed may be at a low temperature below 0 °C due to low temperature of the ambient outdoor surroundings, and the addition of steam to heat the feed to a level greater than 0 °C would be an improvement over a colder temperature. During hot summer conditions, the temperature of the bituminous feed may exceed 0 °C, in which case, it may not be beneficial to heat the bituminous feed. Addition of steam may be desirable for processing efficiency reasons, and it is possible that the upper limit of the ranges provided may be exceeded.

[00211] The optional step of steam pre-conditioning of the oil sands before making contact with solvent in the slurry system has the beneficial effect of raising the temperature of the input bituminous feed. The amount of steam added is lower or equal to the amount of water required for agglomeration. Slurrying the input feed with a low boiling point solvent is promoted without the use of a pressurized mixing system. Since steam pre-conditioning permits the use of low boiling point solvents, higher level of solvent recovery from tailings can be realized with reduced energy intensity relative to conventional processes.

[00212] During the winter, incoming oil sands may be about -3 °C. At this temperature, the separation process would require more heat energy to reach the process temperatures between about 0 °C and 60°C, or more particularly for an exemplary processing temperature of about 30 °C. Optimally, a solvent boiling point is less than about 100 °C. For a low boiling point solvent, this heating obtained through steam pre-conditioning is adequate to meet the processing requirement. For example, by heating the oil sands in a pre-conditioning step, a temperature can be achieved that is higher than could be achieved by heating the solvent alone, and adding it to a cold bituminous feed. In this way, optimal process temperatures can be achieved without any need to use a pressurized mixing system for solvent heating. Therefore, the steam not only provides water, but also some of the heating required to bring the components of the initial slurry to a desired temperature.

[00213] Once included as steam in a pre-conditioning step, the water content of the initial slurry would optimally be about 11 wt% or less, and when expressed as a percent of solids, about 15 wt% is an upper limit to the optimal level.

[00214] The steam pre-conditioning need not occur, as it is optional. Some water may be added at the agglomeration step if it is not added through steam pre-conditioning. In instances where steam pre-conditioning is used, optimally about half of the water requirement is added as steam, and further amounts of water can be added when the fine solids stream is transferred into the agglomerator.

[00215] In embodiments in which no steam pre-conditioning is employed, a slurry comprising the bituminous feed together with the first solvent may be prepared within the slurry system. Optionally, a solvent vapor could be added to the bituminous feed in the slurry stage to capture the latent heat at atmospheric pressure without need to pressurize the mixing vessel.

[00216] ***Low Oxygen for Initial Slurry.*** The initial slurry of the process described herein may optionally be formed in a low oxygen environment. A gas blanket may be used to provide this environment, or steam may be used to entrain oxygen away from the bituminous feed prior to addition of solvent. The gas blanket, when used, may be formed from a gas that is not reactive under process conditions. Exemplary gasses include, but are not limited to nitrogen, methane, carbon dioxide, argon, steam, or a combination thereof.

[00217] ***Separation of Fine Solids Stream and Coarse Solids Stream.*** The processes described herein may involve separation of a fine solids stream from a coarse solids stream from the initial slurry after it is mixed in a slurry system. This aspect of the process may be said to occur within a fine/coarse solids separator. An exemplary separator system may include a cyclone, a screen, a filter or a combination of these. The size of the solids separated, which may determine whether they are forwarded to the fine solids stream versus the coarse solids stream can be variable, depending on the nature of the bituminous feed. Whether a bituminous feed contains primarily small particles and fines, or is coarser in nature may be taken into consideration for determining what size of particles are considered as fine solids and directed toward agglomeration. Notably, embodiments of the process described herein do not require separation of coarse and fine solids from the initial slurry. In such instances, both coarse and fine solids will be present in the agglomerator. When separation of coarse and fine solids is desired, a typical minimum size to determine whether a solid is directed to the coarse solids stream would be about 140 microns. Fines entrainment in the coarse stream is unavoidable during this separation. The amount of fines entrained in the coarse solids stream is preferably less than 10 wt%, for example, less than 5 wt%.

[00218] ***Fine/Coarse Solids Separator.*** A coarse solids stream derived from the fine/coarse solids separator may be derived from the system. When the fine/coarse solids separator is present, the coarse solids stream may be directed for combination with the agglomerated slurry arising from the agglomerator prior to entry of the slurry into the solid-liquid separator.

[00219] The feed stream entering the agglomerator unit is pre-conditioned to separate out coarse particles before entry into the agglomerator unit. Thus, the stream entering the agglomerator is predominantly comprised of finely divided particles or a "fine solids stream". The slurry fraction containing predominantly coarse particles or the "coarse solids stream" may by-pass the agglomerator unit and can then be combined with the agglomerated slurry before the solid-liquid separation stage in which low solids bitumen is extracted from the agglomerated slurry.

[00220] A fine solids stream is processed separately from the coarse solids stream, in part because coarse solids are readily removed and need not be subjected to the processing within the agglomerator. The separator permits separation of a fine solids stream as a top stream that can be removed, while the coarse solids stream is a bottom stream flowing from the separator.

[00221] The coarse solids fraction derived from the separator may be combined with the effluent arising from the agglomerator, as the coarse solids together with the agglomerates will be removed in a later solid-liquid separation step. This would permit recovery of bituminous components that were removed in the coarse solids stream.

[00222] ***Re-combining Coarse Solids with Agglomerated Slurry.*** It is optional in the process to utilize the coarse solids stream derived from the fine/coarse solids separator by re-combining it with the agglomerated slurry prior to separating the low solids bitumen extract from the agglomerated slurry. Alternatively, the coarse solids stream may be processed separately, or added back into the slurry system for iterative processing.

[00223] ***Agglomeration.*** The step of agglomerating solids may comprise adding steam to the bituminous feed. The addition of steam may be beneficial to the bituminous feed because it may begin solids nucleation prior to the step of agglomerating.

[00224] The step of agglomerating solids may comprise adding water as bridging liquid to the fine solids stream and providing suitable mixing or agitation. The type and intensity of mixing will dictate the form of agglomerates resulting from the particle enlargement process.

[00225] Agitation could be provided in colloid mills, shakers, high speed blenders, disc and drum agglomerators, or other vessels capable of producing a turbulent mixing atmosphere. The amount of bridging liquid is balanced by the intensity of agitation to produce agglomerates of desired characteristics. As an example of appropriate conditions for a drum or disc agglomerator, agitation of the vessel may typically be about 40% of the critical drum rotational speed while a bridging liquid is kept below about 20 wt% of the slurry. The agitation of the vessel could range from 10% to 60% of the critical drum rotational speed, and the bridging liquid may be kept between about 10 wt% to about 20 wt% of solids contained in the slurry, in order to produce compact agglomerates of different sizes.

[00226] ***Solvents.*** Two solvents, or solvent systems, are sequentially employed in this process. The terms "first solvent" and "second solvent" as used herein should be understood to mean either a single solvent, or a combination of solvents which are used together in a first solvent extraction and a second solvent extraction, respectively.

[00227] While the stage of the process at which the solvent is introduced can be used to determine whether a solvent is the first or second solvent, as the sequential timing of the addition into the process results in the designations of first and second.

[00228] It is emphasized that the first and second solvents are not required to be different from each other. There are embodiments in which the first solvent and second solvent are the same solvent, or are combinations which include the same solvents, or combinations in which certain solvent ingredients are common to both the first and second solvents.

[00229] 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 solvent is selected, it may be one having a boiling point of less than 100 °C.

[00230] The solvents 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 agglomeration step. Exemplary agglomerating agent additives included 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.

[00231] While the solvent extractions may be initiated independently, there is no requirement for the first solvent to be fully removed before the second solvent extraction is initiated.

[00232] When it is said that the first solvent and the second solvent may have "similar" boiling points, it is meant that the boiling points can be the same, but need not be identical. For example, similar boiling points may be ones within a few degrees of each other, such as, within 5 degrees of each other would be considered as similar boiling points. The first solvent and the second solvent may be the same according to certain embodiments, in which case, having "similar" boiling points permits the solvents used to have the same boiling point.

[00233] ***First Solvent.*** The first solvent selected according to certain embodiments may comprise an organic solvent or a mixture of organic solvents. For example, the first 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. Should an alkane be selected as the first 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 first solvent, it may comprise a cycloalkane of 4 to 9 carbon atoms. A mixture of C_4-C_9 cyclic and/or open chain aliphatic solvents would be appropriate.

[00234] Exemplary cycloalkanes include cyclohexane, cyclopentane, or a mixture thereof.

[00235] If the first 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 the final boiling point of the distillate may be less than 100°C.

[00236] A mixture of C_4-C_{10} cyclic and/or open chain aliphatic solvents would also be appropriate. For example, it can be a mixture of C_4-C_9 cyclic aliphatic hydrocarbons and paraffinic solvents where the percentage of the cyclic aliphatic hydrocarbon in the mixture is greater than 50%.

[00237] ***Second Solvent.*** The second solvent may be selected to be the same as or different from the first solvent, and may comprise a low boiling point alkane or an alcohol. The second solvent, when different from the first solvent, may be one that improves the washing of agglomerates. Under certain circumstances, the second solvent is not selected as one that can cause deasphalting. For example, in embodiments described herein, a stream derived from solvent-based extraction may later be directed to a froth treatment process, or other deasphalting process, within a water-based extraction process. In such an embodiment, it is undesirable to cause deasphalting within the solvent-based extraction process (through selection of the second solvent) because deasphalting can be deferred to the later froth treatment stage. Throughout embodiments described herein, it is understood that in instances where the product of solvent-based extraction is later deasphalted and further cleaned in a water-based process (such as PFT), the second solvent utilized in solvent-based extraction should not be one that causes deasphalting (product cleaning), but rather should be selected to accomplish further washing and/or bitumen extraction, without effectively deasphalting the stream during the solvent-based extraction process.

[00238] The second solvent may have an exemplary boiling point of less than 100°C. In some embodiments, the second solvent can be mixed with feed into the solid-liquid separation steps. Because the first solvent is not used in both agglomeration and the solid-liquid separation steps as described in prior art, a second solvent that is miscible with the agglomerate bridging liquid (for example, miscible with water) can be employed at the solid-liquid separation stage. In other words, the two processing steps can be conducted independently and without the solid-liquid separation disrupting the agglomeration process. Thus, selecting the second solvent to be immiscible in the first solvent, and/or having the ability to be rendered immiscible after addition, would be optional criteria.

[00239] The second solvent may comprise a single solvent or a solvent system that includes a mixture of appropriate solvents. The second solvent may be a low boiling point, volatile, polar solvent, which may or may not include an alcohol or an aqueous component. The second solvent can be C_2 to C_{10} aliphatic hydrocarbon solvents, ketones, ionic liquids or biodegradable solvents such as biodiesel. The boiling point of the second solvent from the aforementioned class of solvents is preferably less than 100°C.

[00240] ***Process Temperatures.*** The process may occur at a wide variety of temperatures. In general, the heat involved at different stages of the process may vary. One example of temperature variation is that the temperature at which the low solids bitumen extract is separated from the agglomerated slurry may be higher than the temperature at which the first solvent is combined with the bituminous feed. Further, the temperature at which the low solids bitumen extract is separated from the agglomerated slurry may be higher than the temperature at which solids are agglomerated. The temperature increase during the process may be introduced by recycled solvent streams that are re-processed at a point further downstream in the process. By recycling pre-warmed solvent from later stages of the process into earlier stages of the process, energy required to heat recycle stream is lower and heat is better conserved within the process. Alternatively, the temperature of the dilution solvent may be intentionally raised to increase the temperature at different stages of the process. An increase in the temperature of the solvent may result in a reduced viscosity of mixtures of solvent and bitumen, thereby increasing the speed of various stages of the process, such as washing and/or filtering steps.

[00241] ***Solid-Liquid Separator.*** 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.

[00242] 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 primary and secondary unit are both employed, generally, the primary unit separates agglomerates, while the secondary unit involves washing agglomerates.

[00243] ***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 countercurrently 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 conduced completely separately in a secondary solid-liquid separator. By "countercurrently 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.

[00244] A secondary solid-liquid separator for countercurrently 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 conventional fractionation tower or a distillation unit.

[00245] The temperature for countercurrently washing the agglomerates may be selected to be higher than the temperature at which the first solvent is combined with the bituminous feed. Further, the temperature selected for countercurrently washing the agglomerates may be higher than the temperature at which solids are agglomerated.

[00246] When conducted in the process, the secondary stage for countercurrently washing the agglomerates may comprise a gravity separator, a cyclone, a screen, a belt filter, or a combination thereof.

[00247] ***Recycle and Recovery of Solvent.*** The process involves removal and recovery of solvent used in the process. In this way, solvent is used and re-used, even when a good deal of bitumen in 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. 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 have 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. For example, in steps of the process when solvent is recovered from a low grade or high grade bitumen extract leaving a bitumen product, it is understood that some solvent may remain within that product

[00248] The system may contain a single solvent recovery unit for recovering the first and second solvents arising from the gravity separator. The system may alternatively contain more than one solvent recovery unit. For example, another solvent recovery unit may be incorporated before the step of adding the second solvent to recover part or all of the first solvent.

[00249] In order to recover either or both the first solvent or the second solvent, conventional means may be employed. For example, typical solvent recovery units may comprise a fractionation tower or a distillation unit. A primary and/or secondary solvent recovery unit may be desirable for use in the process described herein.

[00250] Solvent recovery and recycle is incorporated into embodiments of the process. For example, the first solvent derived from the slurry of agglomerated solids, which may contain bitumen, can be recycled in the process, such as at the slurrying or agglomerating step. Further, the second solvent may be recovered by using a solvent recovery unit and recycled for addition to the low solids bitumen extract.

[00251] Solvent recovery may be controlled to ensure that the second solvent is added at the appropriate time. For example, the first and second solvent may be recovered by distillation or mechanical separation following the solid-liquid separation step. Subsequently, the first solvent may be recycled to the agglomeration step while the second solvent is recycled downstream of the agglomerating step. In the exemplary embodiment where the second solvent is immiscible with the first solvent, the process will occur with no upset to the agglomeration process since interaction of the second solvent with the bridging liquid only occurs downstream of the agglomerating step.

[00252] Heat entrained in recycled solvent can advantageously be utilized when the solvent is added to the process at different stages to heat that stage of the process, as required. For example, heated solvent with entrained bitumen derived from washing of the agglomerates in the secondary solid-liquid separator, may be used not only to increase the temperature of the initial slurry in the slurry system, but also to include a bitumen content that may be desirable to keep the solvent:bitumen ratio at a desired level so as to avoid precipitation of asphaltenes from solution during agglomeration. By including heated solvent as well as bitumen, this addition provides an advantage to the agglomeration process.

[00253] The first solvent recovered in the process may comprise entrained bitumen therein, and can thus be re-used for combining with the bituminous feed; or for including with the fine solids stream during agglomeration. 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 within the initial slurry to achieve the selected ratio within the agglomerator that avoids precipitation of asphaltenes.

[00254] ***Extraction Step is Separate from Agglomeration Step.*** Solvent extraction may be conducted separately from agglomeration in certain embodiments of the process. Unlike prior art processes, where the solvent is first exposed to the bituminous feed within the agglomerator, embodiments described herein include formation of an initial slurry in which bitumen dissolution into a solvent occurs prior to the agglomeration step. This has the effect of reducing residence time in the agglomerator, when compared to previously proposed processes which require extraction of bitumen and agglomeration to occur simultaneously. The instant process is tantamount to agglomeration of pre-blended slurry in which extraction via bitumen dissolution is substantially or completely achieved separately. Performing extraction upstream of the agglomerator permits the use of enhanced material handling schemes whereby flow/mixing systems such as pumps, mix boxes or other types of conditioning systems can be employed.

[00255] Because the extraction occurs upstream of the agglomeration step, the residence time in the agglomerator is reduced. One other reason for this reduction is that by adding components, such as water, some initial nucleation of particles that ultimately form larger agglomerates can occur prior to the slurry arriving in the agglomerator.

[00256] **Figure 1** is a schematic representation of an embodiment of processes (10) described herein. The combining (11) of a first solvent and a bituminous feed from oil sand to form initial slurry is followed by separating (12) of a fine solids stream and coarse solids stream from the initial slurry. Agglomerating (13) of solids from fine solids stream then occurs to form agglomerated slurry comprising agglomerates and low solids bitumen extract, optionally subsequently adding coarse solids stream to agglomerated slurry. Subsequently, separation (15) of low solids bitumen extract from agglomerated slurry occurs. Further, mixing (16) of a second solvent with low solids bitumen extract to extract bitumen takes place, forming a solvent-bitumen low solids mixture. Separation (18) of low grade bitumen extract and high grade bitumen extracts from the mixture occurs. Further, recovery (19) of solvent from the high grade extract is conducted, leaving a high grade bitumen product. Further details of these process steps are provided herein.

[00257] **Figure 2** outlines an embodiment of the processes described herein, in which the second solvent is mixed with a low solids bitumen extract derived from separation of the agglomerated slurry in a clarifier.

[00258] In this embodiment, a bituminous feed (202) is provided and combined with a first solvent (209a), which may contain entrained bitumen (203a), in a slurry system (204) to form an initial slurry (205). The slurry system (204) may be any type of mixing vessel, such as a mix box, pump or pipeline or combination thereof, having a feed section with gas blanket that provides a low oxygen environment. Steam (207) may be added to the slurry system (204) so as to heat the initial slurry (205) to a level of, for example, 0 to 60 °C. The initial slurry (205) is separated in a fine/coarse solids separator (206) to form a fine solids stream (208), which is directed into an agglomerator (210), as well as a coarse solids stream (212), which later, optionally, joins with the agglomerated slurry (216) arising from the agglomerator (210) for further processing. The fine/coarse solids separator (206) may be a settling vessel, cyclone or screen, or any suitable separation device known in the art.

[00259] Bitumen (203b) which may be entrained in the first solvent (209b), for example, as derived from downstream recycling of the first solvent, may be added to the agglomerator (210) in order to achieve an optimal ratio of solvent to bitumen within the agglomerator (210). Such a ratio would be one that avoids precipitation of asphaltenes within the agglomerator (210), and an exemplary ratio may be less than 2:1.

[00260] An aqueous bridging liquid (214), such as water, may optionally be added to the agglomerator (210) in the interests of achieving good adherence of fines into larger particles, and the process of agglomeration of the solids contained within the fine solids stream (208) occurs by agitation within the agglomerator (210). The agglomerated slurry (216) arising from the agglomerator (210) comprises agglomerates (217a) together with a low solids bitumen extract (220a), all of which is optionally combined with the coarse solids stream (212) in the event that the coarse solids stream is directed to be combined at this stage. The slurry (216) is then directed to the primary solid-liquid separator (218), which may be a deep cone settler, or other device, such as thickeners, incline plate (lamella) settlers, and other clarification devices known in the art.

[00261] The low solids bitumen extract (220b) is separated from the agglomerated slurry within the primary solid-liquid separator (218). This extract (220b) is subsequently combined in a mixer (221) with a second solvent (222a). Extract (220b) may optionally be sent to a solvent recovery unit, not shown, where the first solvent is recovered from the extract, before the mixing with the second solvent (222a) is undertaken within the mixer (221).

[00262] The second solvent may be one having a low boiling point. The bitumen-containing mixture (223) obtained from the mixer (221) is separated in a gravity separator (224), which may for example be a clarifier or any other type of separator employing gravity to separate solids and water. Streams arising from the gravity separator (224) are the overflow (225), which is directed toward forming a high grade bitumen product (226) once the solvent has been extracted in a solvent recovery unit (228), and the underflow which may be removed as a low grade bitumen extract (230), which may then optionally have solvent removed to form a low grade bitumen product. The solvent recovery unit (228) may advantageously be used to recover any of the first solvent (209c) remaining within the effluent of the gravity separator (224), in the interests of solvent recovery and re-use. Advantageously, the second solvent (222b) is easily removed and recovered due to its volatility and low boiling point. There may be bitumen entrained in recovered solvents.

[00263] The agglomerates (217b) can also be utilized, as they leave the primary solid-liquid separator (218) and are subsequently subjected to a separation in a secondary solid-liquid separator (232), permitting recovery of the first solvent (209a) and bitumen (203a) in the process. First solvent (209c) derived from the solvent recovery unit (228) may also be recycled to the secondary solid-liquid separator (232), to wash agglomerates, for example in a belt filter using countercurrent washing with progressively cleaner solvent. Additional quantities of first solvent (209d) can be used if additional volumes of solvent are needed. Tailings may be recovered in a TSRU or tailings solvent recovery unit (234) so that agglomerated tailings (236) can be separated from recyclable water (238). Either or both the recovered first solvent (209e) derived from the TSRU (234) and/or from the solvent recovery unit (228) may be recycled in the secondary solid-liquid separator (232).

[00264] A combination containing the first solvent (209a) plus bitumen (203a) arising from the secondary solid-liquid separator (232) can be processed with the intent of achieving a bottom sediment and water (BS & W) content lower than about 0.5 wt% on a dry bitumen basis. In particular, the product would have less than 400 ppm solids. This combination may also be recycled back into the process by including it in the agglomerator (210) or slurry system (204) as a way of recycling solvent, and maintaining an appropriate solvent:bitumen ratio within the agglomerator to avoid precipitation of asphaltenes.

[00265] Advantageously, such processes as outlined in **Figure 2** permit recovery of both the first solvent and the second solvent. In one embodiment, the first solvent may be a low boiling point solvent, such as a low boiling point cycloalkane, or a mixture of such cycloalkanes, which substantially dissolves asphaltenes. The first solvent may also be a paraffinic solvent in which the solvent to bitumen ratio is maintained at a level to avoid precipitation of asphaltenes.

[00266] For the second solvent, a low boiling point n- or iso-alkane and alcohols or blends are candidates. Surface modifiers may be added to the alcohol if needed. With the alkanes, solvent deasphalting is achieved with concurrent cleaning of the high grade bitumen product (226) to achieve pipeline quality. Therefore, the low grade bitumen extract (230) is comprised predominantly of asphaltenes or other more polar bitumen fractions.

[00267] Another advantage is that the process forms two different grades of bitumen product from the gravity separator (224). Specifically, partial product upgrading is conducted to produce a first product of high grade bitumen product (226). The low grade bitumen extract (230) formed may also be processed to a low grade bitumen product after solvent recovery, so as to also possesses some commercial value.

[00268] This process facilitates recovery of bitumen with no need for handling more than one solvent in the tailings loop of the TSRU (234), thereby allowing for simplified solvent recovery/recycling processes.

[00269] **Figure 3** is a schematic representation of a further embodiment of a process (30) described herein. The combining (31) of a first solvent and a bituminous feed from oil sand to form the initial slurry is followed by separating (32) of a fine solids stream and coarse solids stream from the initial slurry. Agglomerating (33) of solids from fine solids stream then occurs to form an agglomerated slurry comprising agglomerates and low solids bitumen extract, optionally subsequently adding the coarse solids stream into the agglomerated slurry. Further, mixing (36) of a second solvent with the agglomerated slurry occurs, to extract bitumen, forming a solvent-bitumen agglomerated slurry mixture. Removal (37) of agglomerates from the mixture then occurs. Separation (38) of high grade and low grade bitumen extracts then occurs. Further, recovery (39) of the solvents from the bitumen extracts is conducted, leaving a high grade bitumen product and a low grade bitumen product. Further details of these process steps are provided herein.

[00270] **Figure 4** illustrates an embodiment of the processes described herein which can be characterized by the feature that the second solvent is mixed with the agglomerated slurry upon entry into the primary solid-liquid separator.

[00271] In this embodiment, a bituminous feed (402) is provided and is combined with a first solvent (409a), which may have bitumen (403a) entrained therein, into slurry system (404) to form an initial slurry (405), optionally in the presence of steam (407) to heat the initial slurry (405). The initial slurry (405) is mixed and the first solvent (409a) is given time to contact the bituminous feed so as to extract bitumen. The slurry (405) is then directed to a separator (406) to form a fine solids stream (408) which is directed into an agglomerator (410). Further arising from the separator (406) is a coarse solids stream (412) for later processing and solid-liquid separation.

[00272] A bridging liquid (414), such as water, is added to the agglomerator (410), optionally together with bitumen (403b) which may be entrained in the first solvent (409b) as derived from downstream solvent recovery. The process of agglomeration of the solids from the fine solids stream (408) occurs by agitation of the agglomerator. The agglomerated slurry (416) arising from the agglomerator (410) comprises agglomerates (417a) together with a low solids bitumen extract 420a), all of which may be combined with the coarse solids stream (412) and directed to a mixer (421) so as to be combined prior to entry into the primary solid-liquid separator (418). The agglomerated slurry (416) is mixed with the second solvent (422a) to form a solvent-bitumen agglomerated slurry mixture (423) within the mixer, and is then separated within the primary solid-liquid separator (418), which may be a deep cone settler or any other sort of separator. Concurrently, the second solvent (422a) can be added to the primary solid-liquid separator (418). The second solvent (422a) may also be added to the mixer (421) before entry into the primary solid-liquid separator (418). The second solvent (422a) may be one having a low boiling point, such as a boiling point below 100 °C, and is immiscible in the first solvent, or can be rendered immiscible in the first solvent.

[00273] The bitumen-containing mixture within the primary solid-liquid separator (418) is separated and either directed toward forming high grade bitumen product (426) once the solvent has passed through the separator (418) to form a high grade bitumen extract (425) and has been extracted in a primary solvent recovery unit (428), or can be directed toward forming a low grade bitumen product (430). Advantageously in this embodiment, the second solvent (422b, 422c) is easily removed and recovered due to its volatility, low boiling point, and optionally due to its immiscibility in the first solvent.

[00274] The agglomerates (417b) can also be processed as they leave the primary solid-liquid separator (418) and are subsequently subjected to a separation in a secondary solid-liquid separator (432), permitting recovery of the second solvent (422d), first solvent (409c) and any bitumen entrained therein in the process. Residual solvent in the tailings may be recovered in a TSRU or tailings solvent recovery unit (434) so that agglomerated tailings (436) may be separated, and optionally water (438) used in the process may be recovered and recycled.

[00275] The recovered first solvent (409d) arising from the primary solvent recovery unit (428) may be recycled for use in the process, for example when combined with the bituminous feed (402) in the separator (406). This recovered solvent may contain bitumen entrained therein. Quantities of a combination comprising recycled first solvent (409d) plus any entrained bitumen arising from the primary solid-liquid separator (418) or solvent recovery unit (428) may be directed to the agglomerator (410) for further processing. The second solvent (422b) recovered from the primary solvent recovery unit (428) may be also be recycled.

[00276] Secondary recovery of bitumen occurs within the secondary solid-liquid separator (432). The separated low grade bitumen extract (450) may be subjected to separation within a secondary solvent recovery unit (444), which may be a distillation unit, to recover and recycle the second solvent (422g) and to arrive at a low grade bitumen product (430). The low grade bitumen product (430) possesses some commercial value, as it can be processed further with the intent of achieving a bottom sediment and water (BS&W) content lower than about 0.5 wt% solid in dry bitumen.

[00277] Solvent recovered may be held in a first solvent storage (429) in the case of the first solvent (409d), or in a second solvent storage (445), in the case of the second solvent (422b, 422g) for later use in the upstream aspects of the process. High grade bitumen (431) may be added to the first solvent derived from first solvent storage (429), if there is a need to alter the solvent to bitumen ratio prior to adding a combination of solvent (409a) and bitumen (403a) to the slurry system (404). Further, additional first solvent (409e) make-up quantities or second solvent (422e) make-up quantities may be included in respective solvent storage, if the solvent volume requires replenishing. Additional second solvent (422f) may also be added to the secondary solid-liquid separator (432) if needed.

[00278] This embodiment of the process forms different grades of bitumen product and advantageously permits recovery and/or recycling of both the first solvent and the second solvent.

[00279] In this embodiment, the first solvent may be a low boiling point cyclic aliphatic solvent, such as a low boiling point cycloalkane, or a mixture of such cycloalkanes, which substantially dissolves asphaltenes. The first solvent may also be a paraffinic solvent in which the solvent to bitumen ratio is maintained at a level to avoid precipitation of asphaltenes.

[00280] The second solvent may be a polar solvent, such as an alcohol, a solvent with an aqueous component, or another solvent which is immiscible in the first solvent or which could be rendered immiscible in the first solvent. A low boiling point n- or iso-alkane and alcohols or blends of these with or without an aqueous component are candidates. Surface modifiers may be added to the alcohol if needed. Good agglomerate strength is achieved if the agglomerates are modified with hydrating agents, such as a cement, a geopolymer, fly ash, gypsum or lime during agglomeration. Optionally, the second solvent may comprise a wetting agent in an aqueous solution. A further option is to employ controlled precipitation of asphaltenes within either the agglomerator (410) or the primary solid-liquid separator (418) by employing a mixture of solvent and bitumen in a ratio that avoids precipitation of asphaltenes. For example, a ratio of solvent to bitumen of 2:1 or less may be used within the agglomerator to control asphaltene precipitation.

[00281] The embodiment depicted in **Figure 4** results in enhanced liquid drainage during agglomerate washing when the second solvent comprises predominantly of polar component, such as an alcohol. Further, enhanced solvent recovery may be achieved, which results in a more environmentally benign tailings stream.

[00282] The product upgrading of low grade bitumen product (430) can be undertaken to produce a low grade product with some commercial value. If the commercial value involves alternate fuel applications, it would be possible to have a residual alcohol content remaining in the low grade bitumen product (430) from the second solvent. Generally, the low grade bitumen product (430) is comprised predominantly of asphaltenes or other more polar bitumen fractions.

[00283] **Figure 5** is a schematic representation of an additional embodiment of the process (50) described herein. The combining (51) of a first solvent and a bituminous feed from oil sand to form initial slurry is followed by separating (52) of a fine solids stream and coarse solids stream from the initial slurry. Recovery (54) of the first solvent from the coarse solids stream is then conducted. Agglomerating (53) of solids from the fine solids stream then occurs to form agglomerated slurry comprising agglomerates and low solids bitumen extract. In this embodiment, the coarse solids stream is not optionally added to the agglomerated slurry, as the coarse solids stream is processed separately. Subsequently, separation (55) of low solids bitumen extract from agglomerated slurry occurs. Further, mixing (56) of a second solvent with low solids bitumen extract to extract bitumen takes place, forming a solvent-bitumen low solids mixture. Separation (58) by gravity of low grade and high grade bitumen extracts from the mixture then occurs. Further, recovery (59) of the solvents is conducted, leaving a high grade bitumen product. Further details of these process steps are provided herein.

[00284] **Figure 6** illustrates an embodiment similar to that depicted in **Figure 2**, except that coarse solids stream separated out of the bituminous feed is processed separately, and not re-combined with an agglomerated slurry.

[00285] A bituminous feed (602) is provided and combined with a first solvent (609a), optionally with bitumen (603a) entrained therein, in a slurry system (604) to form an initial slurry (605). Steam (607) may be added to the slurry system (604) to heat the initial slurry (605). The initial slurry (605) is then directed from the slurry system (604) to a separator (606) for separation, which may be a fine/coarse solids separator, in order to form a fine solids stream (608), which is directed into an agglomerator (610), as well as a coarse solids stream (612), which is processed separately from the agglomerated slurry (616) arising from the agglomerator (610). Additional quantities of first solvent (609b) having bitumen (603b) entrained therein, may be added to the agglomerator (610). A bridging liquid (614), such as water, may be added to the agglomerator (610), and the process of agglomeration of the solids contained within the fine solids stream (608) occurs by agitation within the agglomerator (610). The agglomerated slurry (616) arising from the agglomerator comprises agglomerates (617a) together with a low solids bitumen extract (620a). In this example, there is no combination with the coarse solids stream. Instead, the agglomerated slurry (616) itself is directed to the primary solid-liquid separator (618).

[00286] The low solids bitumen extract (620) is separated from the agglomerated slurry (616) within the primary solid-liquid separator (618). This extract (620) is subsequently combined in a mixer (621) with a second solvent (622a). Extract (620) may optionally be sent to a solvent recovery unit, not shown, where all of the first solvent contained therein is recovered from the extract, before mixing with the second solvent within the mixer (621).

[00287] The second solvent may be one having a low boiling point. The solvent-bitumen low solids mixture (623) derived from the mixer (621) is separated in a gravity separator (624), and streams arising from the gravity separator (624) are directed either toward forming a high grade bitumen product (626) once the solvent has been extracted in a solvent recovery unit (628), or toward forming a low grade bitumen extract (630). The solvent recovery unit (628) may advantageously be used to recover the majority of the first solvent (609d) remaining within the effluent, or overflow, of the gravity separator (624), in the interests of solvent recovery and re-use. Streams derived from the gravity separator (624) include high grade bitumen extract (625), and low grade bitumen extract (630) as underflow. Advantageously, the second solvent (622b) is easily removed and recovered due to its volatility and low boiling point.

[00288] The separated agglomerates (617b) can also be utilized, as they leave the primary solid-liquid separator (618) and are subsequently subjected to a separation in a secondary solid-liquid separator (632), permitting recovery of the first solvent (609c) and bitumen (603c) entrained therein in the process. Solvent (609d) derived from the solvent recovery unit (628) may also be recycled to the secondary solid-liquid separation separator (632). Additional quantities of the first solvent (609e) may be added to the secondary solid-liquid separator, if desired, for example for washing purposes. Tailings may be recovered in a TSRU or tailings separation recovery unit (634) so that agglomerated tailings (636) can be separated from recyclable water (638). Either or both the recovered first solvent (609g or 609d)) derived from the TSRU (634) and/or from the solvent recovery unit (628) may be recycled in the secondary solid-liquid separator (632).

[00289] A combination containing the first solvent (609c) plus bitumen (603c) arising from the secondary solid-liquid separator (632) can be processed with the intent of achieving a bottom sediment and water (BS&W) content lower than about 0.5 wt% solid in dry bitumen. In particular, the product may have less than 400 ppm solids. This combination containing the first solvent plus bitumen may also be recycled back into the process by including it in the agglomerator (610) or slurry system (604).

[00290] Advantageously, the process permits recovery of both the first solvent and the second solvent. In one embodiment, the first solvent may be a low boiling point solvent, such as a low boiling point cycloalkane, or a mixture of such cycloalkanes, which substantially dissolves asphaltenes. The first solvent may also be a paraffinic solvent in which the solvent to bitumen ratio is maintained at a level to avoid precipitation of asphaltenes.

[00291] For the second solvent, a low boiling point n- or iso-alkane and alcohols or blends are candidates. Surface modifiers may be added to the alcohol if needed. With the alkanes, solvent deasphalting is achieved with concurrent cleaning of the high grade bitumen product (626) to achieve pipeline quality. Therefore, the low grade bitumen extract (630) is comprised predominantly of asphaltenes or other more polar bitumen fractions.

[00292] In this embodiment, the coarse solid stream (612) derived from the separator (606) is kept segregated from the agglomerated slurry (616). Thus, the separator (606) can be reduced in size compared to the approach described with respect to **Figure 2**, as only quick settling solids are removed. These coarse solids may form the majority of the particulate, especially for high grade oil sands, and will exhibit high drainage rates in the secondary solid-liquid separator for coarse solids (652). The non-agglomerated nature of the coarse solids allows for efficient solvent recovery of both first solvent (609f) and bitumen (603f) entrained therein.

[00293] The agglomerated slurry (616) may thus enter a reduced size primary solid-liquid separator (618) and can be processed as described above in the secondary liquid-solid separator (632) and TSRU (634). Agglomerated tailings (636) can be removed using the TSRU (634). The rate determining step in solvent recovery from tailings is the time required for release of residual solvent from the pores of the agglomerated solids. With segregation, the solvent recovery from the fine particles can be optimized independent of the coarse particles. The combination of first solvent (609f) and bitumen (603f) recovered permits separation of coarse tailings (656), once drained from the secondary solid liquid separator for coarse solids (652). Coarse tailings (656) isolated from the tailings solvent recovery unit for coarse solids (654) can be sent to the primary solid-liquid separator (618) for residual fine solids removal, or may be recycled upstream of the process to form the initial slurry (605) in slurry system (604). The tailings solvent recovery unit for coarse solids (654) may be used to recover recyclable water (638) or solvent from the secondary solid-liquid separator for coarse solids (652). Coarse tailings (656) may also be removed.

[00294] **Figure 7** is a schematic representation of a system (70) according to an embodiment described herein. The system comprises a slurry system (71) in which a bituminous feed is mixed with a first solvent to form an initial slurry. A separator (73) is present, in which a fine solids stream and a coarse solids stream are separated from the initial slurry. An agglomerator (75) is present in the system, for receiving fine solids stream from separator, and in which agglomerated slurry is formed. A primary solid-liquid separator (77) is included in the system (70) for receiving the agglomerated slurry, and separating it into agglomerates and a low solids bitumen extract. A gravity separator (78) is included for receiving the low solids bitumen extract and a second solvent. Further, a primary solvent recovery unit (79) is also included in the system (70) for recovering first and/or second solvent arising from primary solid-liquid separator, leaving bitumen product.

[00295] Embodiments described below may involve integration of a stream or product from a solvent-based extraction process into a water-based extraction process. Further, embodiments are described which involve integration of a stream or product of a water-based extraction process into a solvent-based extraction process. These integrated processes may employ a number of different streams and/or products, and may involve introduction of such streams at various stages of the process into which the streams or products are to be integrated. For example, a bitumen product formed as a result of the solvent-based extraction process may itself be integrated back into a water-based extraction process, thereby permitting solvent-based extraction to serve as a closed loop component of the overall process. Another example, as described below may involve dry tailings, having a low water content (also referred to herein as "agglomerated tailings") being directed into a water-based extraction process. Other streams which may be produced as intermediate streams or bitumen-lean streams within the solvent-based process can be directed into the water-based process, regardless of solvent content. A bitumen-containing stream from the solvent-based extraction process may be integrated into a water-based extraction process, so as to derive an even higher quality bitumen product than can be achieved using solvent-based extraction alone. Numerous options for integrating water-based and solvent-based processes are outlined in section **(A)** to section **(G)** below.

[00296] ***(A) Integration of Water-Based Extraction and Solvent-Based Extraction Processes and Systems***

[00297] An aspect described herein relates to the integration of water-based processes for extraction of bitumen with solvent-based processes for extraction of bitumen in order to capture previously unrecognized synergies between the two extraction processes. Advantages of water-based extraction process include: the dominate use of water, which is relatively an inexpensive and environmentally benign liquid; and the production of a fungible bitumen product when paraffinic froth treatment is used to treat the bitumen froth. Advantages of solvent-based extraction process include: good recovery of bitumen from streams containing a large amount of fines; reduced volume of tailings produced compared to water-based extraction tailings; and that solvent extracted bitumen can have a reduced solids and water content compared to bitumen froth, for example, containing 2 wt% or less of entrained solids and 1 wt% or less of entrained water in the final product.

[00298] **Figure 8** is a schematic representation of an embodiment of the process (800) which water-based extraction streams are directed into a solvent-based extraction process. Recovery of bitumen from an oil sands into a bitumen-rich stream is achieved. The bitumen is separated (802) from oil sands by addition of water to form a bitumen-enriched aqueous stream and a first bitumen-lean stream. The first bitumen-lean stream is mixed (804) with additional oil sands to form a mixed stream. Subsequently solvent is added (806) to the mixed stream to extract bitumen from the mixed stream into the solvent, forming a second bitumen-lean stream and an extracted bitumen stream. The extracted bitumen stream is then mixed (808) with the bitumen-enriched aqueous stream to form a bitumen-rich stream.

[00299] **Figure 9** illustrates numerous exemplary feed streams derived from a water-based extraction process, which can be directed to and further extracted within a solvent-based extraction process. Such streams include, but are not limited to, middlings of the primary separation vessel, flotation tails, and froth treatment tailings, such as FSU underflow. In this illustration, an "X" is shown for each process component of a water-based process which could be impacted by either elimination or reduction by forwarding such streams into the solvent-based extraction process.

[00300] **Figure 9** depicts an example of the integration of the water-based extraction process with the solvent-based extraction process, and shows that many of the common unit processes used to handle bitumen-lean streams produced in the water-based extraction process may be eliminated and the bitumen-lean streams can be directed to a solvent-based extraction process in order to extract the bitumen within. The bitumen-lean streams may be combined with additional oil sands, which are minimally altered or unaltered, prior to entry into a solvent-based extraction process. The bitumen-lean streams may be conditioned so that the resulting slurry with the oil sands has a water content that does not impede solvent extraction. According to one embodiment, the ratio of water to solids within a bitumen-lean stream and oil sands slurry is conducive to the formation of agglomerates in a solvent-based extraction process employing solids agglomeration such as the process described in Canadian Patent Application No. 2,724,806. As described below with reference to **Figure 9**, the residual solids and water that are contained in the solvent extracted bitumen stream are removed by mixing the stream with bitumen froth and directing the combined streams to the froth treatment unit of the water-based extraction process.

[00301] **Figure 9** shows, a process (900) which is typical of those processes used for water-based extraction of bitumen from oil sands comprises the initial input of ore (901) from oil sands, or another bitumen-containing product. Primary water-based separation occurs in a primary separation vessel or PSV (902). The primary separation vessel typically produces three streams, a bitumen enriched stream containing some fines (903) that is typically directed as froth (904) to further treatment, a middling stream (906) with a considerable fines content, and an underflow of tailings (908a). Middlings (906) may be directed to secondary floatation (910) from which residual froth (912) can be removed and re-directed to the PSV or directed to froth treatment. An underflow of tailings (908b) from secondary floatation (910) can be directed to a further settling unit (914) from which an underflow of coarse tailings (916) is derived. The remaining fines-containing stream (918) can be directed to subsequent floatation (920), from which residual froth (912) is redirected to the PSV or directed toward downstream froth treatment, while fine tailings (922) or "floatation tails" go on to processes of fines capture

(924), for example using centrifugation or other means such as consolidated tailing (CT) technology.

[00302] In a typical water-based extraction process, froth (904) is directed to froth treatment where the froth separation unit (930) is used to isolate bitumen from the water and solids that carried over to the froth stream. The tailings-containing FSU underflow (932) is directed to a tailings solvent recovery unit (934), in the presence of dilution water (936) where applicable. The solvent-containing FSU overflow (938) can be sent for solvent removal and recovery in the solvent recovery unit (940). A fungible bitumen product (942) may be formed upon solvent removal.

[00303] The described embodiments are not limited by type of solvent-based extraction process. However, a solvent-based extraction process (944) may preferably involve extraction with a solvent together with a solids agglomeration process in order to produce a low solids bitumen product (943) and agglomerated tailings (946), which is relatively low in water (also referred to as "dry tailings").

[00304] The nature of this integrated system is to form a closed loop. The solvent-based extraction process results in a low solids bitumen product (943) that can then be fed back into the water-based process at one or more entry point. For example, the bitumen product (943) of solvent-based extraction may be included with the product of the solvent recovery unit (940) of a water-based extraction process, or can be combined with a bitumen enriched stream (903) for formation of froth (904), at which stage, further cleaning or deasphalting can occur.

[00305] Bitumen-lean streams (for example the middlings stream), derived from a primary separation unit of a water-based extraction process, usually contain a sufficient amount of bitumen that requires additional recovery stages to be conducted in order to recover residual bitumen. However, such secondary and tertiary recovery stages can be expensive, energy intensive, and may result in an increase in water usage in the extraction process. Furthermore, such additional recovery stages recover much less than 90% of the residual bitumen in the tailings streams. By contrast, solvent-based extraction processes may result in bitumen recoveries in excess of 90% even for feeds containing a bitumen content lower than 10 wt%. Thus, as described herein, bitumen-lean streams from a water-based extraction process can be additionally processed in a solvent-based extraction process in order to maximize recovery of residual bitumen.

[00306] Bitumen extracted from a solvent-based extraction process is likely to contain fines and water droplets that need to be removed in order to yield a fungible bitumen product. Paraffinic froth treatment (PFT), as a component of water-based extraction processes, is a proven technology that can yield a fungible bitumen product. Residual bitumen from the bitumen-lean streams that has been extracted in a solvent-based extraction process can thus be redirected back to a water-based extraction process in order to produce a fungible bitumen product. In particular, directing a stream resulting from solvent-based extraction to PFT of the water-based extraction process can result in a high quality bitumen product.

[00307] In general, water-based extraction streams that are lean in bitumen content, and that are likely to be high in fines content, are directed to a solvent based extraction process in order to recover the residual bitumen within. Recovered residual bitumen is made into a fungible bitumen product when mixed with a water-based extraction stream, such as bitumen froth, prior to paraffinic froth treatment or the bitumen product after paraffinic froth treatment.

[00308] Bitumen-lean streams derived from a water-based extraction process may optionally be dewatered in a water separation system before being directed to the solvent based extraction process, for example as described below in section **(B)**.

[00309] Closed loop integration of water-based extraction with solvent-based extraction is accomplished. The product of a solvent-based extraction process is fed into a water-based extraction process to achieve an enhanced result in outcome of the water-based process. The aspects described herein relating to closed loop integration of the solvent-based extraction with water-based extraction permit the combining of solvent-based processes and streams with water-based extraction processes and streams, in order to combine the unique advantages of each extraction process. The utilization of solvent-based extraction processes to recover bitumen within intermediate streams or tailings of a water-based extraction process, and subsequently feeding the bitumen, so recovered, back into a step of a water-based extraction process offers advantages for this closed loop integration scheme such as an overall increase in bitumen recovery and production of a high quality bitumen product. Additional advantages of such an integrated process include reduced utilization or outright elimination of process equipment typical of water based processes, and a commensurate reduction in water use. Other benefits include reduced tailings volumes resulting from water-based extraction, and a more robust water-based extraction system, especially for extraction feed streams produced using a no-reject slurry systems. Furthermore, clarification steps within a solvent-based extraction can be reduced or eliminated in integrated processes, because product cleaning or deasphalting can be affected in the froth treatment process.

[00310] Operations for water-based and solvent-based extractions may be able to integrate streams or other operational aspects when these systems are geographically proximal and/or when a product of one system can be readily utilized by the other system. Integrating such processes can introduce efficiencies, for example increase bitumen recovery, production of a cleaner or otherwise desirable product, and reduction of heat loss by heat integration.

[00311] Processes and systems are described herein which integrate solvent-based extraction procedures with water-based extraction procedures used in extraction of hydrocarbon from mineable deposits.

[00312] Process streams from water-based extraction processes can be directed to appropriate entry points in a solvent-based extraction process. Extraction of bitumen from high fines streams is challenging in water-based extraction processes. By directing such streams to a solvent-based extraction process that promotes agglomeration of fines, the separation of hydrocarbon from high fines streams can be conducted with less water use. For example, high fines streams from a water-based extraction process can be directed into a solvent-based extraction process involving a water separation system (WSS), to ultimately produce a bitumen product and agglomerated tailings. Exemplary streams derived from water-based processes which may be directed in this manner include middlings, flotation tails, and froth treatment tailings, for example the underflow from a froth separation unit, mature fine tailings from tailings ponds, as well as other hydrocarbon-containing streams. Such streams include, but are not limited to streams high in fines which are susceptible to agglomeration.

[00313] The term “middlings” or “middling fraction” as used herein refers to the portion of a mixture derived from a separation vessel, for example the primary separation vessel used in water-based extraction process. The upper phase of the vessel, the overflow, may comprise froth, while the lowermost phase comprises tailings. This mid-level phase of such a separation vessel may be referred to as "middlings". In the case of middlings from a primary separation vessel (PSV), the middlings may be directed to floatation for further processing in a water-based extraction process, and in the integrated process described herein, may alternatively be directed to solvent-based extraction process.

[00314] The term "mature fine tailings" or MFT as used herein refers to the dense mixture of clay, silt and water found in the tailings ponds of water-based extraction facilities. The mixture has a typical solids content of about 30 wt%. Mature fine tailings are formed when tailings from the water-based extraction process is deposited within the tailings ponds. The raw tailings separate and settle into a coarse fraction that forms the beach of the tailings pond, a layer of clarified water, which is recycled back to the extraction process, and below the water layer is the mature fine tailings layer, which remains unconsolidated for decades or more.

[00315] Embodiments of the process which permit the elimination of certain conventionally used components from water-based extraction processes will advantageously permit cost reduction through removal of such components (when an existing operation is retroactively fitted to include the solvent-based extraction processes), or will stream-line new operations which would not initially require certain equipment that would have normally been required in a typical water-based extraction site. As illustrated in **Figure 9**, the elimination of process equipment from the water-based process may involve elimination or reduction in the number of floatation vessels which are used in secondary and tertiary recovery of bitumen after a primary separation process in water-based extraction. The floatation step required in a water-based extraction process can be reduced or eliminated, by directing such streams into the solvent-based extraction process. In addition to improved bitumen recovery, this integration could eliminate the need to capture fines from the floatation tailings, which require energy intensive processing, such as centrifugation, or consolidated tailing (CT) technology to decrease water content. Further, the underflow derived from a froth separation unit (FSU) of water-based extraction froth treatment technology, could be directed into the solvent-based extraction process, thereby reducing or eliminating the need for a tailings solvent recovery unit within the water-based extraction process and/or use of dilution water at this particular stage for treating the FSU underflow.

[00316] Advantageously, the solvent-based extraction components of the overall process may be used to process such high fines streams, and may then produce a bitumen product that can be further cleaned in a manner similar to bitumen froth produced in the water-based extraction process. Advantageously, the level of fines in solvent extracted bitumen would be low, and tailings derived from the product cleaning step would be minimized.

[00317] The bitumen product derived from the solvent-based extraction process can be directed to water-based extraction processes for further processing. For example, the solvent extracted bitumen may be directed to the froth treatment stage of the water-based extraction process to undergo further product cleaning. Before being directed to the froth treatment stage of the water-based extraction process, the solvent extracted bitumen may first be mixed with process water or streams derived from the water-based extraction process such as bitumen froth, middlings, flotation tailings, or mature fine tailings. The resulting mixture yields a froth-like material that can be processed in a froth treatment unit such as paraffinic froth treatment. In this case, the paraffinic froth treatment has the advantage of producing a cleaner pipelineable product from the solvent-based extracted bitumen product, which is optimally fungible, with less than 300 ppm solids. Furthermore, when the solvent extracted bitumen is mixed with low hydrocarbon-containing streams such as middlings, fine tailings, and mature fines tailings to produce a hydrocarbon-rich bitumen froth that is then directed to a froth treatment stage, the froth treatment stage may provide the added advantage of increasing the recovery of bitumen that would have been lost in those low hydrocarbon streams. In yet another advantage of mixing the solvent extracted bitumen with low hydrocarbon-containing streams and then directing the resulting bitumen froth-like material to a paraffinic froth treatment stage, the froth treatment stage may provide the added advantage of producing tailings that are more amendable to dewatering and reclamation than the original low hydrocarbon-containing streams. In an embodiment described herein, a low hydrocarbon-containing stream, such as middlings, fines tailings and mature fine tailings, may first be partially dewatered before mixing with the solvent extracted bitumen product.

[00318] Benefits of certain embodiments of an integrated system which combines water-based extraction processes with solvent-based extraction processes include less water usage, reduced tailings volumes, and more robust extraction systems for both water-based and solvent-based extraction with increased overall bitumen recovery. Furthermore, a product cleaning step may not be necessary within the solvent-based extraction process in those embodiments where product cleaning of the solvent extracted product stream occurs within the froth treatment stage of the water-based extraction process.

[00319] Additional advantages of integrating water-based extraction and solvent-based extraction include the benefit that heat integration can be introduced between components of the two extraction processes. Utilization of waste or heat generated by one step of a process for introducing heat into another step of the process can reduce costs and lower energy intensity of the overall process. For example, particular streams that would normally have required de-watering in the water-based extraction process can be utilized directly in the solvent-based extraction process. By utilizing such streams directly, 100% of their energy is integrated into the solvent-based extraction process.

[00320] ***Reusing Heat in Integrated System.*** River-derived process or cooling water may be directed from a water-based extraction process to capture heat from a solvent-based extraction process. Major sources of heat in a solvent-based extraction process are hot streams from the bitumen product and tailings solvent recovery units. Hot waste streams from water-based extraction may be added to feed streams in the solvent-based extraction process for preconditioning. In particular, the tailings solvent recovery unit (TSRU) tailings from water-based extraction may be added to the oil sand feed for heat, or may be added to the mix box or agglomerator feed in the solvent-based extraction process to provide required moisture content when forming agglomerates.

[00321] The re-utilization of heat, water, and solvent in the integrated system can have the benefit of reducing the overall energy intensity of a bitumen extraction system, compared with conventional systems in which water-based extraction is employed, and also relative to the use of a solvent-based extraction processes alone.

[00322] ***Recovery of Heat Loss from Steam.*** A modeling of the energy intensity for producing bitumen from a water-based system, versus the energy intensity for producing bitumen from an integrated system having both water-based extraction features and solvent-based extraction features would reveal that energy attributable to steam, typically lost in the water-based extraction process can be nearly entirely re-utilized for heat capture in the integrated system. Further, energy losses attributable to steam produced within the SRU and TSRU of the solvent-based extraction process can be reduced if the integrated system directs the steam to the water-based extraction process or upstream of the solvent-based extraction process.

[00323] ***Reducing Solvent Recovery Requirement from Water-Based Extraction Process.*** According to an embodiment of the integrated process, the required heat for the extraction processes may be additionally reduced when the froth separation unit tailings from the water-based extraction process are mixed with the solvent-wetted solids of the solvent-based extraction process. The combined streams can then be processed in the TSRU of the solvent-based extraction process. In this way the tailings solvent recovery requirement of the water-based extraction process could be of reduced importance, or eliminated if the entire FSU tailings stream is combined with solvent-wetted solids.

[00324] ***Optimized System Layout and Component Proximity.*** By setting up the various system components to conduct the processes described herein with advantageous proximity, further efficiencies can be realized. The distance between the distinct processing aspects can be optimized so as to limit heat loss and/or to address economic considerations in those instances where an existing water-based extraction operation is to be retroactively fitted for solvent-based extraction operations.

[00325] ***Building Integrated Systems for Optimal Layout.*** While retroactive fitting of an existing water-based extraction system can be conducted, efficiencies may be optimized in an exemplary system according to an embodiment described herein, by building an integrated system from the beginning. In this way, the location of solvent-based extraction equipment can be determined without deference to the existing location of water-based extraction components. A system is provided herein which encompasses components in which water-based extraction steps are conducted, and components in which solvent-based extraction steps are conducted. This system results in a site that integrates both processes for optimal efficiency, stream proximity, heat re-use, and solvent re-use. In this embodiment for example, a middlings stream derived from a primary separation vessel of a water-based extraction process may be directed directly into the solvent-based extraction process in relative close proximity.

[00326] ***Advantages of Component Proximity and/or Optimal Layout of Extraction processes.*** The extraction of bitumen from low quality ore in a water-based extraction process typically results in poor bitumen recovery and low quality bitumen froth. Low quality ores may be ones in which the bitumen is either low in quantity (less than 10 wt% bitumen), poor in quality, or in which bitumen is entrained in such a manner that renders it difficult to extract. High fines content in resulting process streams may be characteristic of low quality ores. Poor bitumen recovery is defined as the recovery of less than 90% of the ore's bitumen in the bitumen froth and low quality froth is defined as froth with a bitumen content of less than 55 wt%.

[00327] In typical water-based extraction facilities, the method for improving recovery and froth quality of extracted low quality ores involves blending said ores with higher quality ores. The blending of the low quality ores with high quality ores results in an average grade ore that gives consistently higher bitumen recoveries and froths that have approximately 60 wt% bitumen content. However, the blending of varying ores has significant CAPEX and OPEX implications as mining logistics complexity and truck requirements.

[00328] Efficiencies can be realized if the solvent-based extraction process and the water-based extraction process are in close proximity to each other so that the solvent-based extraction process can initially treat low quality ores rather than the water-based extraction process. By providing low quality ores to a solvent-based extraction process first, prior to conducting any water-based extraction steps, the solvent-based extraction serves to extract bitumen therefrom at a higher level of bitumen recovery (greater than 90%) and product quality. Additional advantages include; the volume of water used in extraction is reduced and the formation of fines and coarse tailings is reduced. Thus, a greater proportion of hydrocarbon entrained in such a low quality ore can be extracted in a more efficient manner using an integrated system.

[00329] The bitumen product resulting from the solvent-based extraction process may require further cleaning in order to be pipelineable and/or fungible when held to high standards of purity. Efficiencies can be realized if the solvent-based extraction process and the water-based extraction process are in close proximity to each other so that transportation is inexpensive to direct solvent extracted bitumen product to a nearby paraffinic froth treatment unit of a water-based extraction process for product cleaning of the solvent extracted bitumen to the fungible specifications. Further, if the heat entrained in the product or stream derived from the solvent-based extraction process can be captured and contributed into the water-based extraction process through integration, then less heat input from other sources would be needed in the water-based extraction process.

[00330] An exemplary solvent-based extraction process is described in Canadian Patent Application No. 2,724,806. In this process a solvent is combined with a bituminous feed derived from oil sand to form an initial slurry. The initial slurry can be separated into a fine solids stream and coarse solids stream followed by 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. Solvent is recovered from the bitumen extract to produce a bitumen product.

[00331] When the water-based extraction process and the solvent-based extraction process are combined into an integrated process that accepts a stream from the water-based extraction process into the solvent-based extraction process, there are various optional efficiencies, as indicated in **Figure 9** with "X" showing at different stages, to mean that certain process components become eligible for reduced use or elimination altogether when these two processes are integrated in this way. Secondary floatation (910), subsequent floatation of fines (920) derived from coarse tailings, and processes of fines capture (924) may be reduced or eliminated from the process, if the streams conventionally directed to these processes were to instead be directed to a solvent-based extraction process (944). The middling stream (806) derived from the primary separation vessel (902) could be sent directly to the solvent-based extraction process (904). The settled mixture (918) remaining from the further settling unit (914) could be sent directly into solvent-based extraction, which would have the effect of eliminating the production of fine tailings (922) from the further floatation, and the need for specialized equipment for subsequent processes of fines capture (924).

[00332] By integrating the processes in a manner consistent with **Figure 9**, secondary recovery, occurring in secondary floatation (910), and tertiary recovery, occurring in (920), can be reduced are eliminated in the water-based extraction process since the bitumen-lean streams are directed to a solvent-based extraction process (944). Additional oil sands (945) can be included into the solvent-based extraction process (944) together with the high fines bitumen-lean streams, which can be one of or a combination of the middlings (906), PSV tailings (908a), flotation tailings (908b) (918), fine tailings (922), froth treatment tailings (929) and FSU underflow (932). In combining oil sands with a high fines bitumen lean stream (939), a slurried mixture can be directed into solvent-based extraction. The product of a solvent-based extraction process (944) can ultimately be characterized as solvent extracted agglomerated tailings (946) and a low solids bitumen product (943). In the integrated scheme, the need for TSRU (934) can be reduced or eliminated, as the FSU underflow, which is a high fines bitumen lean stream (939) could be directed to solvent-based extraction (944) instead of to the TSRU. This also negates the requirement to add dilution water (936), which would have been needed for FSU underflow (932) to proceed to TSRU (934).

[00333] Tailings derived from primary separation (908a) in the water-based extraction system, which may have been considered too energy intensive a process to direct to further purification in water-based extraction processes can now be further processed through the solvent-based extraction system in such an integrated process. The solvent-based extraction process can assist in deriving further amounts of bitumen from coarse tailings.

[00334] The low solids bitumen product (943) resulting from the solvent-based extraction (944) process may require further cleaning in order to be pipelineable and/or fungible when held to high standards of purity. For this reason, the low solids bitumen product (923) is directed to the froth treatment unit (948) of the of the water-based extraction process. It is preferable that the froth treatment unit (948) be a paraffinic froth treatment unit capable of producing a fungible bitumen product. The low solids bitumen product (943) is mixed with a bitumen enriched stream (903) to form bitumen froth (904) prior to froth treatment. The mixture then undergoes a paraffinic froth treatment in order to produce a fungible bitumen product (942). Alternatively, in the situation where bitumen product (942) produced by the paraffinic froth treatment process may have a solids and water content that is much less than the fungible limit, the low solids bitumen product (943) from the solvent-based extraction process may bypass the paraffinic froth treatment process and directly mix with the fungible bitumen product (942) and still yield a combined stream that meets the fungible specifications.

[00335] The low solids bitumen product (943) generally contains very low water content. Thus, this product may first be mixed with a water-containing stream before being directed to the froth treatment unit (948) of the water-based extraction process. The addition of water to the process may improve the froth treatment process. The water-containing stream may comprise low hydrocarbon-containing streams, such as a middling stream (906), tailings (908b), a fines-containing stream (918), or fine tailings (922), and mature fine tailings. In these cases, the froth treatment stage may provide the added advantage of increasing the recovery of the bitumen that would have been lost in those low hydrocarbon streams.

[00336] The froth separation unit of a water-based extraction system is generally in communication with a solvent recovery unit (SRU) (940), which receives a bituminous solvent-containing stream, relatively free of fines and water. This SRU serves to remove solvents, resulting in a bitumen product. This type of solvent removal can also be conducted within the solvent-based extraction process. Thus, in an integrated system, the SRU may be a consolidated unit, accepting streams from both the water-based extraction and the solvent-based extraction processes.

[00337] Solvent-based extraction processes (944) which tolerate a bitumen feed having water entrained therein can be extracted according to the described method. This permits a feed containing more water than typical oil sands to be processed with the solvent-based extraction process (944), and even permits enrichment of an aqueous stream with additional oil sands (945).

[00338] ***(B) Recovery of Bitumen from Aqueous Sources***

[00339] Processes will now be described in which bitumen can be recovered from aqueous streams arising from water-based extraction. Such techniques can operate efficiently in the presence of fines, or which are largely unaffected by the presence of fines.

[00340] Streams derived from water-based extraction processes that may be bitumen-lean are not necessarily utilized to full advantage within the water-based extraction process. Integration of a water-based extraction process with a solvent-based extraction process is a way of utilizing aqueous streams that would not necessarily have resulted in bitumen recovery within a water-based process. Such aqueous streams may be referenced herein as bitumen-lean, as waste-streams, aqueous hydrocarbon-containing streams, or simply as aqueous streams.

[00341] Aspects described herein which generally relate to a process and system for recovery of hydrocarbon associated with or entrained within an aqueous stream. Such aqueous streams may be ones having in excess of 50% water. Such streams may be ones produced or rejected from water-based bitumen extraction processes, or may be streams that are directly derived from oil sands which include a high water content, but which were not necessarily intended for a water-based bitumen extraction process. Certain rejected streams from water-based bitumen extraction processes (generally, bitumen-lean streams), as well as intermediate streams produced in the extraction process which may be intended for further bitumen-recovery steps, may be relatively high in water content, and thus can advantageously be processed further through solvent-based extraction once the water content of the high water stream streams is reduced to a level acceptable within the solvent-based extraction process, such as for example reduced below 40% water.

[00342] Recovery of bitumen from relatively high fines aqueous feed streams may involve using a combination of solvent-based extraction and agglomeration of solids. In such a solvent-based extraction and solids agglomeration process the desired amount of water in the feed mixture is between 5 to 50 wt% or more preferably between 5 to 20 wt%. Thus, solvent-based extraction and solid agglomeration processes can employ aqueous feed streams, provided the water content is not so high as to negatively impact the agglomeration aspect. Aqueous feed streams may be used, despite a high fines content, and in this way, such aqueous streams that may have previously been considered difficult to recover because of the fines content, can be effectively utilized. High fines content is a characteristic previously considered problematic in conventional methods for extracting hydrocarbon from aqueous feed streams. For example, bitumen-lean streams arising from water-based methods of hydrocarbon recovery, which may have previously been directed to tailings ponds, can be used in the solvent-based extraction processes described herein, provided the water content is in an appropriate range to permit use of the stream without causing excessive dilution to the solvent-based extraction process thereby impeding efficient agglomeration of fines. Thus, bitumen-lean streams arising from conventional water-based extraction processes, intermediate streams from conventional water-based extraction processes, or any bituminous aqueous stream can be used in the solvent-based extraction process if pre-conditioned to achieve desired characteristics. The process is described herein for utilization of streams that are high in water content, which may require concentration through pre-treatment in order to be effectively used in solvent-based extraction process.

[00343] Hydrocarbon-containing streams bearing levels of water that are not in excess of a level that would be of detriment to a solvent-based extraction process (such as streams containing less than about 40 wt% water), can be fed directly into the solvent-based extraction processes as described herein, without the need for concentration through a water removal pre-treatment process. Such streams that already contain water at a lower, acceptable level for solvent-based extraction are encompassed in the processes described herein.

[00344] One embodiment provides a process for pre-treating an aqueous hydrocarbon-containing feed for downstream solvent-based extraction processing for bitumen recovery, the aqueous hydrocarbon-containing feed comprising from 50 wt% to 95 wt% water, from 0.1 wt% to 10 wt% bitumen, and from 5 wt% to 50 wt% solids, wherein the solids comprise fines, the process comprising: removing water from the aqueous hydrocarbon-containing feed to produce an effluent comprising 40 wt% water or less; and providing the effluent to a downstream solvent-based extraction and solids agglomeration process to recover bitumen. The step of removing water from the aqueous hydrocarbon-containing feed may comprise: flowing the aqueous hydrocarbon-containing feed into a primary water separation system to remove water from the aqueous hydrocarbon-containing feed, producing a reduced-water stream of from 30 wt% to 60 wt% solids, and recycled water; and removing water from the reduced-water stream using a secondary water separation system to produce an effluent comprising 40 wt% water or less. The primary water separation system may comprise a clarifier, a settler, a thickener or a cyclone. Flocculant may be added to the aqueous hydrocarbon-containing feed in the clarifier. A solvent or flocculant may be mixed with the aqueous hydrocarbon-containing feed prior to water separation in the clarifier. The solvent may be mixed with the aqueous hydrocarbon-containing feed with a solvent:bitumen ratio of less than about 2:1. A low boiling point cycloalkane solvent may be mixed with the aqueous hydrocarbon-containing feed. The secondary water separation system may comprise a centrifuge with filtering capacity, a shale shaker, a vacuum belt filter, or one or more clarifiers.

[00345] In an optional embodiment, the values may be thathe aqueous hydrocarbon-containing feed comprises from 60 wt% to 95 wt% water, from 0.1 wt% to 10 wt% bitumen, and from 5 wt% to 40 wt% solids,

[00346] The aqueous hydrocarbon-containing feed may comprise middlings from a primary separation vessel. The aqueous hydrocarbon-containing feed may comprise effluent of a froth separation unit. The aqueous hydrocarbon-containing feed may comprise tailings from a tailings solvent recovery unit.

[00347] There are many sources of aqueous hydrocarbon-containing feed streams in excess of 50 wt% water which can be subjected to processing as described herein, so that hydrocarbon may be extracted. Such streams that are referred to as aqueous hydrocarbon-containing feed streams may interchangeably be referenced herein as "high water content streams". The variety of aqueous hydrocarbon-containing feed streams which could be used as feed streams in the processes described herein contains over 50 wt% water. Thus, possible streams for processing according to the processes described herein include streams derived either as intermediates, as bitumen-lean streams, or as an end-products of water-based extraction processes. For example, streams that may not normally have been considered for further bitumen-recovery processing within in a conventional water-based extraction process can now be subjected to processing, and recovery of hydrocarbon. While such streams need not be designated as waste streams *per se*, they may be bitumen-lean streams, and/or intermediate streams which would have normally proceeded to further processing within an water-based extraction process. Aqueous streams need not be derived from a water-based extraction process, but may contain water for other reasons, such as steam exposure, water-heating, slurry transport, or due to mixing of water with oil sands that have not yet been subjected to any extraction process, but which have been rendered aqueous for alternative reasons.

[00348] The integration of the solvent-based extraction and agglomeration process described herein with a conventional water-based extraction process,is problematic that, except for oversized rejects, other potential feed streams have a very large proportion of water. This large proportion of water is higher than the optimum needed for effective fines agglomeration in the process. An advantage of the utilization of high water content streams, as described herein is that pre-conditioning of such streams can reduce water content to permit such streams to be used as feed streams in solvent-based extraction process, thereby addressing this challenge. Another advantage is that the aqueous hydrocarbon-containing stream with reduced water content will have enough water to provide the needed bridging liquid for the agglomeration process. The treatment process for bitumen-lean streams according to embodiments described herein permits aqueous streams with high fines content to be used as feed streams for the solvent-based extraction and solids agglomeration process, so as to permit successful recovery of bitumen that would have otherwise been lost.

[00349] Typical aqueous hydrocarbon-containing feed streams for use in the de-watering process include, but are not limited to middlings derived from a primary separation vessel (PSV), froth treatment tailings, floatation tails which may not yet have been directed to a tailings pond, and/or mature fine tailings (MFT), which may have already been present in a tailings pond. Appropriate aqueous hydrocarbon-containing feed streams may be ones containing bitumen and/or other hydrocarbon components, which may or may not include bitumen.

[00350] Bitumen-lean feed streams arising from conventional water-based extraction processing techniques are particularly attractive for pre-conditioning as described herein, to reduce water content prior to use as a feed in an solvent-based extraction process. The pre-conditioning process described herein may have previously been considered as an effective way to recover waste water; however, it has not been viewed as an optimal way to recover bitumen that would have otherwise been lost. By pre-treating a bitumen-lean stream in this way, in preparation for subsequent recovery in a solvent-based extraction process, both a reduction in waste, recovery of waste water, and an increase in recovery of bitumen from bitumen-lean aqueous streams can be realized.

[00351] Advantageously, the middlings from a primary separation vessel used in a conventional water-based extraction process may be processed less efficiently on the assumption that further hydrocarbon components can be recovered in downstream solvent-based extraction processes. This results in an energy saving at this step, as not all bitumen need be removed in a water-based bitumen extraction process.

[00352] A mixer may be used as the aqueous hydrocarbon-containing stream enters a primary water separation system or vessel. One or more points of entry of the hydrocarbon-containing feed stream may be used on the way to a primary water separation vessel, so as to allow turbulence to occur. As an exemplary embodiment, multiple injection points of an aqueous hydrocarbon-containing feed are used on the way to the primary water separation vessel.

[00353] Flocculants or other additives, such as coagulants or pH modifiers may be added to the aqueous hydrocarbon-containing feed streams. Typically, a pH of 8.5 is achieved, and a drop in pH may be achieved. Thus, pH may be modified from a level above pH 7 to a level below pH 7. A reduction in pH may reduce surface activities of the clays, which may result in precipitation of fines. A solvent may be added to the aqueous hydrocarbon-containing feed streams, for example a solvent may be used which may be lighter or heavier than water. When solvent is present, deriving recycled water may be accomplished in an appropriate way so that the recycled water may be recovered separately from the solvent. Further, small quantities of solvent may adhere to solids and thus sink to the bottom in a dewatering unit, permitting concentration of solids in the underflow.

[00354] In the primary water separation step for water removal, a clarifier, a settler, thickener, or a cyclone may be used in single or multiple units which may be in communication in serial, or employed in parallel. Thus, the dewatering unit may comprise one or more of such units. The resulting effluent may contain from 30 wt% to 60 wt% solids. The hydrocarbon content of the effluent arising from this stage of the process is enriched, relative to the initial aqueous feed. A doubling of the hydrocarbon content, or a further enriched content, may be achieved. However, the effluent from this stage is still pumpable so as to permit transport and movement through to further aspects of the process. The content of solids may in fact be above a level of 60 wt%, and water content could be lower that 40%, provided the effluent from the underflow derived from the primary water separation is still pumpable or made to be pumpable by the addition of extraction liquor from the solvent-based extraction process.

[00355] When present, a secondary water separation system of the dewatering unit may be employed. Similar types of apparatuses may be employed in such secondary separation, or a filter, filter centrifuge, centrifuge, vacuum filter, or vibration filter may be employed. The system may employ a single dewatering unit, or the dewatering unit may comprise individual components, such as primary water separation system and a secondary water separation system. Each of the primary and secondary water separation systems may have multiple individual components operating in parallel or in serial.

[00356] A feed stream comprising bitumen, water and solids with or without residual solvent is pre-conditioned according to the process described herein. The feed stream may be derived from a mixture of oils and, oversized rejects stream, and high water content streams or blends thereof. An exemplary high water content stream may be one derived from a middling stream of a primary separation vessel, or from secondary flotation tails and/or froth treatment tailings from a water-based extraction process. Such feed streams or blends thereof are processed via a single or dual staged water separation system (WSS) in order to be adequately pre-conditioned for use as a feed stream in solvent-based extraction and agglomeration processes.

[00357] **Figure 10** is a schematic representation of the process (1000) in which an aqueous hydrocarbon-containing feed stream is conditioned according to the process described herein. The initial aqueous hydrocarbon-containing feed (1030) is one derived from a water-based extraction process, for example, it may be a bitumen-lean stream derived from a conventional water-based extraction process. Advantageously, the feed may have high fines content, as such fines can be subsequently removed. The feed (1030) contains 50% to 95% water on a weight basis, and also contains from 0.1 wt% to 10 wt% bitumen, and from 5 wt% to 40 wt% solids. The step of water removal (1032) is conducted in any manner that would be acceptable so as to achieve an effluent (1034) having about 40% water, or less, by weight. This effluent goes on to downstream solvent-based extraction (1035), for example using a process that involves solids agglomeration.

[00358] **Figure 11** represents processes (1100) for pre-treating an aqueous hydrocarbon-containing stream or feed (1102) with water content of from 50 wt% to 95 wt% water, with from 0.1 wt% to 10 wt% bitumen, and with 5 wt% to 40 wt% solids.

[00359] The aqueous hydrocarbon-containing stream or feed (1102) is passed into a primary water separation system or PWSS (1104). In the PWSS, a portion of the water contained in the feed (1102) is recovered as recycled water (1106). The remaining portion is a reduced-water stream (1108) is then fed into a secondary water separation system or SWSS (1110) to produce an effluent (1112) having the consistency of a pumpable slurry or made to have a consistency of a pumpable slurry by downstream processing. The effluent (1112) contains predominantly fine solids and hydrocarbon, and has a water content of up to 40 wt%. More recycled water (1106) is recovered from the secondary water separation system (1110). The effluent (1112) of the secondary water separation system, having the consistency of a pumpable slurry or made to have the consistency of pumpable slurry, may be combined with oversized rejects (1114) and/or recycled extraction liquor from a solvent-based extraction process (1116) in proportions which permit the water content of the resulting slurry (1118) to remain within the desired level for solids agglomeration in later downstream processing. The recycled extract liquor may be added to the effluent (1112) of the secondary water separation system to ensure that the effluent has the consistency of a pumpable slurry.

[00360] The primary water separation system (1104) may preferably be a clarifier unit or cyclone which takes advantage of inherent or induced high settling characteristics of the high water content feeds. The primary water separation system my optionally be a thickener unit or more preferably a paste thickener. In contrast to conventional water-based extraction processes in which additives are employed to disperse fines in water and prevent slime coating of bitumen, flocculants or coagulants may optionally be used to induce the aggregation of fines and hydrocarbons within the water-based extraction process or within the clarifier. Large quantities of recycled water, which is low in total suspended solids, may thus be recovered. Advantageously, by recovering water at this stage, efficiencies are introduced, due to the reduced volume forwarded for downstream processing in a solvent-based extraction process.

[00361] The secondary water separation unit (1110) may be a filtering device that can provide one or a combination of pressure, centrifugal or vibrational forces for phase separation. A slurry of coarse solids may be added to the secondary water separation system to promote efficient dewatering. In exemplary embodiments, the secondary water separation system (1110) may comprise a centrifuge with filtering capacity, shale shaker, or a vacuum belt filter. It may be possible in certain embodiments that the dewatering achieved in the secondary water separation system is enough to allow for direct feed of the effluent (1112), without addition of oversize rejects or oil sands, into a solvent-based extraction process.

[00362] As shown in **Figure 11**, optionally, solvent (1120) may be added to the feed (1102) entering the primary water separation system (1104) so as to dissolve bitumen and decrease the feed density sufficiently for selective phase separation under gravity or for application of a centrifugal force field. If solvent is added, an exemplary solvent:bitumen ratio is less than 2:1.

[00363] As a further option, a flocculant (1122) with selective reactivity for the fines may be added to aggregate clays contained in the feed (1102) thus promoting faster settling or drainage. The flocculant may be added prior to entry of the feed (1102) into the primary water separation system (1104), via a mixer (1121) or may be added directly into the primary water separation system. The resulting reduced-water stream (1108) resulting from the primary water separation system (1104) is passed through the secondary water separation system (1110) and the effluent (1112) may be subsequently combined with the oversize rejects (1114) to produce a slurry (1118) ready for processing via the solvent-based extraction process.

[00364] The resulting slurry (1118) may be combined with any other appropriate feed source as a bituminous feed (1130) for later downstream processing in a process (1132) capable of separating fines out of a high fines content aqueous bituminous feed, such as one capable of agglomerating tailings (1134) while forming a hydrocarbon product (1136).

[00365] **Figure 12** is a schematic illustration of a process (1200) incorporating the preparation of a aqueous hydrocarbon-containing stream according to **Figure 10** and **Figure 11** together with an exemplary solvent-based extraction and solids agglomeration process for recovery of bitumen. An aqueous hydrocarbon-containing feed is derived (1230) from water-based extraction of oil sands and has at least 50% water. The feed may have, for example, from 50 wt% to 95 wt% water, from 0.1 wt% to 10 wt% bitumen, and from 5 wt% to 40 wt% solids. This feed is potentially derived from bitumen-lean streams recovered from water-based extraction processes, but may also be derived from intermediate streams from a water-based extraction process. Further, an aqueous hydrocarbon-containing stream meeting these criteria that has not been prepared through a water-based extraction process may nevertheless be used as a feed stream.

[00366] Water is removed (1232) from the aqueous hydrocarbon-containing feed having 50 wt% to 95 wt% water, resulting in an effluent comprising 40 wt% water or less, which goes on to be used (1234) as bituminous feed either alone or in combination with further hydrocarbon-containing sources. Other hydrocarbon-containing sources may include oversized rejects, recycled extraction liquor, or other sources of bitumen. The resulting mixture should have the consistency of a pumpable slurry. After extraction liquor is added (1212) to form the pumpable slurry, the slurry may be directed to further processing. Fine solids and coarse solids are separated (1214) from the slurry as a fine solids stream and a coarse solids stream from the initial slurry. Fine solids are agglomerated (1216) from the fine solids stream to form an agglomerated slurry comprising agglomerates and low solids bitumen extract. A low solids bitumen extract is separated (1218) from the aggregated slurry. In the depicted embodiment, a second solvent is added (1220) to the low solids bitumen extract to recover a bitumen extract that may be essentially free of solids. In this way, a hydrocarbon product is derived from an aqueous hydrocarbon-containing stream.

[00367] ***(C) Extracting Hydrocarbons from PFT Tailings by Directing Tailings into a Solvent-Based Extraction Process***

[00368] Approximately 10% of the bitumen extracted in a conventional water-based extraction process is lost in the tailings of paraffinic froth treatment (PFT). Although a majority of these hydrocarbons are asphaltenes, they still have sufficient amount of value to justify recovery, which would result in an increase the overall volume of bitumen produced. The aspect of the process described herein relates to the use of solvent-based extraction to recover the hydrocarbons in paraffinic froth treatment tailings. It is desirable to further increase recovery of hydrocarbons from paraffinic froth treatment tailings by directing such tailings into a solvent-based extraction and solids agglomeration process. Advantageously, when the solvent-based extraction process used involving fines agglomeration, the extraction of residual hydrocarbons from the tailings and the formation of agglomerates from solids in the tailings can occur simultaneously during the agglomeration step. In this way, the agglomerated solids may be readily separated from the bitumen extract.

[00369] A conventional water-based extraction process may include flotation separation steps that result in the formation of a bitumen froth. The bitumen within the bitumen froth includes about 5 to 15 wt% asphaltenes. To remove solids and water from the bitumen froth, solvent deasphalting is conducted within a froth treatment unit. In the froth treatment unit, the bitumen froth is mixed with a deasphalting solvent and is subjected to one or more settling stages. The solvent can be, for example, a paraffinic hydrocarbon solvent having a chain length from about 5 to about 8 carbons. An exemplary solvent combination may be a mixture of pentane and hexane. The precipitated asphaltenes flocculate with the solids and water droplets resulting in large flocs that rapidly settle out of the hydrocarbon solution as the froth settling unit (FSU) underflow. The residual solvent within the FSU underflow is typically recovered and recycled, to avoid release to the environment. Separation of the solvent can occur, for example, in a tailings solvent recovery unit (TSRU). Conventionally, the solvent is recycled and the tailings that exit the TSRU are disposed of as a waste product.

[00370] In an exemplary process, the PFT tailings may comprise froth separation unit underflow. Additionally, the PFT tailings may comprise tailings from a tailings solvent recovery unit (TSRU). Advantageously, when froth separating unit (FSU) underflow is employed as the PFT tailings that are directed to a solvent-based extraction and solids agglomeration process, this allows exclusion of the TSRU component from a conventional froth treatment processes. The residual PFT tailings solvent recovery would occur in the solvent recovery units of the solvent-based extraction process described herein. Thus, in a conventional process that would typically treat underflow from a FSU using TSRU, the use of the FSU underflow in the solvent-based extraction process negates the requirement for recovery of solvent in a TSRU of the froth treatment unit.

[00371] In embodiments described herein, paraffinic froth treatment tailings are contacted with additional oil sands and a solvent (or solvent mixture), or extraction liquor, capable of dissolving asphaltenes to form a slurry. The slurry is mixed to dissolve the hydrocarbons and to agglomerate fines within the slurry. The extracted hydrocarbon solution can then be separated from the majority of the solids and water, including the solids and water originally present in the paraffinic froth treatment tailings.

[00372] In an exemplary embodiment, the paraffinic froth treatment tailings stream is dewatered to a water content of less than about 40 wt%. The dewatered tailings stream is mixed with additional oil sands and a solvent to form a slurry. The fines within the slurry are agitated to agglomerate with each other, and then most of the solids are separated from the extracted hydrocarbon solution. The agglomerating stage of the process advantageously permits a majority of the fines present in the froth treatment tailings to agglomerate with the fines from the additional oil sands, so that the agglomerates can be easily separated from the extracted hydrocarbon solution. The recovered hydrocarbon solution, which is low in solids content, can then proceed through the later stages of a solvent-based extraction process, ultimately forming a bitumen product, of which a portion would have otherwise been lost as a waste product of the water-based extraction process.

[00373] **Figure 13** is a schematic representation of an exemplary process (1300) in which paraffinic froth treatment tailings are directed to a solvent-based extraction process to recover bitumen. The process permits recovery of hydrocarbon from said tailings. A froth treatment tailings stream from a paraffinic froth treatment process is accessed (1302). The froth treatment tailings stream is combined (1304) with a solvent and additional oil sands to form a slurry. The solvent may comprise a combination of different solvents, and may be an extraction liquor which contains bitumen entrained within the solvent. The slurry is agitated (1306) to dissolve hydrocarbons into the solvent and agglomerate the fines. The extracted hydrocarbons are separated from the solids (1308) to form a low solids extracted hydrocarbon stream and an extracted tailings stream. The solvent is then recovered (1310) from the extracted tailings stream.

[00374] **Figure 14** is a schematic representation of an embodiment of the process (1400) depicted in **Figure 13**, in which hydrocarbons from paraffinic froth treatment tailings are extracted in a solvent-based extraction and solids agglomeration process. The process involves providing bitumen froth (1402) to a paraffinic froth treatment (PFT) process (1404) within which separation occurs, and PFT tailings (1406) are produced. PFT tailings (1406) are then directed into a solvent-based extraction process (1408) that employs fines agglomeration. In another embodiment of this process, underflow (1426) from a froth settling unit (FSU) (1428) bypasses the tailings solvent recovery unit (TSRU) of the PFT plant (1404) and serves in lieu of the PFT tailings as input into the solvent-based extraction process (1408), as illustrated by the dashed line representing underflow (1426) being directed into slurry preparation unit (1412).

[00375] The PFT tailings (1406) and/or FSU underflow (1426) are combined with oil sands (1410) and an extraction liquor (1411) in a slurry preparation unit (1412) to form a slurry. The fines within the slurry are agglomerated within the agglomerator (1413) to allow for easy solid-liquid separation within the belt filter (1414). Solvent (1422 and 1416) from the solvent recovery units (1424 and 1417) can be used in a countercurrent washing of the solids on a belt filter (1414). Solvent is recovered from the solvent-wet solids in a tailings solvent recovery unit (1419) to form dry tails (1420). Solvent is recovered from the bitumen extract in a solvent recovery unit (1417) to form a low solids bitumen product (1418). The process described herein permits integration PFT tailings (1406) of a water-based extraction process into a solvent-based extraction process (1408), to recover further amounts of bitumen therefrom, which would have otherwise been difficult or inefficient to recover.

[00376] ***(D) Directing Bitumen-Rich Stream into a Solvent-Based Extraction Process***

[00377] An embodiment described below relates to a process directing a bitumen-rich stream into a solvent-based extraction process. The bitumen-rich stream may be derived from a conventional water-based extraction process, and thus its utilization may capture synergies between the water-based and solvent-based extraction processes.

[00378] This embodiment addresses the issue of the source of "recycle bitumen" (RB) needed to form "bitumen product" (BP). Typically, a ratio of RB:BP employed in solvent-based extraction processes can be as high as 3:1. Recycling such a large amount of bitumen entrained in the solvent has several advantages. Importantly, the recycle bitumen (RB) reduces the required inventory of solvent needed for bitumen extraction from the oil sands. In a solvent-based extraction process, the extraction liquor that is mixed with the oil sand may contain as much as 50 wt% bitumen, the remainder being attributable to solvent. Herein the term extraction liquor refers to the solution of bitumen with the solvent prior to extraction. Further, when a non-aromatic or partially aromatic solvent is used, such as naphtha, cycloalkanes, paraffinic solvents or crude distillates, the presence of dissolved bitumen within the extraction liquor advantageously increases the ability of the extraction liquor to dissolve additional bitumen into the liquor. Another advantage of having dissolved bitumen in the extraction liquor is that the presence of bitumen reduces the liquor's vapor pressure, which can allow for higher operating temperatures for the solvent-based extraction process.

[00379] Although the recycling of bitumen has its advantages, it does mean that the extraction and solid-liquid separation equipment employed in the solvent-based extraction process must be sized to process a majority of bitumen that is not produced. This is costly because the process equipments used in solvent extraction of oil sands have certain sealing and safety requirements to ensure that solvent remains contained. These requirements are significantly more expensive to meet than are the requirements of water-based extraction equipments. Thus, it is desirable to reduce the amount of recycle bitumen while maintaining the advantages provided by having dissolved bitumen in the extraction liquor.

[00380] The embodiment described herein additionally addresses the issue of directing large solid streams to a solvent-based extraction process. Solids that are directed to a solvent-based extraction process necessarily come into contact with solvents that absorb into the pores of the solids and coat the surface of the solids. In order for these solids to be introduced back into the environment, almost all the solvent must be removed from them. Unfortunately, a tremendous amount of energy is usually required to evaporate the solvent from the solids in typical tailings solvent recovery units of a solvent-based extraction process. This energy requirement has been one of the major factors preventing the wide application of solvent-based extraction technology to the oil sands industry. Thus, it is also desirable to reduce the amount of solids processed within a solvent-based extraction process per unit of bitumen produced.

[00381] An embodiment described herein discloses the use of a water-based extraction process to extract from oil sands a bitumen-rich stream comprising a bitumen to solids ratio that is greater than that of the oil sands. Specifically the bitumen-rich stream has a bitumen to solids ratio of greater than 0.2:1. The water extracted bitumen-rich stream is mixed with a solvent to produce the extraction liquor that is then used to solvent extract bitumen from additional oil sands.

[00382] Further, there is described herein an embodiment in which a water-based extraction process is used to extract from oil sands a bitumen-rich stream comprising a majority bitumen with water and solids making up the minority components of the stream. The water extracted bitumen-rich stream is mixed with a solvent to produce the extraction liquor that is then used to solvent extract bitumen from additional oil sands. The bitumen-rich stream may be a bitumen forth stream from a water-based extraction process.

[00383] Utilization of a bitumen-rich stream from water-based extraction process, as a source of bitumen for the extraction liquor of a solvent-based extraction process has advantages over the conventional option of further processing said bitumen-rich stream in the water-based extraction process. For example, a reduction in water use and/or required water quality within the water-based extraction process may be realized since the bitumen-rich stream will be further processed in a solvent-based extraction process. Another advantage include that the bitumen yield of a solvent-based extraction process can be three-fold higher, or even greater, than conventional solvent-based extraction processes where bitumen in the extraction liquor is bitumen that is recycled within the process. While the cost of the solvent-based extraction facilities is high, this increased yield may more than offset the added cost associated with operating and integrating water-based and solvent-based extraction facilities.

[00384] In the application of certain described embodiments, an amount of the solids within the oil sands are separated from the bitumen-rich stream prior to the bitumen-rich stream mixing with the solvent. Advantageously, these separated solids will not add to the load on the tailings solvent recovery unit of the solvent-based extraction process. Furthermore, in the cases where the oil sands processed in the water-based extraction process are high or medium grade oil sands, or more preferably only high grade oil sands, the separated solids are mostly coarse sands grains that may be easily dewatered and prepared for reclamation.

[00385] In the exemplary solvent-based extraction and solids agglomeration processes described above, a bridging liquid (i.e. water) is added to the extraction process in order to agglomerate fines for improved solid-liquid separation. Water may be added, for example, in the form of steam to heat the initial slurry or as a component of an input stream. The bitumen-rich stream, derived from water-based extraction, may have a water content from 40 to 20 wt%, and thus can serve as the water source needed for solids agglomeration in the solvent-based extraction process.

[00386] The majority of the water and solids within the bitumen-rich stream can bind with the solids of the solvent extracted oil sands. Thus, the solvent-based extraction process can effectively displace or reduce the function of the froth treatment unit used in a conventional water-based extraction process. The produced bitumen from the solvent-based extraction process, which comprises bitumen from the bitumen-rich stream as well as bitumen derived directly from solvent extraction of oil sands, may have a BS&W of approximately 2 to 3 wt%, ore more preferably between 0.1 to 2wt%. This bitumen quality is similar to the quality of bitumen produced from the naphthenic froth treatment process of a conventional water-based extraction process.

[00387] Advantageously, this embodiment combines product cleaning of bitumen froth with additional bitumen extraction from oil sands. The produced bitumen ultimately formed as a result of the solvent extraction steps, as is, may be sent to an upgrader. An additional product cleaning step may be utilized to advantageously remove residual solids and water in order for the produced bitumen to meet the fungible specification. Gas flotation or membrane filtration may be used as suitable product cleaning methods.

[00388] **Figure 15** shows a flow chart of the steps involved in the embodiment in which a bitumen-rich stream of a water-based extraction process is directed to solvent-based extraction. The process (1500) permits recovery of bitumen from oil sands. The process comprises: extracting (1502) bitumen from oil sands in a water-based extraction process to form a bitumen–rich stream and a bitumen-lean streams. The bitumen-rich stream is defined as a stream with a bitumen to solids ratio that is greater than that of the oil sands. Instead of further processing the bitumen-rich stream within a water-based extraction process, such as a naphthenic froth treatment unit, the bitumen-rich stream is directed to a solvent-based extraction process. The bitumen-rich stream is mixed (1504) with a solvent to form an extraction liquor. The solvent may be derived from a recycled source of solvent, and may be interchangeably referred to as an extraction liquor. The bitumen-rich stream may optionally mix with a solvent with recycled bitumen entrained therein. The extraction liquor is then mixed (1506) with additional oil sands to form a slurry comprising solids and bitumen extract. The solids are then separated (1508) from the slurry to form a low solids bitumen extract. Solvent is then recovered (1510) from the bitumen extract to form a solvent extracted bitumen product.

[00389] **Figure 16** illustrates a process (1600) in which extraction liquor (1602) used in a solvent-base extraction process (1604) is produced by mixing solvent (1614) with a bitumen-enhanced stream (1606), which may specifically be froth, derived from a water-based extraction process (1608). High grade (low fines) oil sands (1610) may preferentially be directed to the water-based extraction process (1608) in order to reduce the required intensity of the this process when compared with the intensity of the process if a lower grade oil sands are used. Low grade oil sands (1612) and/or medium grade oil sands can be directed to the solvent-based extraction process (1604) to maximize bitumen recovery. The bitumen-enhanced stream (1606) from the water-based extraction process (1608) is mixed with the solvent (1614) in an extraction liquor mixing vessel (1616) to form an extraction liquor (1602). The solvent (1614) may have recycle bitumen dissolved therein.

[00390] The extraction liquor (1602) derived from the mixing vessel (1616) is mixed with oil sands (1612) in the solvent-based extraction process to extract bitumen from the low grade oil sands (1612). The solvent (1614) is eventually recovered from the bitumen extract and solvent wet solids formed in the solvent-based extraction process (1604), yielding a bitumen product (1618) and solid dry tailings (1620). Some of the recovered solvent is then redirected back to the extraction liquor mixing vessel (1616), while the bitumen product can be directed to further processing, rendering a fungible product, and/or can be utilized as is. Solid dry tailings (1620) resulting from the solvent-based extraction process will generally have a low bitumen, low solvent, and low water content, and are suited for storage, for example as backfill to a spent mine. In this way, the volume of water wet tailings (1622) formed as a result of water-based extraction, can be reduced when the bitumen-enhanced stream (1606) is ultimately processed by the solvent-based extraction process (1604).

[00391] ***(E) Water-Assisted Deasphalting Technologies for Streams Derived from Solvent-Based Extraction***

[00392] As described below, a process of deasphalting is described through which residual fine solids and residual water droplets can be removed from a bitumen stream derived from a solvent-based extraction process, utilizing a water-assisted deasphalting technology.

[00393] A goal in the extraction of bitumen from a mining operation such as oil sands mining is ultimately to produce a fungible bitumen product that can be pipelined and sold to refineries located considerable distances from the mining operation. An exemplary fungible bitumen product is a product that has been partially deasphalted and has a solids content of 300 ppm or less on a bitumen basis. Paraffinic froth treatment (PFT) of the water-based extraction process is the only technology in current use that produces a fungible bitumen product from water extracted bitumen.

[00394] A bitumen product meeting the fungible requirement of less than 300 ppm solids may be refined in a downstream process, such as hydroprocessing, without danger of dramatically fouling the downstream equipment. In some of the previously known solvent-based extraction processes, such as those discussed above within the background section, the resulting bitumen product may typically have a solids content of approximately 0.1 to 2 wt% on a bitumen basis. The water content of such a bitumen product is usually less than 1 wt%. Although the solids and water content of a product of a solvent-based extraction process is much less than that of bitumen froth produced in a conventional water-based extraction process, the residual fine solids and water content may still render the solvent extracted bitumen product unsuitable for marketing. Removing residual fine solids and water droplets from solvent extracted bitumen to achieve a fungible product is difficult using conventional solids separation methods such as gravity settling, centrifugation or filtering. A water-assisted deasphalting process, similar to what is used to produce a fungible bitumen product from water-based extraction froth, is described herein for the final product cleaning of solvent extracted bitumen.

[00395] The water-assisted deasphalting step can be integrated with the solvent-based extraction process in the following manner. The bitumen extraction occurs in an extraction stage using a solvent that dissolves the bitumen from the oil sands, forming a solvent-based extraction slurry. The slurry is then directed to a solids separation stage where most of the solids are removed from the diluted bitumen. In an exemplary embodiment, the resulting low solid content diluted bitumen is then sent to a solvent recovery unit where the extraction solvent is separated from the bitumen. The resulting low solids bitumen, with some or all solvent removed, is then directed to the product cleaning unit, where it is mixed in a controlled fashion with a water-containing stream and optionally with a solvent. Examples of water-containing streams, which are not limiting but provided here by way of example, include process water and water-based extraction streams such as bitumen froth, middlings, flotation tails, froth treatment tails, and mature fine tailings. The water-containing stream is added in an amount no greater than that which keeps the hydrocarbon phase as the dominant phase by volume of the mixture. However, the water-containing stream is also added in a sufficient amount such that when the mixture is partially deasphalted and introduced into a gravity settling vessel, relatively large asphaltene flocs comprised of water, solids, and precipitated asphaltenes form. Large asphaltene flocs are generally defined as flocs that are significantly greater in size than the asphaltene flocs that would form in the absence of added water. Specifically, the large asphaltene flocs have a hydraulic diameter in the range of 1000 to 10 μm, or more preferably in the range of 500 to100 μm.

[00396] In the water-assisted deasphalting process, the bitumen and water-containing stream mixture is well mixed so that a water-in-bitumen emulsion is formed, containing water droplets of about 100 microns or less in size. A mixture with these properties is similar to froth formed in a conventional water-based extraction process, and thus may be partially deasphalted in a system similar to or the same as existing paraffinic froth treatment (PFT) units. Thus, the known advantages of PFT units over conventional deasphalting units may be applied to the product cleaning of solvent extracted bitumen.

[00397] The process described herein may have an advantage over previously proposed deasphalting technologies for solvent extracted bitumen products. Formation of a water-in-bitumen emulsion can facilitate the removal of asphaltenes from bitumen. One possible explanation for this advantage is the heteroflocculation of water droplets, fine solids and asphaltenes into larger and denser flocs. In the process described herein, added water and optionally added water-wet fine solids are made to flocculate with the residual solids and residual water remaining in solvent extracted bitumen and the precipitated asphaltenes to form flocs that are larger and denser than those formed in the absence of added water. For this reason, the flocs formed according to the process described herein will settle at a much faster rate and result in much faster throughputs for the deasphalting unit compared to in traditional deasphalting processes.

[00398] In an exemplary embodiment of the process, a water-containing stream is added in a sufficient amount such that when the mixture is partially deasphalted and introduced into a gravity settling vessel, the dominant fluid within the settling phase is water. The presence of water as the dominant fluid limits the entrainment of bitumen (specifically maltenes) and solvent within the underflow of the settler. Thus, this embodiment allows for higher bitumen yield. Also, the reduced amount of solvent in the underflow may allow for a tailings solvent recovery unit that consists of flash drums rather than the energy intensive fractionation towers used in traditional deasphalting units.

[00399] In traditional deasphalting processes, the tailings solvent recovery unit must be heated above the minimum asphalt pumping temperature to ensure that the asphaltenes will be pumpable after the solvent is removed. This high temperature requirement reduces the thermal efficiency of the deasphalting unit. The addition of a water-containing stream to the solvent extracted bitumen, as described herein, eliminates the need to melt the asphaltenes. The presence of water ensures that the precipitated asphaltenes and other solids remain fluidized both within the bottom of the settling vessel and within the tailings solvent recovery unit (TSRU) at moderate temperatures.

[00400] Appropriate sources of water and water-wet fines for use in the process described herein include water-based extraction streams such as mature fines tailings, middlings and flotation tails. Mixing one or more of these streams with the bitumen product from the solvent-based extraction, may allow for the recovery of some of the bitumen entrained within these water-based extraction streams. Thus, increase bitumen recovery from low hydrocarbon-containing streams of water-based extraction may be realized in the application of the water-assisted deasphalting process described herein.

[00401] The solvent extracted bitumen product mixed with water and optionally water-wet fines, bears similarity to deaerated bitumen froth formed in a conventional water-based extraction process. For this reason, conventional paraffinic froth treatment methodologies can be readily adapted with minor modification, to serve as the basis of the water-assisted deasphalting technology for the mixture of the solvent extracted bitumen product and the water-containing stream.

[00402] Processes are described herein for product cleaning of bitumen from a solvent-based extraction process to produce a fungible bitumen product. The bitumen may have a combined solids and water content of about 2 to 5 wt. %, while the cleaned bitumen product may be a fungible product with less than 300 ppm solids. To achieve pipeline specifications, a product can be produced having 0.5 wt. % or less of bottom sediment and water. The product cleaning may be accomplished using the water-assisted deasphalting process described herein.

[00403] Embodiments of the water-assisted deasphalting process described herein result in a solvent extracted bitumen stream with a reduced solids and water content. The resulting bitumen product may be a fungible product appropriate for transportation and refining. For example, a fungible product may be one with a fines content of less than 300 ppm on a bitumen basis. Should the pipeline and downstream refining requirements be adjusted to require a solids content of less than 300 ppm, the water-assisted deasphalting process has been shown to produce bitumen product of much less than 300 ppm solids content on a bitumen basis. For example, product quality of 50 ppm or less is achievable.

[00404] Embodiments of the process may differ from previously described deasphalting processes for product cleaning of bitumen in that water, and optionally water-wet fines, may be mixed with a solvent extracted bitumen stream prior to asphaltene precipitation. Mixing occurs, so that a water-in-bitumen emulsion is formed which contains water droplets, on average of less than 100 microns in size. The addition of water to the solvent extracted bitumen stream may result in advantages in the deasphalting process, compared to traditional deasphalting processes used in the absence of a significant amount of water, such as those used in refineries to process heavy crude oils to upgrade heavy bottoms streams to deasphalted oil. Potential advantages include increased thermal efficiency, increased settling rates leading to higher throughputs, and a higher product yield. Processes and systems which can be integrated with solvent-based extraction processes are described herein.

[00405] The solvent-based extraction process, with which the water-assisted deasphalting processes and systems described herein may be integrated, produces a low solids bitumen product. The solvent-based extraction process may be, but is not limited to, solvent-based extraction processes described below or a part thereof, or may be a known solvent-based extraction process, such as processes described herein as background, or a part thereof. For example, the solvent-based extraction process which produces a low solids bitumen product may be, but is not limited to, the one described in Canadian Patent Application No. 2,724,806,

[00406] In a solvent extraction and solids agglomeration process such as described herein, the resulting diluted bitumen stream may have a solid content of approximately 0.1 to 2 wt% on a bitumen basis. The water content of the diluted bitumen may be much less than 1 wt%. Although the solids and water content of the solvent extracted bitumen stream are much less than that of bitumen froth produced in a typical water-based extraction process, the residual fine solids and water content still render the solvent extracted bitumen stream unsuitable for marketing. Removing residual fine solids and water from the solvent extracted bitumen is difficult using conventional solid separation methods such as gravity settling, centrifugation or filtering. For this reason, a water-assisted deasphalting process, similar to what is used to produce a fungible bitumen product from bitumen produced in a water-based extraction process, is employed in the processes described herein, for the final product cleaning of solvent extracted bitumen.

[00407] The water-assisted deasphalting process described herein is generally integrated with the solvent-based extraction and solids agglomeration process in the following manner. Solvent extraction of bitumen occurs in an extraction stage using a solvent that dissolves the bitumen from the oil sands to form an oil sand slurry. Some asphaltene precipitation may be allowed to occur in the extraction step if it is deemed beneficial to product cleaning and/or solids agglomeration. A bridging liquid, such as water, is added to the slurry to agglomerate the solids. The agglomerated slurry is sent to a solids separation stage where most of the solids are removed from the diluted bitumen. In an embodiment described herein, the low solids content diluted bitumen stream is then sent to a solvent recovery unit where the extraction solvent is separated from the bitumen to form a low solids bitumen product.

[00408] The resulting low solids bitumen, which is no longer diluted by solvent, is then directed to the product cleaning unit, where it is mixed in a controlled fashion with a water-containing stream and optionally with a solvent. Examples of water-containing streams include, but are not limited to, process water and water-based extraction streams such as bitumen froth, middlings, flotation tails, froth treatment tails and mature fine tailings. The water-containing stream is added in an amount no greater than that which keeps the hydrocarbon phase as the dominant phase by volume of the mixture. However, the water-containing stream is also added in a sufficient amount such that when the mixture is partially deasphalted and introduced into a gravity settling vessel, relatively large asphaltene flocs comprised of water, solids and precipitated asphaltenes form. Large asphaltenes flocs are generally defined as flocs that are significantly greater in size than the asphaltene flocs that would form in the absence of added water. Specifically the large asphaltene flocs have a hydraulic diameter in the range of 1000 to 10 μm, or more preferably in the range of 500 to 100 μm . Furthermore, the bitumen and water-containing stream mixture is well mixed so that the formed water-in-bitumen emulsion contains water droplets of less than 100 microns in size. A mixture with these properties is similar to water-based extraction froth, and thus the mixture may be partially deasphalted in a system similar to existing paraffinic froth treatment (PFT) units. Thus, the known advantages of PFT units over conventional deasphalting units may be applied to the product cleaning of solvent extracted bitumen.

[00409] The integration of a deasphalting process with a solvent-based extraction and agglomeration process may have potential advantages over existing product cleaning processes for solvent extracted bitumen. For instance, the fungible product may be produced regardless of the wetting behaviour of the residual solids. A single solvent or a solvent mixture of two or more solvents (for examples, aromatic and paraffinic solvents) may be used for a combined bitumen extraction in the agglomerator and water-assisted deasphalting in the product cleaning unit. Such a system would require only one solvent recovery unit. Additionally, the tailings solvent recovery unit for the product cleaning unit may be integrated with that of an existing solvent-based extraction process.

[00410] Advantageously, a water-in-bitumen emulsion, as described herein, may facilitate the partial or full deasphalting of a bitumen stream. See Fuel Processing Technology Vol 89 (2008) 933-940 and Fuel Processing Technology, Vol 89 (2009) 941-948. These articles suggest that a water-in-bitumen emulsion may facilitate the removal of asphaltene from bitumen. Although the mechanism by which emulsified water-in-bitumen facilitates the removal of asphaltenes from bitumen is not fully understood, one possible explanation, given in the above articles, is the heteroflocculation of water droplets, fine solids and asphaltenes into larger and denser flocs. As described herein, added water and optionally added water-wet fine solids are made to flocculate with the residual solids and residual water remaining in solvent extracted bitumen and the precipitated asphaltene to form flocs that are larger and denser than those formed when added water is absent. For this reason, the flocs formed according to the process described herein may settle at a faster rate and result in faster throughputs for the water-assisted deasphalting unit than traditional deasphalting units.

[00411] As described herein, a water-containing stream is said to be added at a sufficient amount such that when the mixture is partially deasphalted and introduced into a gravity separation vessel, the dominant fluid within the settling phase is water. The presence of water as the dominant fluid limits the entrainment of bitumen (specifically maltenes) and solvent within the underflow of the settler. This advantageously allows for higher bitumen production. Also, a reduced amount of solvent in the underflow may allow for a tailings solvent recovery unit that consists of flash drums rather than the energy intensive fractionation towers used in traditional deasphalting units.

[00412] In traditional deasphalting technology, the tailings solvent recovery unit must be heated above the minimum asphalt pumping temperature to ensure that the asphaltenes will be pumpable after the solvent is removed. This high temperature requirement reduces the thermal efficiency of the deasphalting unit. The addition of water to the solvent extracted bitumen as described herein eliminates the need to melt the asphaltenes. The presence of water ensures that the precipitated asphaltenes, and other solids, remain fluidized both within the bottom of the separation vessels and within the tailings solvent recovery unit (TSRU) at moderate temperatures.

[00413] Good sources of water and water-wet fines as described herein include water-based extraction streams such as mature fines tailings, middlings and flotation tails. Mixing one or more of these streams with the bitumen product from the solvent-based extraction may allow for the recovery of some of the bitumen within these water-based extraction streams. Thus, embodiments described herein may permit increased bitumen recovery when integrated with water-based extraction streams that contain bitumen.

[00414] The solvent extracted bitumen product mixture with water, and optionally water-wet fines, may be similar to the deaerated bitumen froth of the water-based extraction process. For this reason, a conventional paraffinic froth treatment technology can be adapted for use in streams derived from solvent-based extraction processes with minor modifications, and thus can possibly be used as the deasphalting unit for the mixtures within embodiments described. Advantageously, in one embodiment, a solvent extracted bitumen product is mixed in a ratio of 1:3, or less, with a deaerated bitumen froth from a water-based extraction process. In this way, the solvent extracted bitumen product can undergo product cleaning in existing paraffinic froth treatment units of a water-based extraction facilities.

[00415] **Figure 17** provides an overview of an exemplary process (1700) for product cleaning a bitumen stream derived from a solvent-based extraction process. The process permits removal of solids from oil sands. An oil sands slurry is formed (1702) by mixing the oil sands with a first solvent, where the amount of solvent added is greater than 10 wt% of the oil sands. Subsequently a majority of the solids are separated (1704) from the oil sands slurry, forming a solids-rich stream and a bitumen-rich stream, wherein the bitumen-rich stream comprises residual solids and residual water. The bitumen-rich stream is emulsified (1706) with a water-containing stream to form a hydrocarbon-external emulsion, wherein hydrocarbons form an external phase of the emulsion. The hydrocarbon-external emulsion is mixed (1708) with a second solvent in sufficient quantity to cause some asphaltene precipitation, wherein precipitated asphaltenes flocculate with at least a portion of the residual solids and water droplets. Subsequently the asphaltene flocs, comprised of water, solids and precipitated asphaltenes, are separated (1710) from the hydrocarbon-external emulsion, thereby forming a cleaned hydrocarbon stream comprising fungible bitumen and solvent, and tailings comprising water, solids, and precipitated asphaltenes.

[00416] **Figure 18** provides a schematic representation of the integration of solvent-based extraction with a water-assisted deasphalting process (1850) for the production of a fungible bitumen product. An optional stage of solvent recovery (1807) is used to remove some or all of the solvent from the bitumen extract. The resulting stream of low solids bitumen (1808) is mixed with a water containing stream (1812) in an emulsification unit (1811). Examples of water-containing streams include, but are not limited to, process water, bitumen froth, mature fine tailings, middlings, flotation tails and froth treatment tailings. In general, the requirement of the water-containing stream is that it is added to the bitumen stream in a sufficient amount that when the formed emulsion is deasphalted, water is the dominant fluid within the settling phase, where the settling phase is additionally comprised of precipitated asphaltenes and solids. The water-containing stream may optionally have water-wet fines within.

[00417] In the depicted process (1850), an oil sands feed (1800) is extracted in an extraction stage (1802), in the presence of an extraction solvent (1801). A diluted bitumen slurry (1803) is formed. For a solvent-based extraction and solid agglomeration process, such as described herein, the extraction stage may include a mixbox and an agglomerator. The mixbox is used to from a slurry comprised of the oil sands feed (1800) and extraction solvent (1801). Bridging liquid may be added to the slurry within the agglomerator to agglomerate the fine solids. The diluted bitumen slurry (1803) is forwarded to a solid liquid separation stage (1804), whereupon solvent wet solids (1806) are removed in and sent to a tailings solvent recovery unit (1809), from which dry tailings (1810) are produced. Diluted bitumen (1805) derived from the solid liquid separation stage (1804) is sent on to solvent recovery (1807), from which a stream of low solids bitumen (1808) is derived. A countercurrent washing is often included in the solid-liquid separation stage to minimize the amount of bitumen extract remaining with the solids. For example, solid-liquid separation may involve a combination of a gravity settler and belt filter with countercurrent washing. A second solvent of lower boiling point and/or lower solids adsorption energy than the extraction solvent (1801) may be used as the washing solvent in order to improve solvent recovery in the tailing solvent recovery unit (1809).

[00418] In the solvent-based extraction and solids agglomeration process described herein, the stream of low solids bitumen (1808) may be of sufficient quality that it may be directed to an on-site upgrader. However, if a fungible bitumen product is desired; the low solids bitumen (1808) must be directed to a special product cleaning unit; that is a water-assisted deasphalting unit (1816). As illustrated in **Figure 18**, the stream of low solids bitumen (1808) is forwarded to a water-assisted deasphalting unit (1816) comprising an emulsification unit (1811) and a deasphalting unit (1813). Within the water-assisted deasphalting unit (1816), the emulsification unit (1811) receives the stream of low solids bitumen (1808) arising from the solvent-based extraction process, and combines the stream with a water containing stream (1812). Within the emulsification unit (1811), a water-in-bitumen emulsion (1822) is formed, and forwarded to the deasphalting unit (1813). A deasphalting solvent (1814) is added to the emulsion (1822) within the deasphalting unit, and froth separation occurs to ultimately produce a fungible bitumen product (1815).

[00419] Similar to the paraffinic froth treatment unit of a water-based extraction process, the deasphalting unit (1813) utilized in this process may comprise two settling units. The first settling unit (FSU 1) is used to separate the clean diluted bitumen from the water phase containing precipitated asphaltenes and solids. The second settling unit (FSU 2) is used to wash the underflow of FSU 1 in order to recover the maltenes entrained in the FSU 1 underflow.

[00420] In embodiments of the process described below with respect to **Figures 19** and **Figure 20**, processes are depicted in which a solvent-based extraction facility is integrated with water-based extraction facility in order to take advantage of synergies gained from the integration of the processes. One advantage of integrating solvent-based extraction with water-based extraction is that paraffinic froth treatment, which is traditionally used to produce a fungible bitumen product from bitumen froth, may also be used to remove the residual contaminants within solvent extracted bitumen. Paraffinic froth treatment can be utilized with product streams derived from both solvent-based extraction and water-based extraction in order to remove residual solids and water from these streams.

[00421] In an embodiment of the process described herein, paraffinic froth treatment of a water-based extraction process is integrated with a solvent-based extraction process. Bitumen extraction occurs in an extraction stage of the solvent-based extraction process using a solvent that readily dissolves the bitumen from oil sands, thereby forming a slurry. The oil sands slurry is sent to a solids separation stage where most of the solids are removed from the oil sands slurry to form a low solids bitumen extract. A residual amount of solids and water remain with the low solids bitumen extract. Further residual solids and water need to be removed from the bitumen extract because they hinder downstream processing of the bitumen. The bitumen extract is then sent to a solvent recovery unit where the extraction solvent is separated from the bitumen. The solvent-free bitumen with residual solids and residual water (low solids bitumen) is then directed to the paraffinic froth treatment unit of a water-based extraction process in order to remove residual solids and water from the low solids bitumen.

[00422] In another embodiment of the process described herein, a low solids bitumen product derived from a solvent-based extraction process, which has a solids and water content higher than desired in a fungible product, may be combined with a cleaner stream derived from paraffinic froth treatment of a water-based extraction process to achieve, on balance, a fungible product. A fungible bitumen product contains bitumen together with a solids content of less than 300 ppm on a bitumen basis. Removing residual fine solids from the solvent extracted bitumen is difficult using conventional solid separation methods such as gravity settling, centrifugation or filtering, and thus, allowing some residual solids and water to remain in a solvent extracted product, while mixing with a fungible bitumen product, which has a solids content much less than 300 ppm, permits formation of a combined product that still meets the required specifications.

[00423] **Figure 19** provides an overview of a process (1900) in which paraffinic froth treatment of a water-based extraction process is used to remove residual solids and residual water within a bitumen product stream derived from solvent-based extraction. The process (1900) permits removal of solids from oil sands comprising bitumen and solids. Oil sands are mixed (1902) with a first solvent to form an oil sands slurry, wherein the amount of solvent added is greater than 10 wt% of the oil sands. A majority of the solids are separated (1904) from the oil sands slurry to form a solids-rich stream and an initial bitumen-rich stream, where the initial bitumen-rich stream comprises residual solids and residual water. The solvent is removed (1906) from the initial bitumen-rich stream to form a solvent depleted bitumen-rich stream. Optionally, additional oil sands are mixed (1908) with water, wherein the amount of water added is greater than 50 wt% of the oil sands, to form bitumen froth, wherein the bitumen froth comprises bitumen, solids and water. The optionally formed bitumen froth is directed (1910) to a paraffinic froth treatment process of a water-based extraction process. Further, at least a portion of the solvent-depleted bitumen-rich stream is directed (1910) to the paraffinic froth treatment process of a water-based extraction process. A fungible bitumen product is thus derived (1912) from the paraffinic froth treatment process.

[00424] **Figure 20** shows a typical paraffinic froth treatment unit (2000) having at least two settling vessels or settling regions. The first froth settling unit FSU 1 (2004) is used to precipitate a fraction of the asphaltenes found in the bitumen froth (2008). Precipitated asphaltenes form large flocs with the residual solids and water that rapidly settle out by gravity separation or enhanced gravity separation. In FSU 1 (2004) it desirable to minimize the amount of asphaltenes precipitated to the minimum amount needed to flocculate all the solids and water.

[00425] Low solids bitumen may feed into the paraffinic froth treatment unit of **Figure 20** at various potential stages upstream of the paraffinic froth treatment unit FSU 1 (2004).

[00426] A low solids bitumen stream derived from a solvent-based extraction process can be mixed with the other feeds going to FSU 1 (2004). Although not depicted, the low solids bitumen may mix with a feed going to an intermediate settling vessel. It is not desired to mix low solids bitumen with the feed entering the last settling vessel of a paraffinic froth treatment unit, depicted here as the second froth settling unit FSU 2 (2006), because this settling vessel is typically used to limit loss of bitumen to the tailings, and specifically the loss of the maltene components of bitumen to the tailings.

[00427] Bitumen froth (2008) is provided to a mixer (2010), optionally with the low solids bitumen (2002b) derived from the solvent-based extraction process. A mixed solution including overflow (2012) from the second froth settling unit (2006) can also be added. The composition so mixed is directed to FSU 1 (2004), from which underflow is mixed with solvent from the solvent recovery unit (2014), and then the mixture is directed to FSU 2 (2006). The underflow of the FSU 2 (2006) can be directed to a tailings solvent recovery unit (2016), from which a tailings stream (2018) comprising asphaltenes, solids and water is derived. The overflow (2005) from FSU 1 is directed to a solvent recovery unit (2014) to ultimately produce a fungible bitumen product (2024). The bitumen product (2026) derived from SRU (2014) may optionally be combined with additional low solids bitumen (2002a) from a solvent-based extraction process not shown, in order that the combined streams becomes a fungible product (2024), as it meets the threshold of fungible specifications. The resulting fungible product (2024) can be transported via pipeline and utilized in downstream refining processes.

[00428] In an optional embodiment, **Figure 20** represents a process in which the bitumen product (2026) arising from solvent recovery unit (2014) produced by paraffinic froth treatment may have a solids content that is much less than the fungible limit. In that case, the low solids bitumen (2002a) from the solvent-based extraction process may bypass the paraffinic froth treatment process and directly mix with the bitumen product (2026) arising from SRU (2014) and still yield a combined stream (2024) that meets fungible specifications.

[00429] ***(F) Directing Solvent Extracted Bitumen Product to Water-based Extraction***

[00430] The embodiment described herein involves directing the product of a solvent-based extraction process into a water-based extraction process at one or more stages prior to froth treatment, resulting in increased bitumen recovery and a higher quality bitumen froth.

[00431] Often a poor froth quality and low recovery rates (≤ 90 %) of bitumen from extraction of low grade oil sands ore are problems encountered when using conventional water-based extraction processes. Recovery of bitumen from oil sands via a water-based extraction processes may drop below the desired recover rate of 90% or greater when the oil sands feed quality (ore grade) contains relatively low amounts of bitumen (≤ 10 wt%) and relatively high amounts of solid fines. Additionally, the quality of the recovered bitumen froth from the water-based extraction of low grade ore is also poor. Good bitumen froth has a bitumen content of approximately 60 wt%. However, the extraction of low grade ore typically yields a froth with bitumen content less than 50 wt%. The mining and extraction of oil sands is an energy intensive and expensive process. For these reasons, maximizing the recovery of mined bitumen is determinative of an operation's rate of return.

[00432] In water-based extraction processes for low grade oil sands, the majority of un-recovered bitumen remains in the middlings. Due to the reduced amount of bitumen, the small bitumen droplets in the middlings fail to collide at a sufficient frequency to coalesce into larger droplets that can readily attach to the air bubbles needed for recovery. The aeration of the bitumen droplets is also hindered by fine particles or "fines" coating the surface of the small bitumen droplets. Fines may act as barriers preventing both coalescing of bitumen droplets and air bubble attachment.

[00433] Improved bitumen recovery and froth quality from low grade oil sand can be realized in a conventional water-based extraction process by blending of different grades of oil sands in order to create a more consistent feed to the front end stage of the water-based extraction process, such as in the oil sands crushing stage. Blending of varying grade of oil sand ores allows for high grade oil sands (≥ 10 wt% bitumen) to be blended with low grade oil sands (≤10 wt% bitumen) in order to produce an average grade ore that gives more consistent bitumen recoveries of ≥ 90 % and froths that have of approximately 60 wt% bitumen content. However, the blending of varying ores has significant capital expenditure (CAPEX) and operational expenditure (OPEX) implications as mining logistics complexity increases and trucking requirements increase.

[00434] According to the process described herein, the bitumen product generated in a solvent-based extraction process, which is a low-solids bitumen product, is blended with a bitumen feed and directed to a stage within a water-based process of bitumen recovery, which is preferably upstream of the froth treatment process. Examples of such feed streams with which the solvent-based extraction product stream can be mixed include the oil sands slurry in the slurry preparation plant and hydrotransport pipeline. The low-solids bitumen product from solvent-based extraction may also be mixed with middlings streams undergoing the secondary and/or tertiary bitumen recovery stages within a water-based extraction process. The increased levels of bitumen in the process will improve the recovery of the original bitumen that was in the water-based extraction stream. The increased level of bitumen within the combined stream will also improve the quality of the recovered bitumen stream formed at the end of the water-based extraction process.

[00435] While the mechanism behind the improved bitumen extraction is not limited by any one particular physical explanation, it is nevertheless possible that the added bitumen coalesces with the small bitumen droplets during stages of the water-based extraction process to form larger bitumen droplets that are readily recoverable, for example by attaching to air bubbles more readily. Large bitumen droplets are more likely to attach to small bitumen droplets even in presence of fine particles which may coat the bitumen droplets. Furthermore, the added bitumen may also increase the level of bitumen derived surfactants in the slurry, assisting in the overall recovery process.

[00436] **Figure 21** depicts a flow chart of a process (2100) in which a stream from solvent-based extraction is added to an input stream of a water-based extraction process. According to this process, a first oil sands ore is contacted (2102) with a solvent to form a solvent-based slurry comprising solids together with a bitumen extract. The solids are separated (2104) from the solvent-based slurry to produce a low solids bitumen extract. Subsequently, solvent is removed (2106) from the low solids bitumen extract to form a solvent extracted bitumen product. In a step that need not be conducted sequentially, but which may be conducted in parallel, a second oil sands ore is contacted (2108) with water to form an aqueous slurry. Exemplary aqueous slurries may be from a water-based extraction processes such as slurry preparation unit effluent, primary separation feed, and secondary and tertiary recovery unit feeds. Subsequently, the solvent extracted bitumen formed as a result of the solvent-based extraction process is mixed (2110) with the aqueous slurry to form a bitumen enriched slurry. Bitumen may then be recovered (2112) from the bitumen enriched slurry in the extraction stages of a water-based extraction process.

[00437] **Figure 22** shows a schematic of a process (2200) in which solvent extracted bitumen is used to improve bitumen recovery in a water-based extraction process. In the depicted process, various locations within a generic water-based extraction facility are depicted where the solvent extracted bitumen may be added. Regarding the ore preparation stage (2208), hydrotransport pipeline stage (2212), and separation stage (2214), solvent extracted bitumen (2202a, 2202b, 2202c) may be added at any one or more of these stages. In general, solvent extracted bitumen (2202a, 2202b, 2202c) from a solvent-based extraction process is added to a water-based extraction process at some stage prior to the froth treatment stage (2204). An added advantage of the described embodiment is that the added solvent extracted bitumen will ultimately be processed in the froth treatment stage (2204) of a froth treatment unit in the water-based extraction facilities. Thus, in the case of paraffinic froth treatment, the residual solids and residual water that are within the solvent extracted bitumen will be removed in this final bitumen product cleaning stage of the water-based extraction process to produce a fungible bitumen product.

[00438] In the depicted process (2200), oil sand (2206) is prepared for extraction in an ore preparation stage (2208). It may be at this stage, when water (2210) is added, that solvent extracted bitumen (2202a) may be added, forming a stream containing water, crushed ore, and solvent extracted bitumen. It is preferable the solvent extracted bitumen is added after the oil sand (2206) and water (2210) slurry is prepared; that is, the effluent of slurry preparation stage. It is optional to add the solvent extracted bitumen at this stage, as downstream optional additions may alternatively be utilized. From the "slurry preparation" or ore preparation stage (2208), solvent extracted bitumen may be directed to any acceptable location upstream of the separation stage (2214), such as within a hydrotransport pipeline (2212) as depicted here. During transport along the hydrotransport pipeline (2212), solvent extracted bitumen (2202b) may optionally be added to the aqueous slurry comprising oil sands. The solvent extracted bitumen (2202b) may be added at any point along the hydrotransport pipeline. However, it is advantageous to add the solvent extracted bitumen further upstream of the pipeline so as to provide the mixing energy needed to properly disperse the solvent extracted bitumen into the aqueous slurry.

[00439] The separation stage (2214) typically comprises of a primary separation step and a secondary separation and optionally a tertiary separation steps. In the primary separation vessel, the upper phase may comprise froth, while the lowermost phase comprises of tailings. The mid-level phase of such a vessel is comprised of middlings. The middlings and tailings may be directed to secondary and tertiary separation steps to recover additional bitumen froth. The low bitumen content of the middlings and tails makes additional bitumen recovery in the secondary and/or tertiary separation steps difficult. The solvent extracted bitumen (2202c) may be added to the secondary and tertiary separation vessels so as to increase the bitumen content within these vessels. The added bitumen may coalesce with the small bitumen droplets from the middlings and tailings during the separation stages of the water-based extraction process to form larger bitumen droplets that are more readily separated from the slurry. For example, large bitumen droplets are more likely to attach to small bitumen droplets even in presence of fine particles which may coat the bitumen droplets. Furthermore, the added bitumen may also increase the level of bitumen derived surfactants in the slurry, assisting in the overall recovery process.

[00440] The bitumen (2218) produced within the separation stage (2214) may be in the form of bitumen froth, comprised of both water extracted bitumen and the added bitumen from the solvent-based extraction process. The bitumen froth is then directed to a froth treatment stage (2204), while tailings (2216) of the separation stage (2214) are processed separately. The froth treatment stage is preferably a paraffinic froth treatment unit, which would yield a fungible bitumen product (2222) and froth treatment tailings (2220). Thus, the described embodiment has the added advantage that the solvent extracted bitumen, which is not a fungible bitumen product, may ultimately be processed in a paraffinic froth treatment unit of a water-based extraction process to produce a fungible bitumen product suitable from for pipeline transport and downstream refining.

[00441] ***(G) Directing Solvent Extracted Tailings to Water-Based Extraction Process***

[00442] A further embodiment described herein involves directing tailings of a solvent-based extraction process to a water-based extraction process. Advantages of a process which combines solvent extraction with fines agglomeration (particle enlargement) include improve solid-liquid separation and improve solvent removal from solid tailings. Further, production of nominally dry tailings from this solvent-based extraction process will result in improvements to tailings management versus currently practiced water-based extraction processes. Additionally, the agglomeration of the fine particles within the dry tailings allows for most of the solids within the dry tailings to behave as coarse particles, which may have certain advantages.

[00443] Dewatering of fine tailings derived from conventional water-based extraction processes may involve the use of expensive flocculants and the capital intensive paste thickener technology. In the non-segregating tailings technology, the dewatered fine tailings can be mixed with dewatered coarse tailings to form a pumpable slurry. The pumpable slurry is usually made non-segregating by the addition of coagulants to the slurry and/or lowering the pH of the slurry. This technology, in various embodiments, has been proposed for use in new oil sands mining facilities, such as, Canadian Natural's Horizon Oil Sands Project. However, dewatering of the non-segregating tailings takes a significant amount of time, and depending on applied shear on the slurry, it can readily lose its non-segregating properties. Furthermore, holding areas, or dedicated disposal areas (DDAs), are needed for the non-segregating tailings since they are not free-standing. These holding areas are expensive to maintain. The above described challenges and others suggest that there is a need to develop alternative strategies to meeting tailings management requirements.

[00444] In an integrated scheme, the dry tailings from the solvent-based extraction process may be combined with tailings or partially dewatered tailings (or mature fine tailings) from the water-based extraction process in order to yield a combined higher volume of tailings that are easier to reclaim. For example, the agglomerated fines produced in the solvent-based extraction process may be treated using heat or chemicals so as to reduce the possibility of the agglomerates disintegrating in the presence of water. These agglomerated and treated fines can be directed to the water-based extraction process where they may serve similar functions as the wet coarse tailings produced within the water-based extraction process. For example, the agglomerated fines can be used in dyke construction, mine refill, soil enhancement and for direct reclamation purposes. In a preferred embodiment, the agglomerated fines may serve the same function of the water extracted coarse tailings in the formation of non-segregating tailings.. The increase volume of coarse-like tailings, provided by the agglomerated dry tailings from the solvent-based extraction process, may yield several advantages. The dry tailings reduces the water content of the non-segregating tailings, which translates to a tailings that is more quickly reclaimable. The dry tailings may also result in the non-segregating tailings having a higher hydraulic conductivity at a given solids content, which will result in faster dewatering and reclamation.

[00445] In an embodiment described herein, dry tailings produced from a solvent-based extraction process are mixed with wet tailings produced from a water-based extraction process to produce a strengthened tailings mixture. The strengthened tailings are expected to have improved properties compared to tailings mixtures produced only with water extracted tailings. The dry tailings produced from the solvent-based extraction process preferably contain fines that have been agglomerated during the solvent-based extraction process. It is also preferred that the dry tailings produced from solvent-based extraction be heat treated and/or chemically treated in order to impart additional strength and/or water-resistance to the tailings. The agglomerated and treated dry tailings are expected to behave as material with a particle size distribution similar to that of coarse particle tailings even in the presence of water.

[00446] **Figure 23** is a flow diagram illustrating steps involved in a process that integrates dry tailings from solvent-based extraction into a water-based extraction process. According to the process (2300), ore is contacted (2302) with a first solvent to form a first slurry comprising solids and a bitumen extract. The bitumen extract is then separated (2304) from the first slurry to form solvent wet tailings comprised of the solids and the first solvent. The first solvent is then removed (2306) from the solvent wet tailings to form dry tailings. The dry tailings are then combined (2308) with water wet tailings produced from a water-based extraction process to form strengthened tailings.

[00447] **Figure 24** is an illustration of a process (2400) by which a solvent-based extraction plant (2402) may be integrated with a water-based extraction and fines thickening plant (2404) in order to produce strengthened tailings (2406) of superior quality when compared with thickened fine tailings (2407) derived from the thickener (2426) and/or non-segregating tailings (2408) derived from the combination of coarse tailings (2432) and thickened fine tailings (2407), produced as a result of the water-based extraction process in the water-based extraction and fines thickening plant (2404). Dry agglomerates (2410) from the solvent-based extraction plant (2402), also referred to as agglomerated tailings, are mixed with non-segregating tailings (2408) from the water-based extraction and fines thickening plant (2404). A portion of dry agglomerates (2410) may be sent to mine refill (2411), and a portion of dry agglomerates (2410) may be mixed with non-segregating tailings (2408). The resulting mixture of strengthened tailings (2406) has a higher solids content and greater strength than the non-segregating tailings (2408). Additionally, the strengthened tailings (2406) may have improved dewatering properties when compared with the non-segregating tailings if the dry agglomerates (2410) are heat treated and/or chemically treated (process not shown) to remain intact even in an increased water environment.

[00448] In one embodiment, agglomerates formed in the agglomerator (2438) of the solvent-based extraction plant (2402) may be chemically treated by including within the bridging liquid (2439) water-soluble adhesives and/or emulsion type adhesives. In another embodiment, agglomerates formed in the aggomerator (2438) may be chemically treated by including within the bridging liquid (2439) dissolved salts. In yet another embodiment, the agglomerates may be chemically treated downstream of the agglomeration process, such as within a solid-liquid separation stage and/or within the tailings solvent recovery stage of a solvent-based extraction process. In another embodiment, the agglomerates may, in addition to chemical treatment or in lieu of chemical treatment, be heat treated by heating the agglomerates to temperatures greater than 500 °C so as to sinter or partially sinter the agglomerates.

[00449] Beneficially, low grade oil sands ore, with a high fines content, depicted in **Figure 24** as high fines ore (2412), can be preferentially directed to solvent-based extraction in a solvent-based extraction plant (2402) while medium to high grade oil sands ore, with medium to low fines content, depicted as low fines ore (2414), can be preferentially directed to the water-based extraction in the water-based extraction and fines thickening plant (2404). The processing of ore in this selective fashion, as shown in **Figure 24**, would reduce the volume of thickened fine tailings produced by the water-based extraction process. The fine particles, which are preferentially directed to the solvent-based extraction process, may be agglomerated and treated in order to impart coarse particle-like properties to these solids. A portion of the coarse tailings produced as a result of the water-based extraction process, as described below, can be used for dike construction as currently done in existing conventional water-based extraction operations. A portion of the dry tailings produced as result of the solvent-based extraction process can be used in dyke construction, mine refill, and/or for direct reclamation.

[00450] In the depicted embodiment, a high fines ore (2412) from oil sands is processed within the solvent-based extraction plant (2402), while a low fines ore (2414) from oil sands is processed in a water-based extraction and fines thickening plant (2404), so that fines can be directed primarily to agglomeration steps. Within the water-based extraction process, the low fines ore (2414) is directed in a conventional manner to a mix-box (2416) in preparation for hydrotransport (2418) toward a primary separation vessel (2420), from which bitumen froth (2422) is produced and forwarded to further processing. Middlings derived from the primary separation vessel are processed within flotation cells (2424), and fine tailing derived therefrom are forwarded to a thickener (2426), resulting in removal of recycle water (2428). The underflow (2430) from the primary separation vessel (2420) is dewatered within hydrocyclones (2431) to produce the underflows, referred to as coarse tailings (2432) and overflows that are directed to the flotation cells (2424). Thickened fine tailings (2407), derived from de-watering of the fine tailings within the thickener (2426), is mixed with a portion of the coarse tails derived in this embodiment from the hydrocyclones (2431) to produce non-segregating tailings (2408). The non-segregating tailings (2408) are combined with a portion of the dry agglomerates (2410) from the solvent-based extraction plant (2402) to produce strengthened tailings (2406). A fraction of coarse tailings (2432) derived from hydrocyclones (2431) may additionally be used within the mine site for construction material and/or reclamation purposes; for example, dike construction. Likewise, a fraction of dry agglomerates (2411) may additionally be used within the mine site for mine refill, as depicted in **Figure 24**, or as construction material, and/or for direct reclamation.

[00451] An exemplary solvent-based extraction plant (2402) is depicted in **Figure 24**. This plant conducts a solvent-based extraction and agglomeration process involving directing high fines ore (2412) to a mix box (2434) where a slurry is formed with a solvent extraction liquor (2436). A slurry is formed, and fines within the slurry are agglomerated in an agglomerator (2438), in the presence of a bridging liquid (2439), and may be washed on a belt filter (2440) using, for example, countercurrent washing with progressively cleaner solvent. The bridging liquid (2439) added to the agglomerator (2438) may contain an adhesive to help strengthen and impart water resistance to the agglomerates. Solvent recovery from the agglomerates can occur in a solvent recovery unit (2442), while a hydrocarbon-containing product (2444) is obtained and forwarded to further processing. The agglomerates formed in the agglomerator (2438) may be treated in the solvent recovery unit (2442) with an adhesive. Additionally, the solvent recovery unit may contain a temperature region (or a separate process unit) to heat treat the agglomerates to a strengthened state. Dry agglomerates (2410), or tailings, from the solvent-based extraction plant (2402) can then be combined with non-segregating tailings (2408) produced from the water-based extraction process to provide a strengthened tailings (2406). The strengthened tailings (2406) may have improved dewatering properties and adequate strength so as to be used in formation of reclaimed land (2454) in much less time than conventional non-segregating tailings produced only within a water-based extraction process. The strengthened tailings (2406) may be pumped by pumps (2452) to the reclaimed land (2454) as part of an integrated reclamation scheme (2450).

[00452] In the preceding description, for purposes of explanation, numerous details are set forth in order to provide a thorough understanding of the embodiments described herein.

However, it will be apparent to one skilled in the art that these specific details are not required in order to practice the described processes.

[00453] 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.

CLAIMS:

1. A process for extracting hydrocarbon from oil sands ore, the process comprising:

(a)contacting the ore with a first solvent to form a first slurry comprising solids and a bitumen extract;

(b)separating the bitumen extract from the first slurry to form solvent wet tailings comprised of the solids and the first solvent;

(c)removing the first solvent from the solvent wet tailings to form dry tailings; and

(d)combining said dry tailings with water wet tailings produced from a water-based extraction process to form strengthened tailings,

wherein the dry tailings comprise a water content of less than 15 wt% and the water wet tailings comprise a water content of more than 25 wt%.

2. The process of claim 1, wherein the solvent wet tailings are washed with a second solvent producing washed solids.

3. The process of claim 2, wherein the first solvent and second solvent are removed from the washed solids to form the dry tailings.

4. The process of any one of claims 1 to 3, wherein a bridging liquid is added to the first slurry so as to agglomerate some or all the solids within the first slurry to form an agglomerated slurry comprising agglomerated solids and a bitumen extract.

5. The process of claim 4, wherein the bridging liquid is process water.

6. The process of claim 4, wherein the bridging liquid is process water with dissolved salts.

7. The process of claim 4, wherein the bridging liquid is water with water-soluble adhesives and/or emulsion type adhesives.

8. The process of claim 1 or 2, wherein the second solvent is a paraffinic solvent of carbon number C7 or less.

9. The process of any one of claims 1 to 8, wherein the dry tailings comprise precipitated asphaltenes.

10. The process of any one of claims 1 to 9, further comprising adding water-soluble adhesives and/or emulsion type adhesives to the solvent wet tailings.

11. The process of claim any one of claims 1 to 9, further comprising adding water-soluble adhesives and/or emulsion type adhesives to the dry tailings.

12. The process of any one of claims 1 to 11, wherein the dry tailings are sintered at a high temperature prior to forming strengthened tailings.

13. The process of any one of claims 1 to 11, wherein the dry tailings are heat treated at a temperatures greater than 500 °C.

14. The process of any one of claims 1 to 13, wherein the water wet tailings are thickened fine tailings from a water-based extraction process.

15. The process of claim 14, wherein the thickened fine tailings are the underflow from a high rate or paste thickener.

16. The process of any one of claims 1 to 13, wherein the water wet tailings are mature fine tailings from a water-based extraction process.

17. The process of any one of claims 1 to 13, wherein the water-wet tailings are non-segregating tailings from a water-based extraction process.

18. The process of claim 17, wherein the non-segregating tailings comprise a mixture of thickened fine tailings and coarse tailings produced within a water-based extraction process.

19. The process of claim 17, wherein the non-segregating tailings comprise a mixture of mature fine tailings and coarse tailings produced within a water-based extraction process.

20. The process of any one of claims 1 to 13, wherein the water wet tailings are partially dewatered prior to mixing with dry tailings.

21. The process of claim 12, wherein the dry tailings are sintered at a temperature greater than 500 °C.

22. The process of any one of claims 1 to 21, wherein strengthened tailings have a strength of 5 kPa or greater.

23. The process of any one of claims 1 to 22, wherein combining the dry tailings with water wet tailings comprises spraying the water wet tailings onto the dry tailings.

24. The process of any one of claims 1 to 22, wherein combining the dry tailings with water wet tailings comprises mixing to form agglomerates.

25. The process of any one of claims 1 to 24, wherein the dry tailings are used for mine construction material, mine refill, or direct reclamation.

26. The process of any one of claims 1 to 25, wherein the strengthened tailings are treated with a coagulant.

27. The process of any one of claims 1 to 25, wherein the strengthened tailings are treated to lower the pH of the strengthened tailings.

28. The process of any one of claims 1 to 27, wherein the oil sands ore comprises a low grade of oil sands with high fines content.

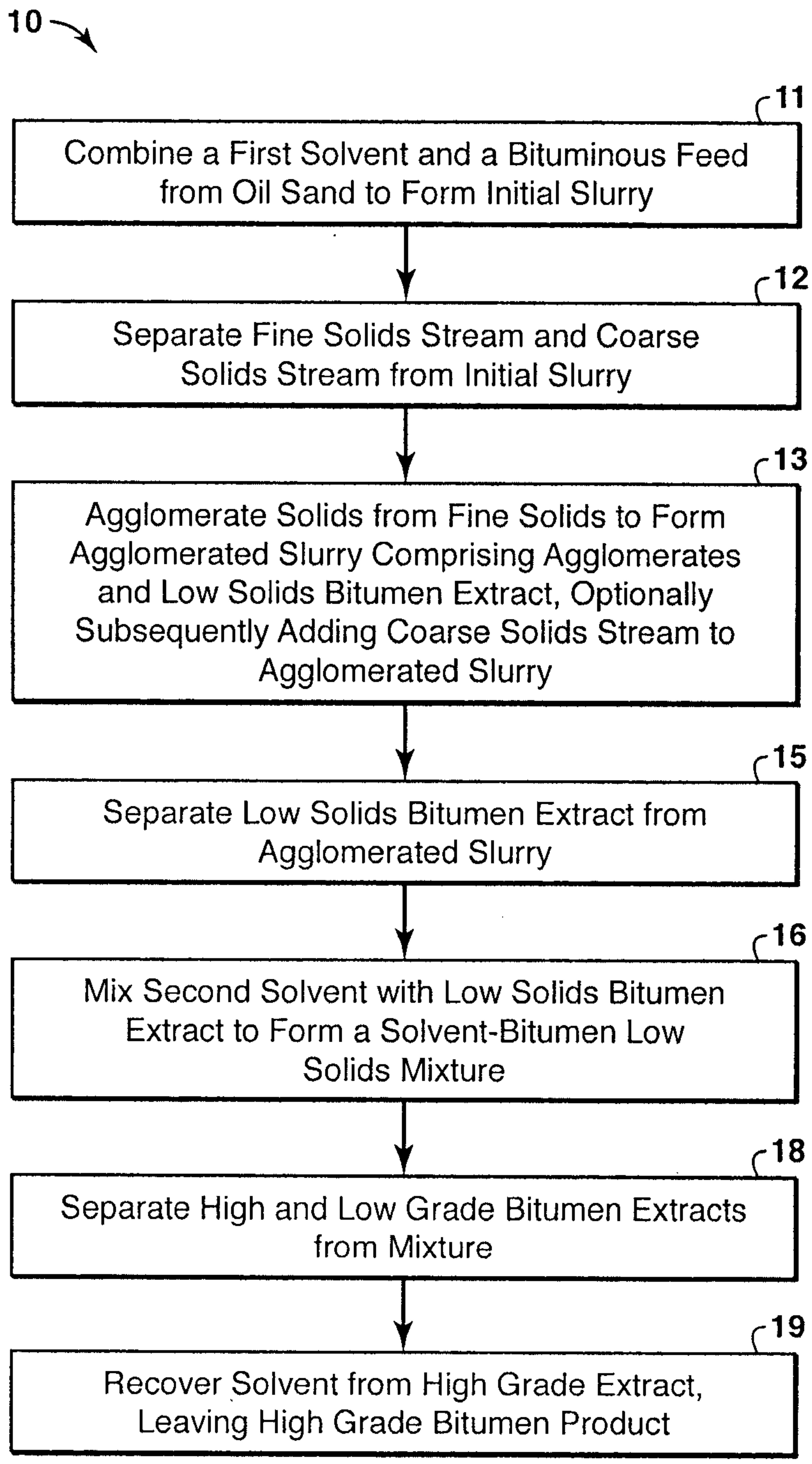
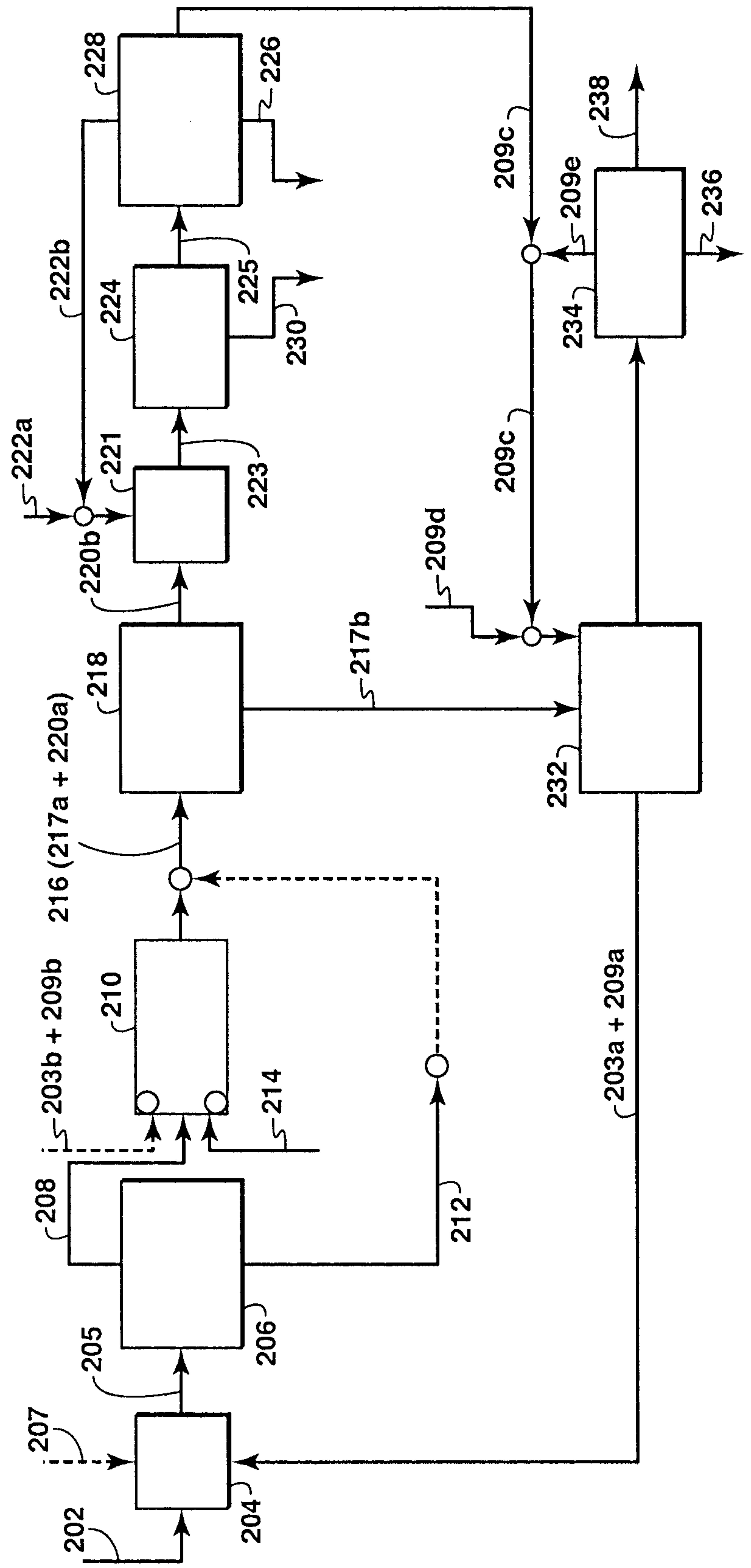

10
11
Combine a First Solvent and a Bituminous Feed from Oil Sand to Form Initial Slurry
12
Separate Fine Solids Stream and Coarse Solids Stream from Initial Slurry
13
Agglomerate Solids from Fine Solids to Form Agglomerated Slurry Comprising Agglomerates and Low Solids Bitumen Extract, Optionally Subsequently Adding Coarse Solids Stream to Agglomerated Slurry
15
Separate Low Solids Bitumen Extract from Agglomerated Slurry
16
Mix Second Solvent with Low Solids Bitumen Extract to Form a Solvent-Bitumen Low Solids Mixture
18
Separate High and Low Grade Bitumen Extracts from Mixture
19
Recover Solvent from High Grade Extract, Leaving High Grade Bitumen Product

FIG. 1



202
207
204
205
206
208
212
203b + 209b
210
214
216 (217a + 220a)
218
217b
220b
222a
221
222b
223
224
225
230
228
226
209c
209c
209d
209e
232
234
236
238
203a + 209a

FIG. 2

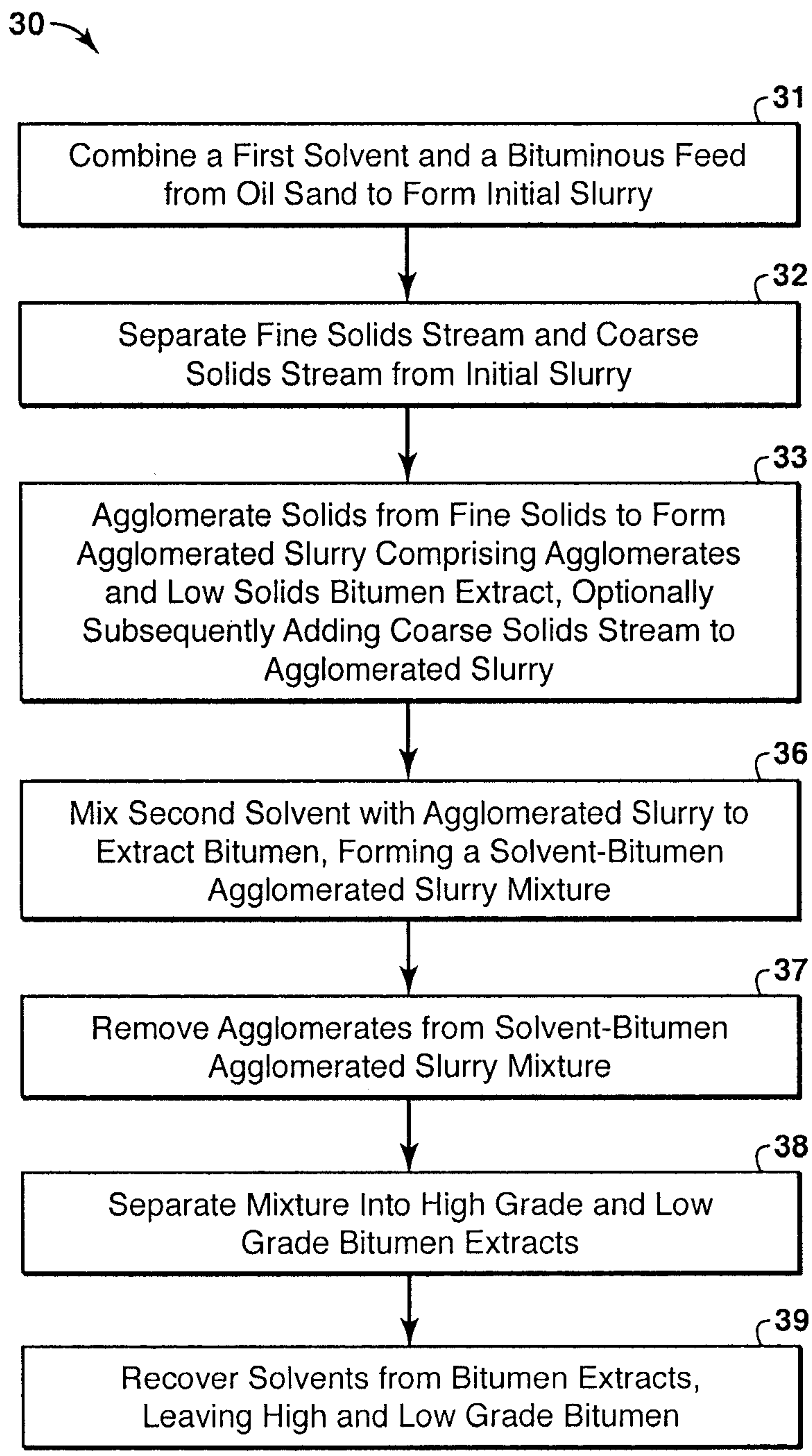
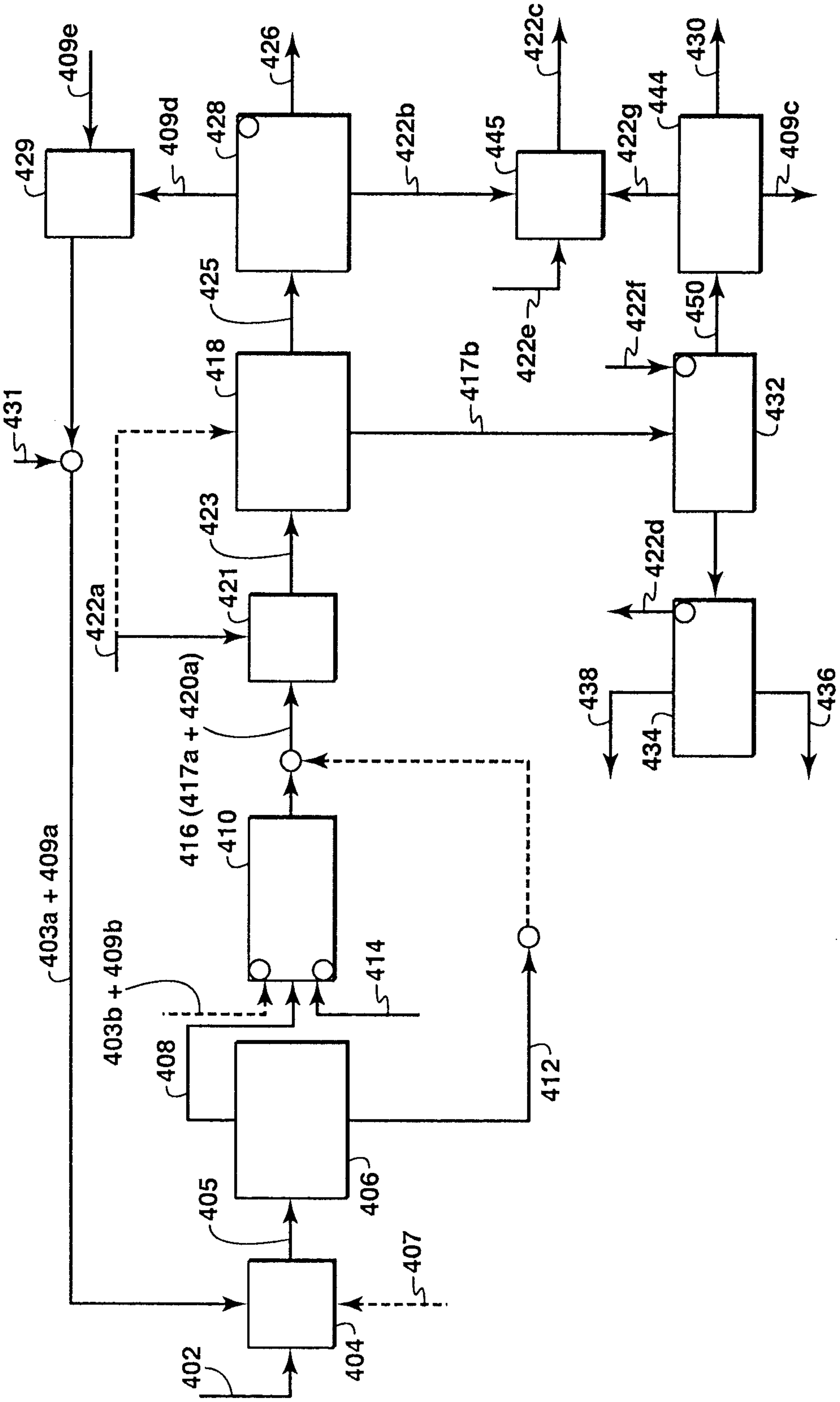

30
31
Combine a First Solvent and a Bituminous Feed from Oil Sand to Form Initial Slurry
32
Separate Fine Solids Stream and Coarse Solids Stream from Initial Slurry
33
Agglomerate Solids from Fine Solids to Form Agglomerated Slurry Comprising Agglomerates and Low Solids Bitumen Extract, Optionally Subsequently Adding Coarse Solids Stream to Agglomerated Slurry
36
Mix Second Solvent with Agglomerated Slurry to Extract Bitumen, Forming a Solvent-Bitumen Agglomerated Slurry Mixture
37
Remove Agglomerates from Solvent-Bitumen Agglomerated Slurry Mixture
38
Separate Mixture Into High Grade and Low Grade Bitumen Extracts
39
Recover Solvents from Bitumen Extracts, Leaving High and Low Grade Bitumen

FIG. 3



402
404
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408
403a + 409a
403b + 409b
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412
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416 (417a + 420a)
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422a
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418
417b
425
428
426
409d
429
409e
431
422b
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422c
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422g
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430
409c
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422f
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422d
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438
436

FIG. 4

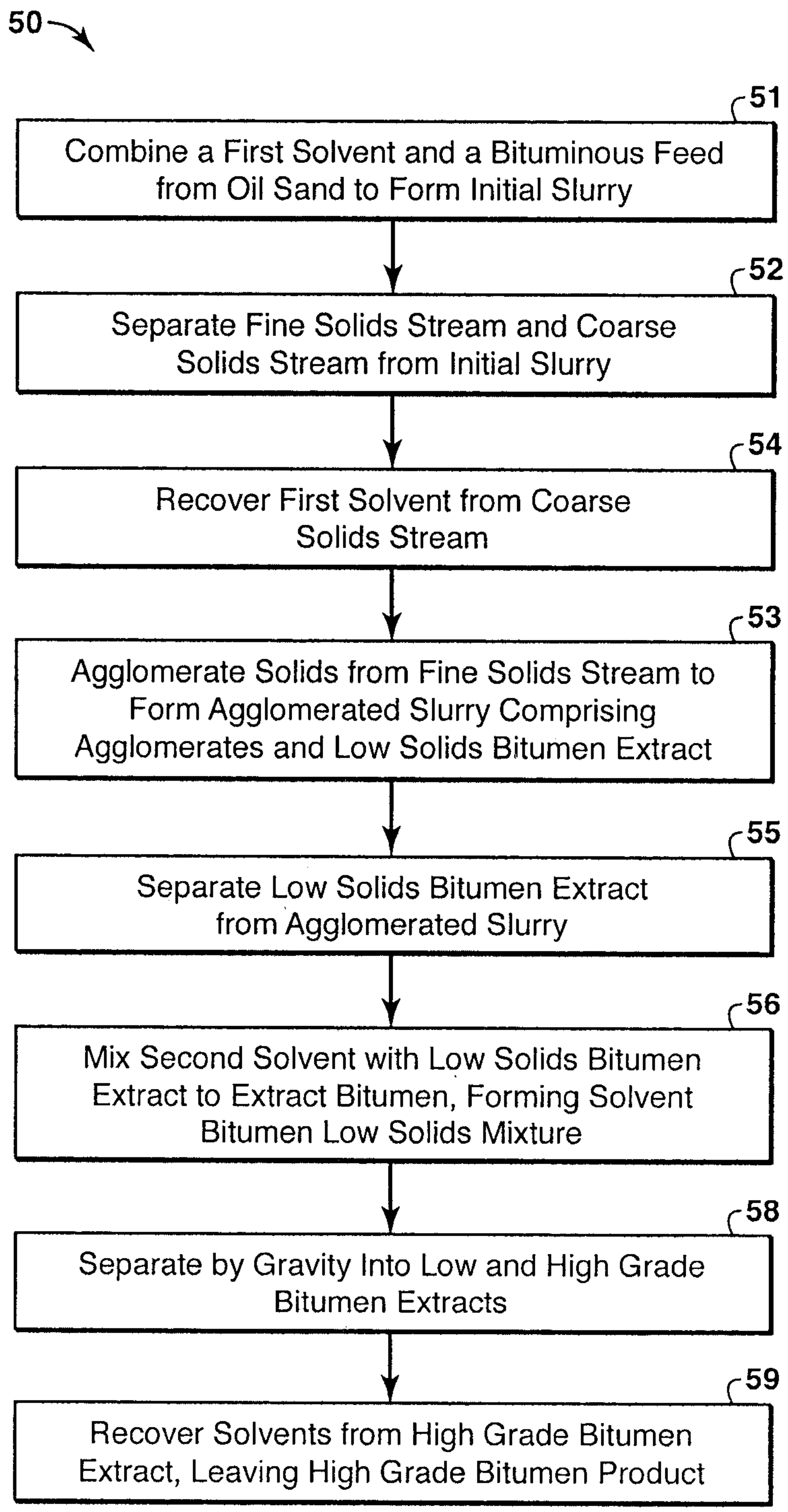
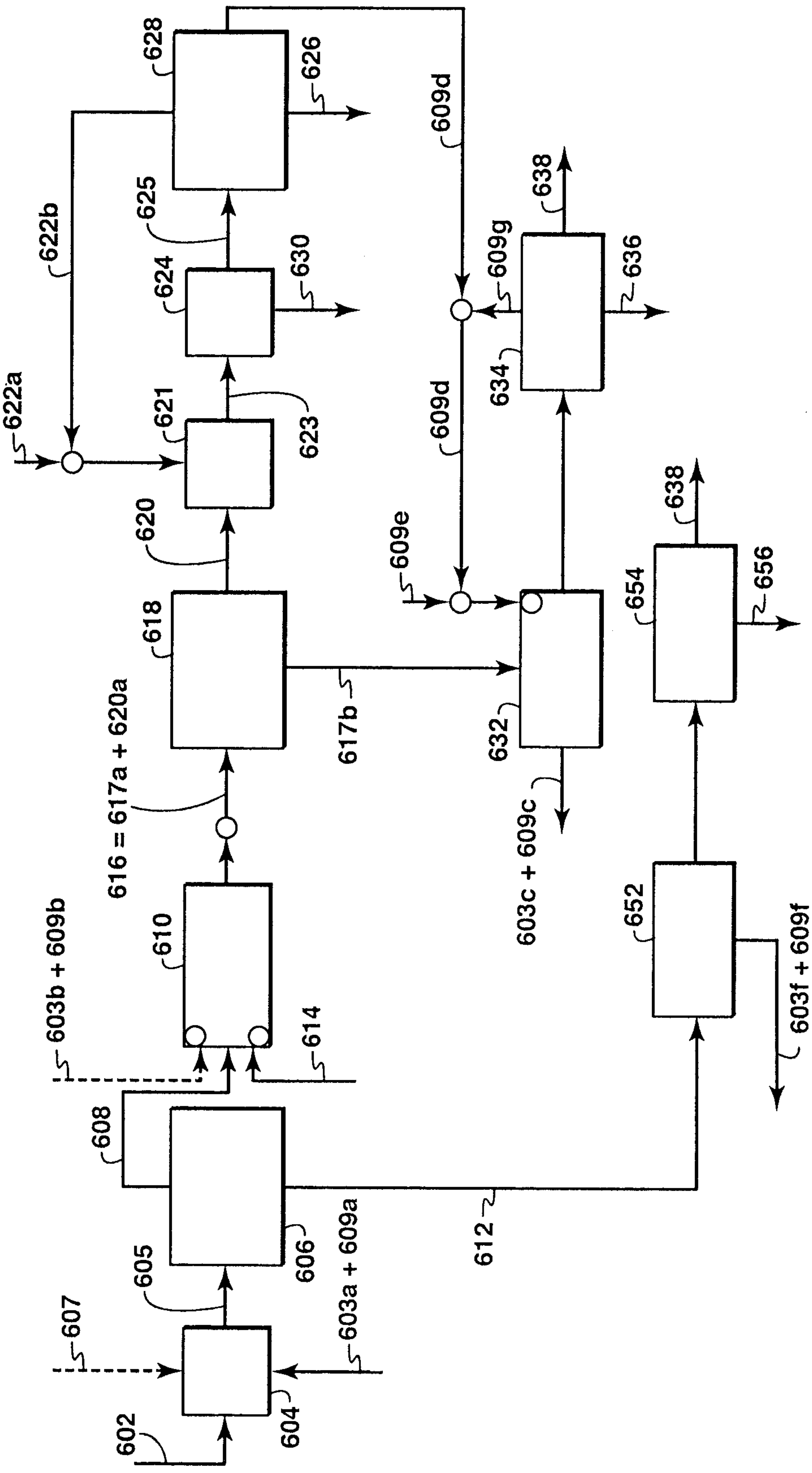

50
51
Combine a First Solvent and a Bituminous Feed from Oil Sand to Form Initial Slurry
52
Separate Fine Solids Stream and Coarse Solids Stream from Initial Slurry
54
Recover First Solvent from Coarse Solids Stream
53
Agglomerate Solids from Fine Solids Stream to Form Agglomerated Slurry Comprising Agglomerates and Low Solids Bitumen Extract
55
Separate Low Solids Bitumen Extract from Agglomerated Slurry
56
Mix Second Solvent with Low Solids Bitumen Extract to Extract Bitumen, Forming Solvent Bitumen Low Solids Mixture
58
Separate by Gravity Into Low and High Grade Bitumen Extracts
59
Recover Solvents from High Grade Bitumen Extract, Leaving High Grade Bitumen Product

FIG. 5


602
604
607
603a + 609a
605
606
608
612
603b + 609b
610
614
616 = 617a + 620a
618
617b
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621
622a
622b
623
624
630
625
628
626
609d
609e
609d
609g
632
603c + 609c
634
636
638
652
603f + 609f
654
656
638

FIG. 6

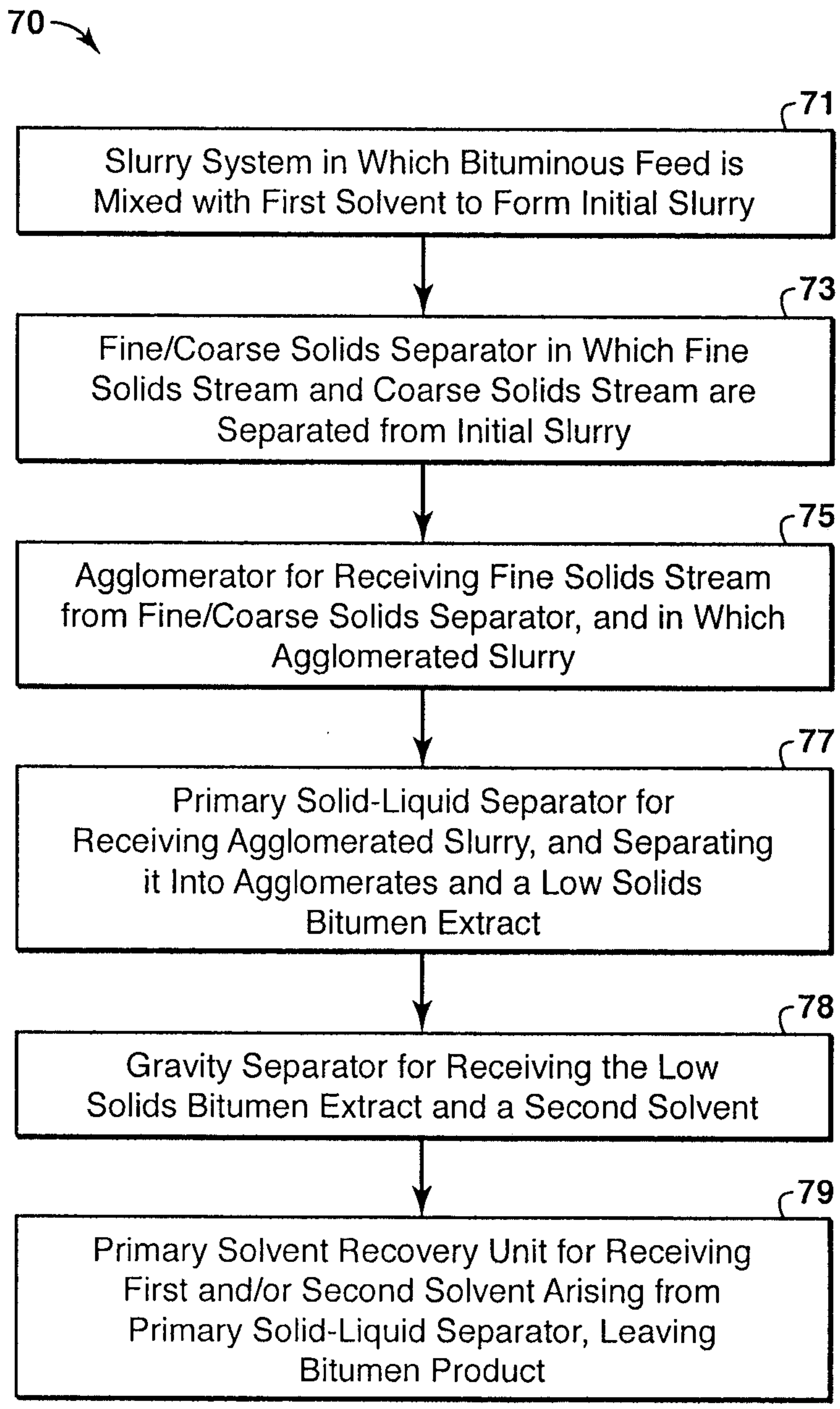

70
71
Slurry System in Which Bituminous Feed is Mixed with First Solvent to Form Initial Slurry
73
Fine/Coarse Solids Separator in Which Fine Solids Stream and Coarse Solids Stream are Separated from Initial Slurry
75
Agglomerator for Receiving Fine Solids Stream from Fine/Coarse Solids Separator, and in Which Agglomerated Slurry
77
Primary Solid-Liquid Separator for Receiving Agglomerated Slurry, and Separating it Into Agglomerates and a Low Solids Bitumen Extract
78
Gravity Separator for Receiving the Low Solids Bitumen Extract and a Second Solvent
79
Primary Solvent Recovery Unit for Receiving First and/or Second Solvent Arising from Primary Solid-Liquid Separator, Leaving Bitumen Product

FIG. 7

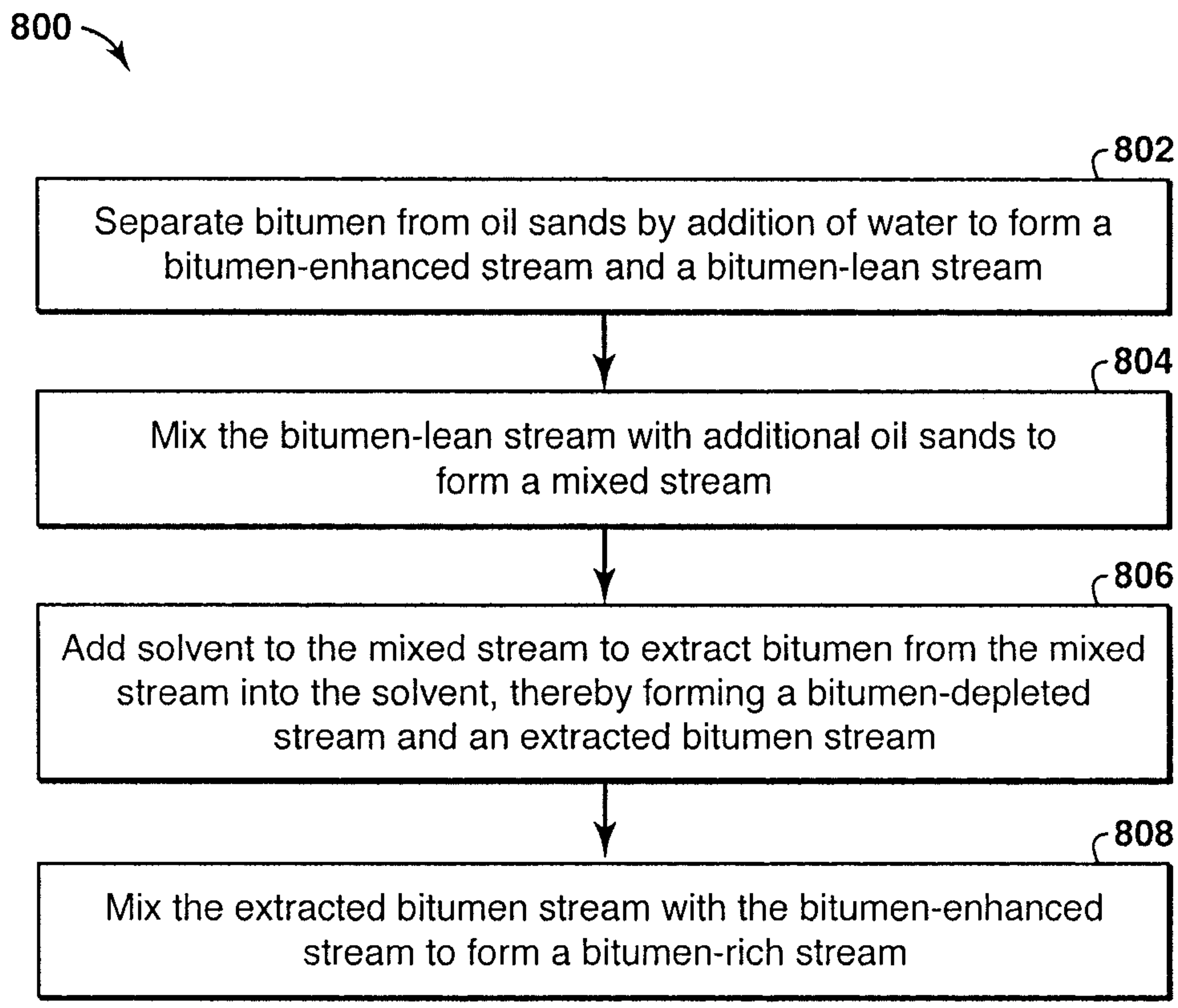

800
802
Separate bitumen from oil sands by addition of water to form a bitumen-enhanced stream and a bitumen-lean stream
804
Mix the bitumen-lean stream with additional oil sands to form a mixed stream
806
Add solvent to the mixed stream to extract bitumen from the mixed stream into the solvent, thereby forming a bitumen-depleted stream and an extracted bitumen stream
808
Mix the extracted bitumen stream with the bitumen-enhanced stream to form a bitumen-rich stream

FIG. 8

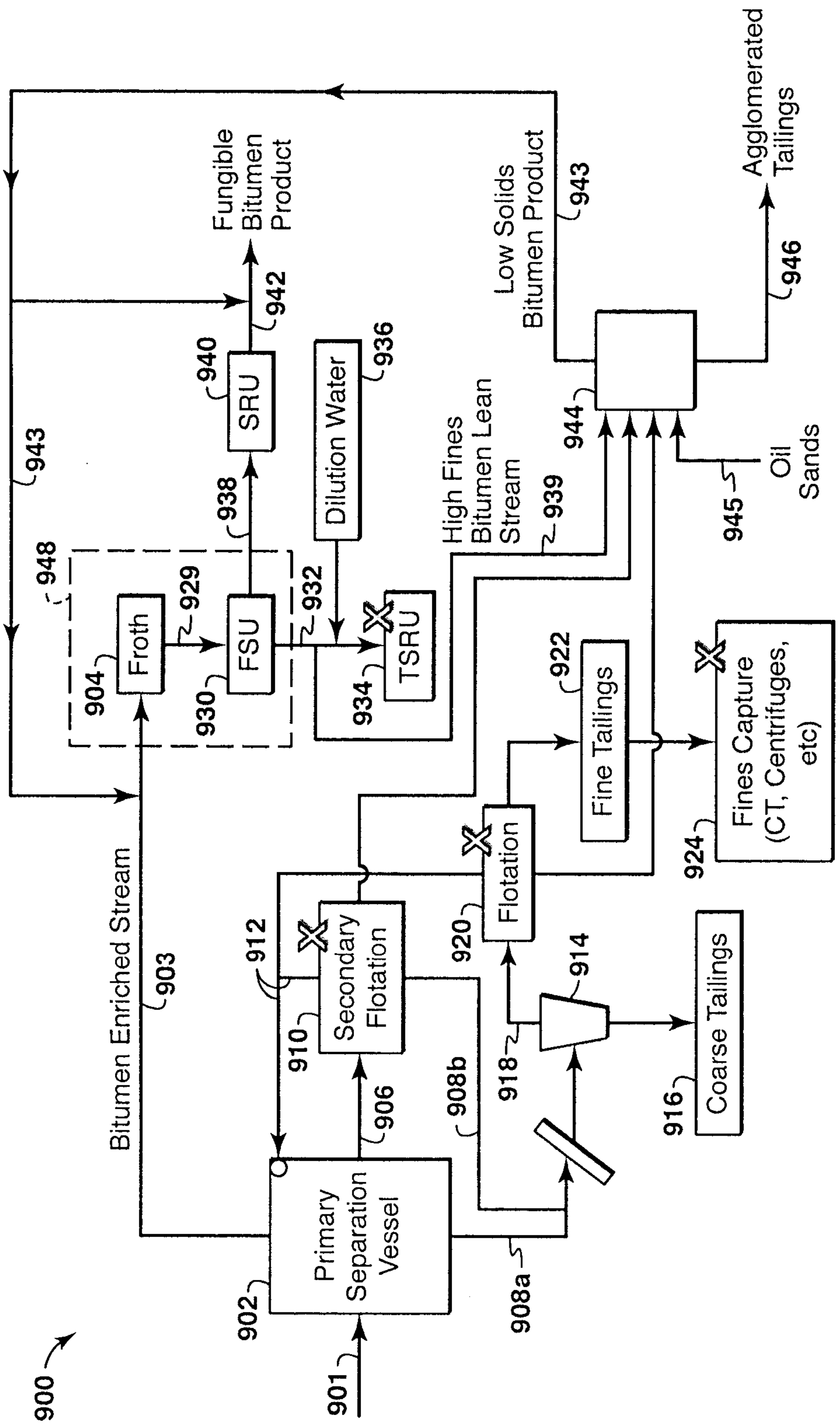

900
901
902
Primary Separation Vessel
903
Bitumen Enriched Stream
904
Froth
906
908a
908b
910
Secondary Flotation
912
914
916
Coarse Tailings
918
920
Flotation
922
Fine Tailings
924
Fines Capture (CT, Centrifuges, etc)
929
930
FSU
932
934
TSRU
936
Dilution Water
938
939
High Fines Bitumen Lean Stream
940
SRU
942
Fungible Bitumen Product
943
Low Solids Bitumen Product
944
945
Oil Sands
946
Agglomerated Tailings
948

FIG. 9

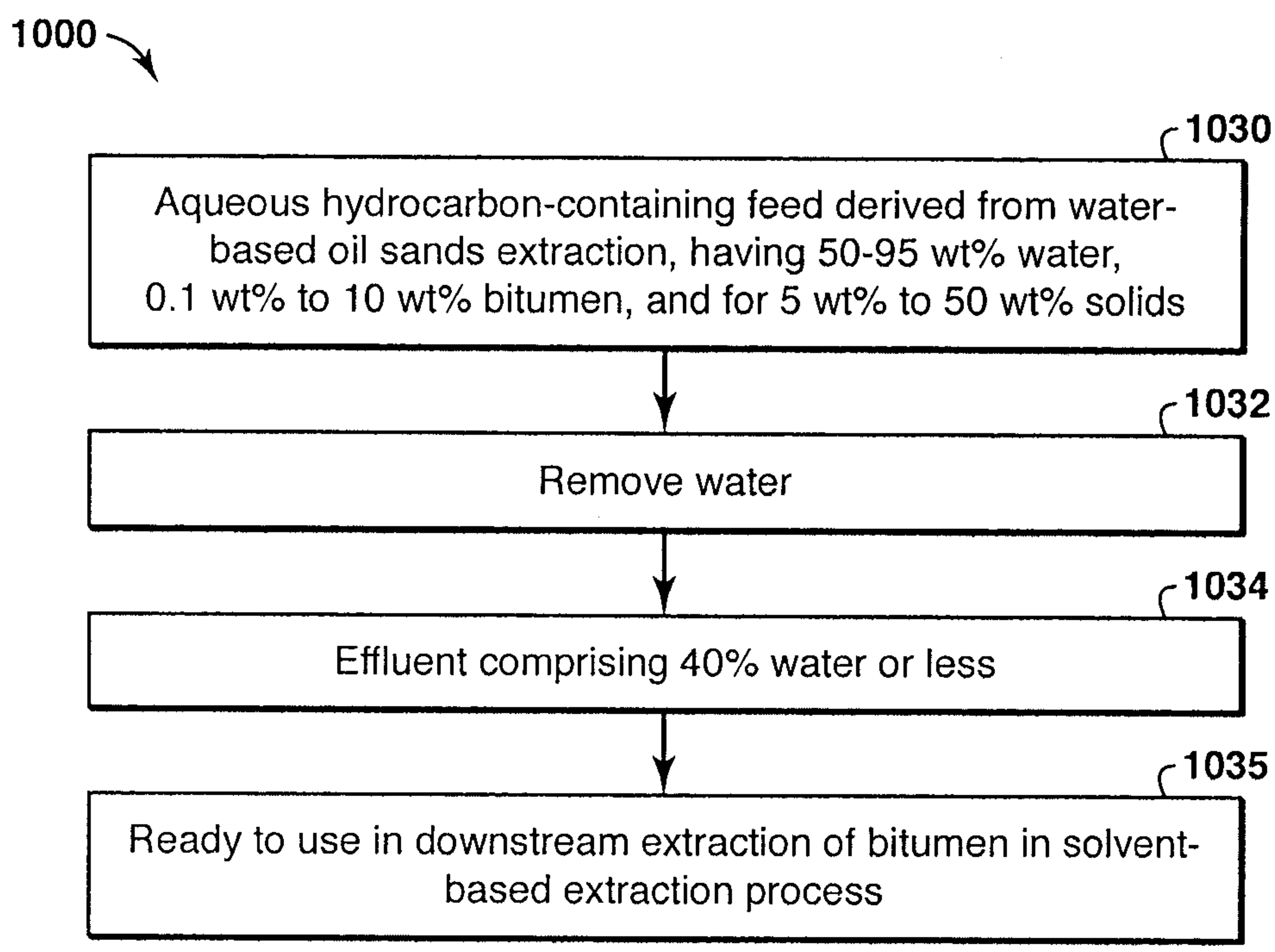

1000
1030
Aqueous hydrocarbon-containing feed derived from water-based oil sands extraction, having 50-95 wt% water, 0.1 wt% to 10 wt% bitumen, and for 5 wt% to 50 wt% solids
1032
Remove water
1034
Effluent comprising 40% water or less
1035
Ready to use in downstream extraction of bitumen in solvent-based extraction process

FIG. 10

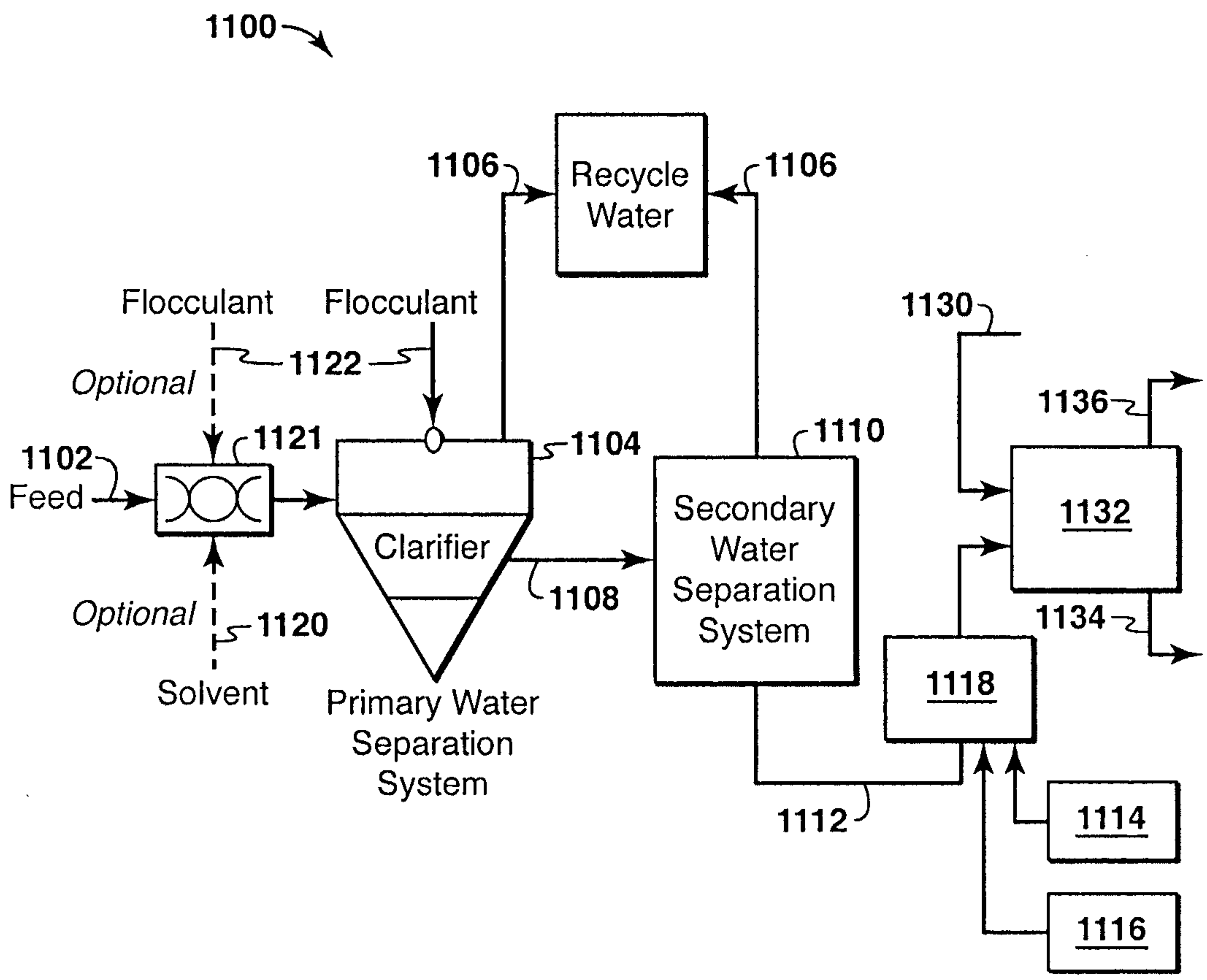

1100
1106
Recycle Water
1106
Flocculant
Flocculant
1122
Optional
1121
1104
1110
1130
1136
1102
Feed
Clarifier
1108
Secondary Water Separation System
1132
Optional
1120
Solvent
Primary Water Separation System
1134
1118
1112
1114
1116

FIG. 11

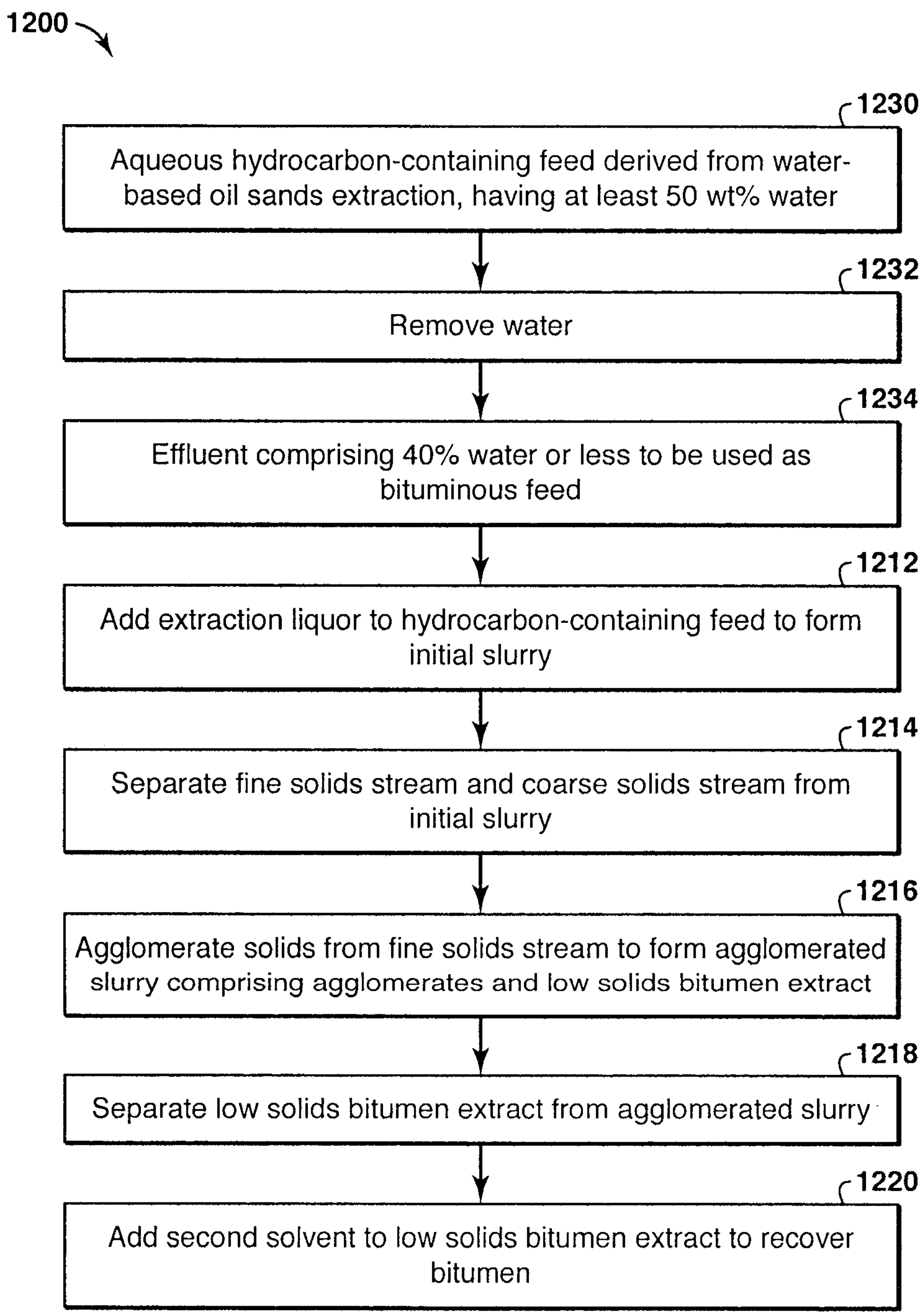

1200
1230
Aqueous hydrocarbon-containing feed derived from water-based oil sands extraction, having at least 50 wt% water
1232
Remove water
1234
Effluent comprising 40% water or less to be used as bituminous feed
1212
Add extraction liquor to hydrocarbon-containing feed to form initial slurry
1214
Separate fine solids stream and coarse solids stream from initial slurry
1216
Agglomerate solids from fine solids stream to form agglomerated slurry comprising agglomerates and low solids bitumen extract
1218
Separate low solids bitumen extract from agglomerated slurry
1220
Add second solvent to low solids bitumen extract to recover bitumen

FIG. 12

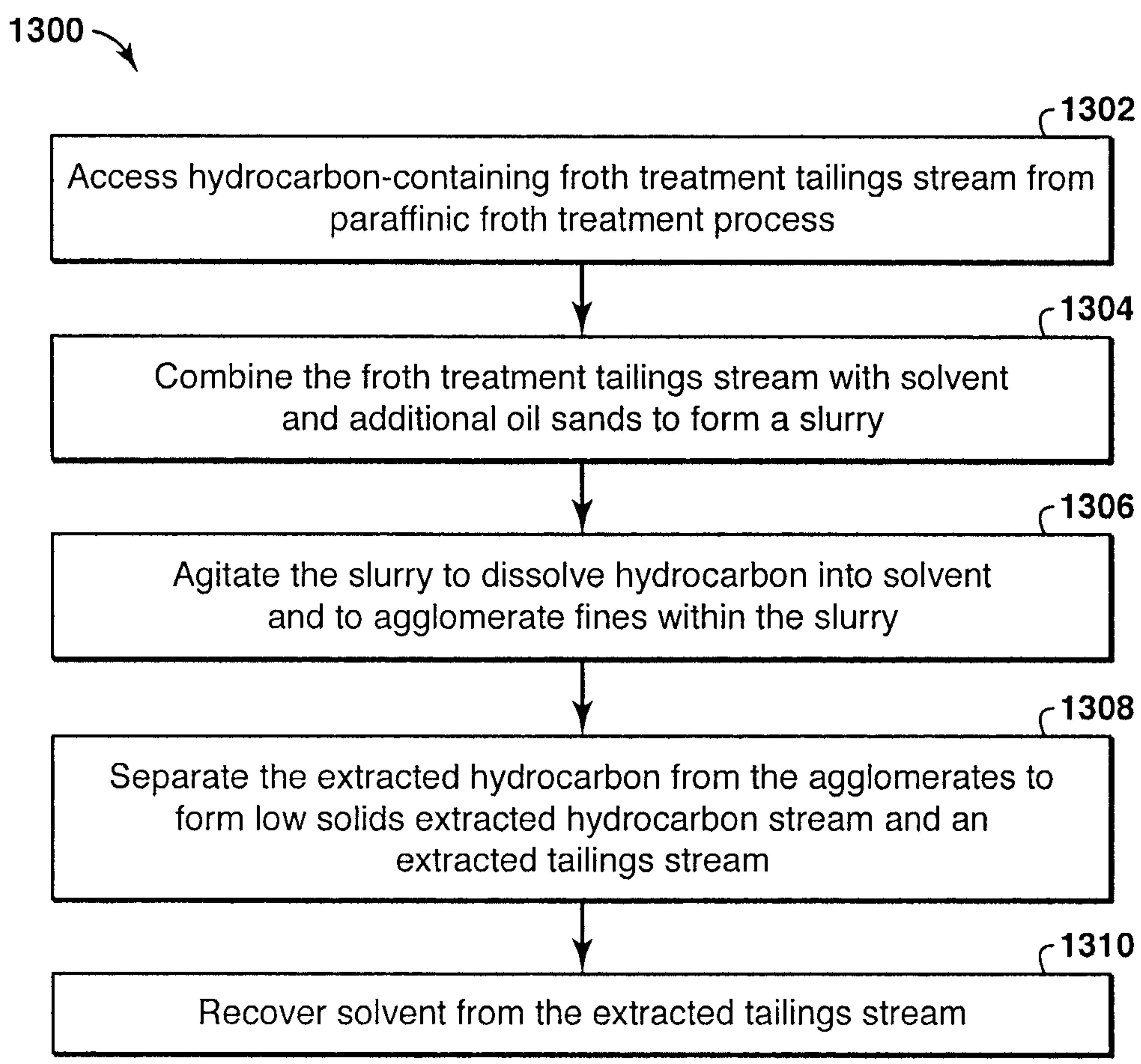

1300
1302
Access hydrocarbon-containing froth treatment tailings stream from paraffinic froth treatment process
1304
Combine the froth treatment tailings stream with solvent and additional oil sands to form a slurry
1306
Agitate the slurry to dissolve hydrocarbon into solvent and to agglomerate fines within the slurry
1308
Separate the extracted hydrocarbon from the agglomerates to form low solids extracted hydrocarbon stream and an extracted tailings stream
1310
Recover solvent from the extracted tailings stream

FIG. 13

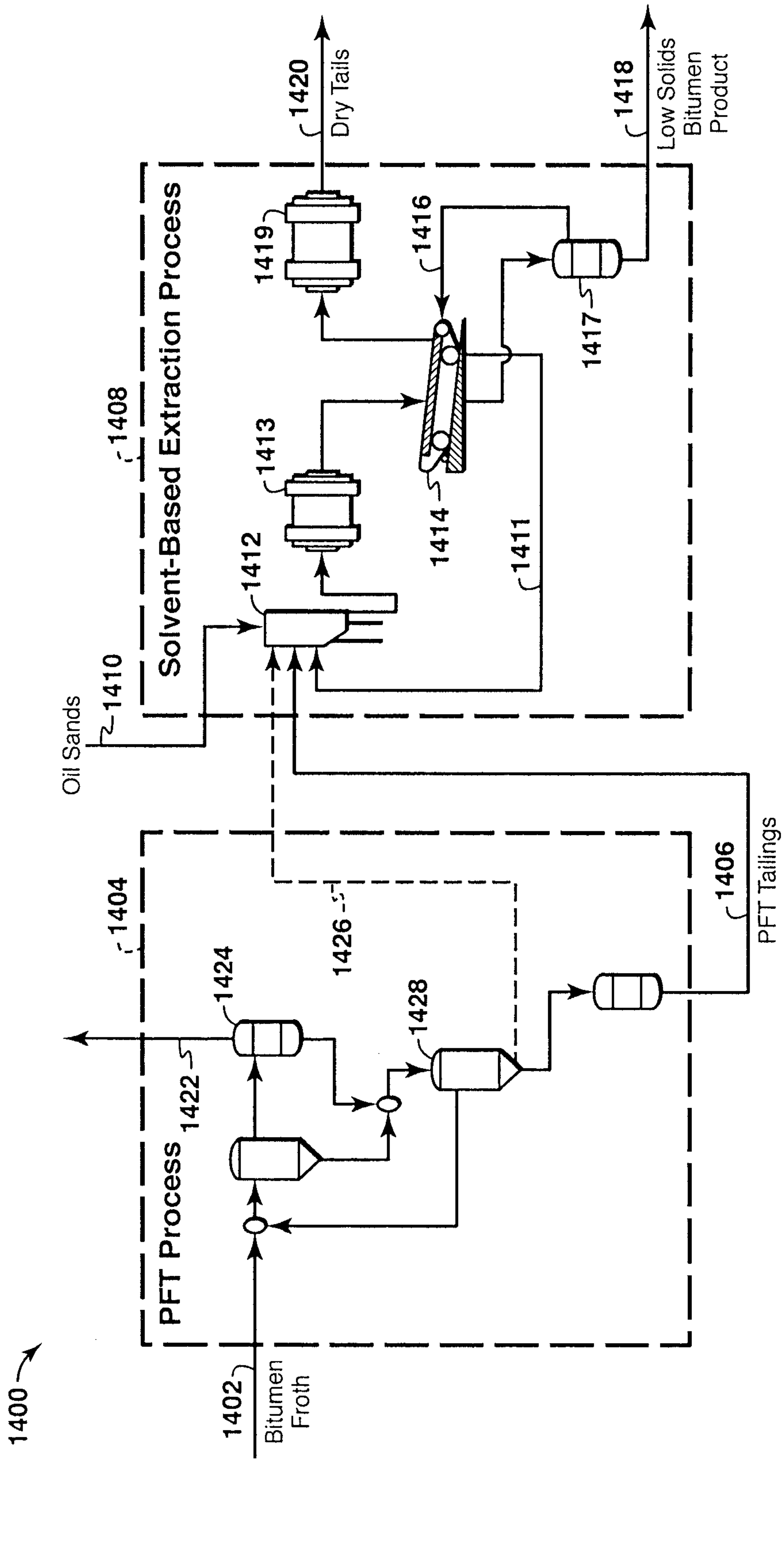

1400
PFT Process
1404
1402
Bitumen Froth
1422
1424
1426
1428
1406
PFT Tailings
Oil Sands
1410
Solvent-Based Extraction Process
1408
1412
1413
1414
1411
1419
1416
1417
1420
Dry Tails
1418
Low Solids Bitumen Product

FIG. 14

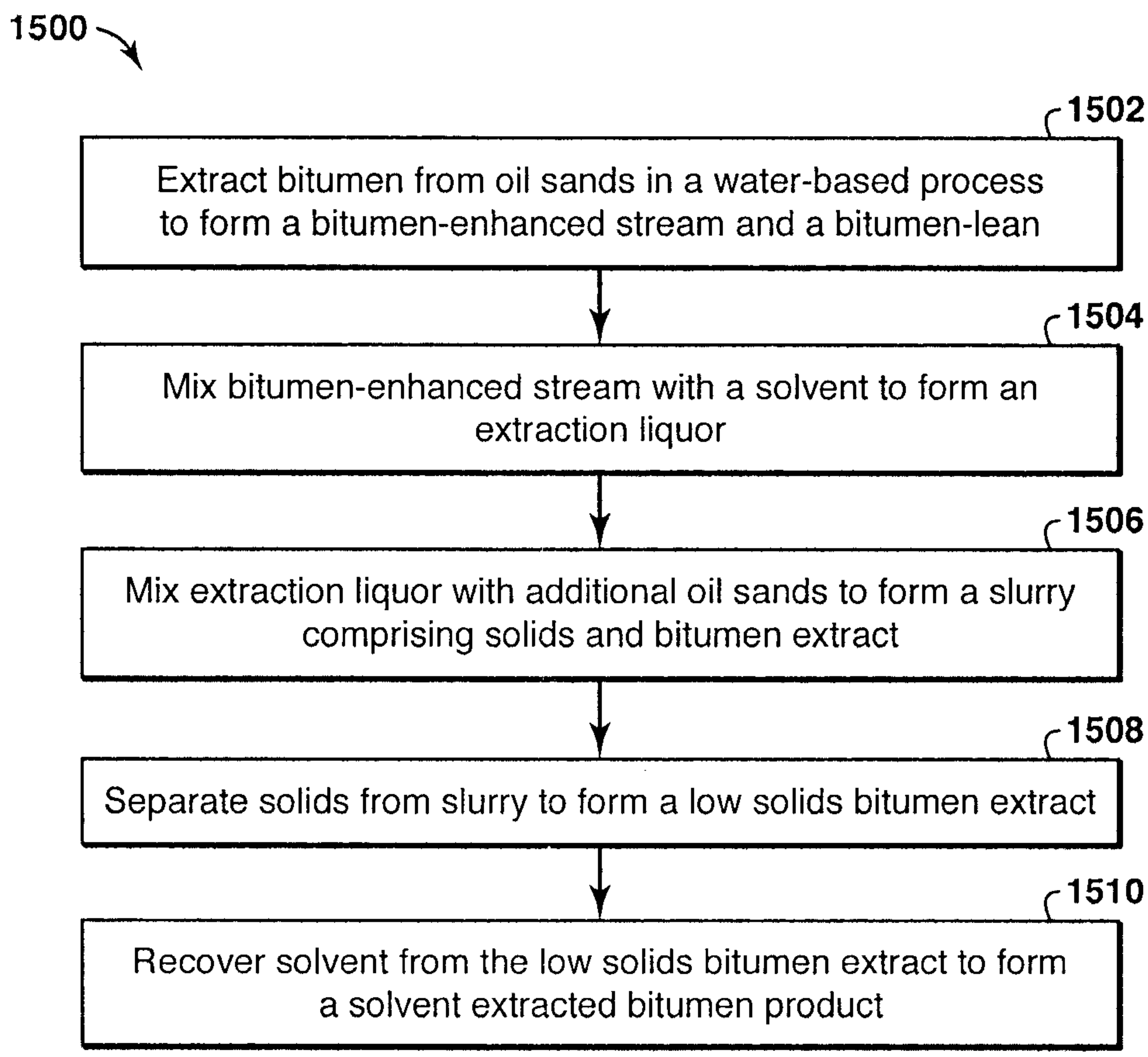

1500
1502
Extract bitumen from oil sands in a water-based process to form a bitumen-enhanced stream and a bitumen-lean
1504
Mix bitumen-enhanced stream with a solvent to form an extraction liquor
1506
Mix extraction liquor with additional oil sands to form a slurry comprising solids and bitumen extract
1508
Separate solids from slurry to form a low solids bitumen extract
1510
Recover solvent from the low solids bitumen extract to form a solvent extracted bitumen product

FIG. 15

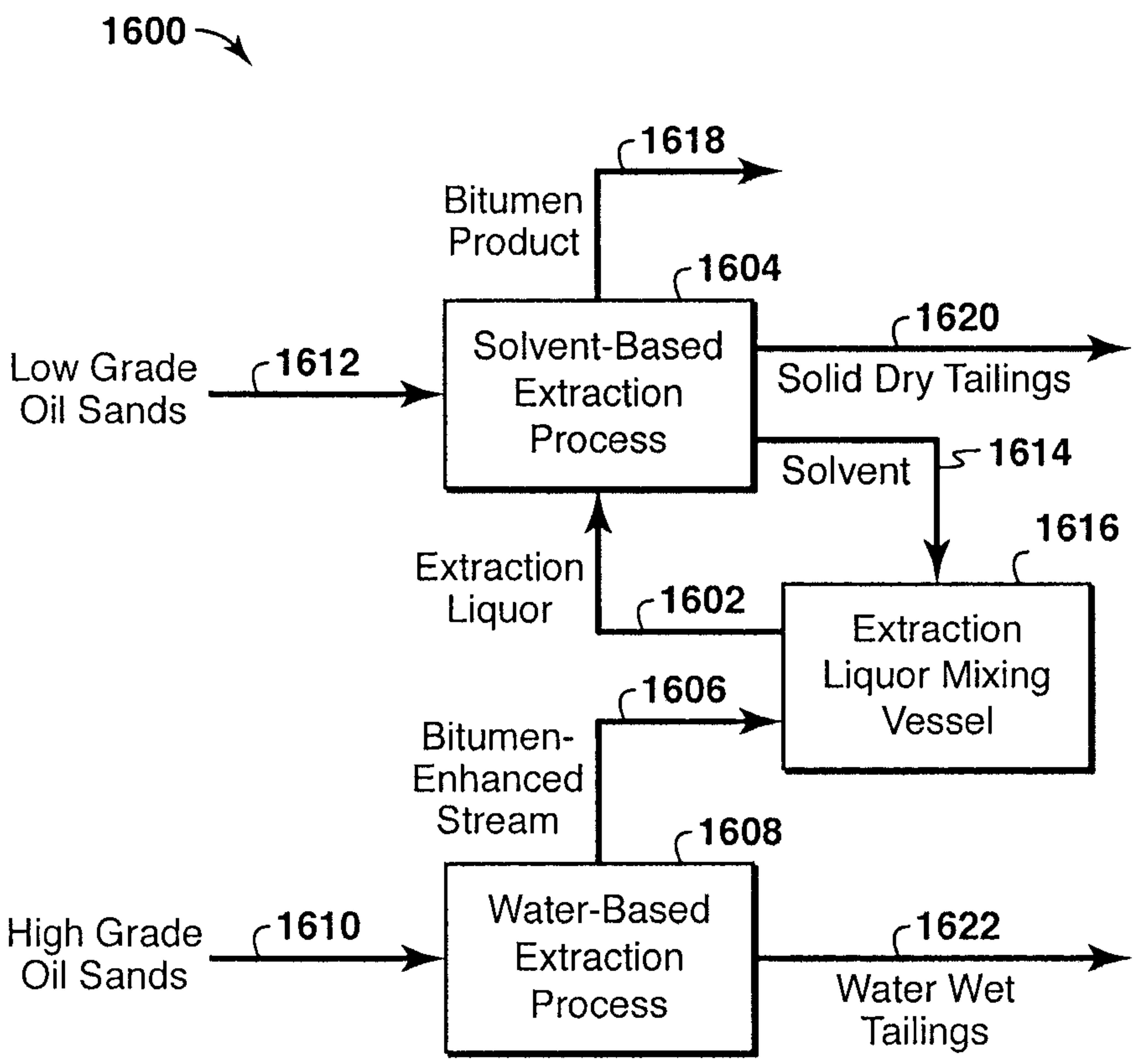

1600
1618
Bitumen Product
1604
Low Grade Oil Sands
1612
Solvent-Based Extraction Process
1620
Solid Dry Tailings
Solvent
1614
1616
Extraction Liquor
1602
Extraction Liquor Mixing Vessel
1606
Bitumen-Enhanced Stream
1608
High Grade Oil Sands
1610
Water-Based Extraction Process
1622
Water Wet Tailings

FIG. 16

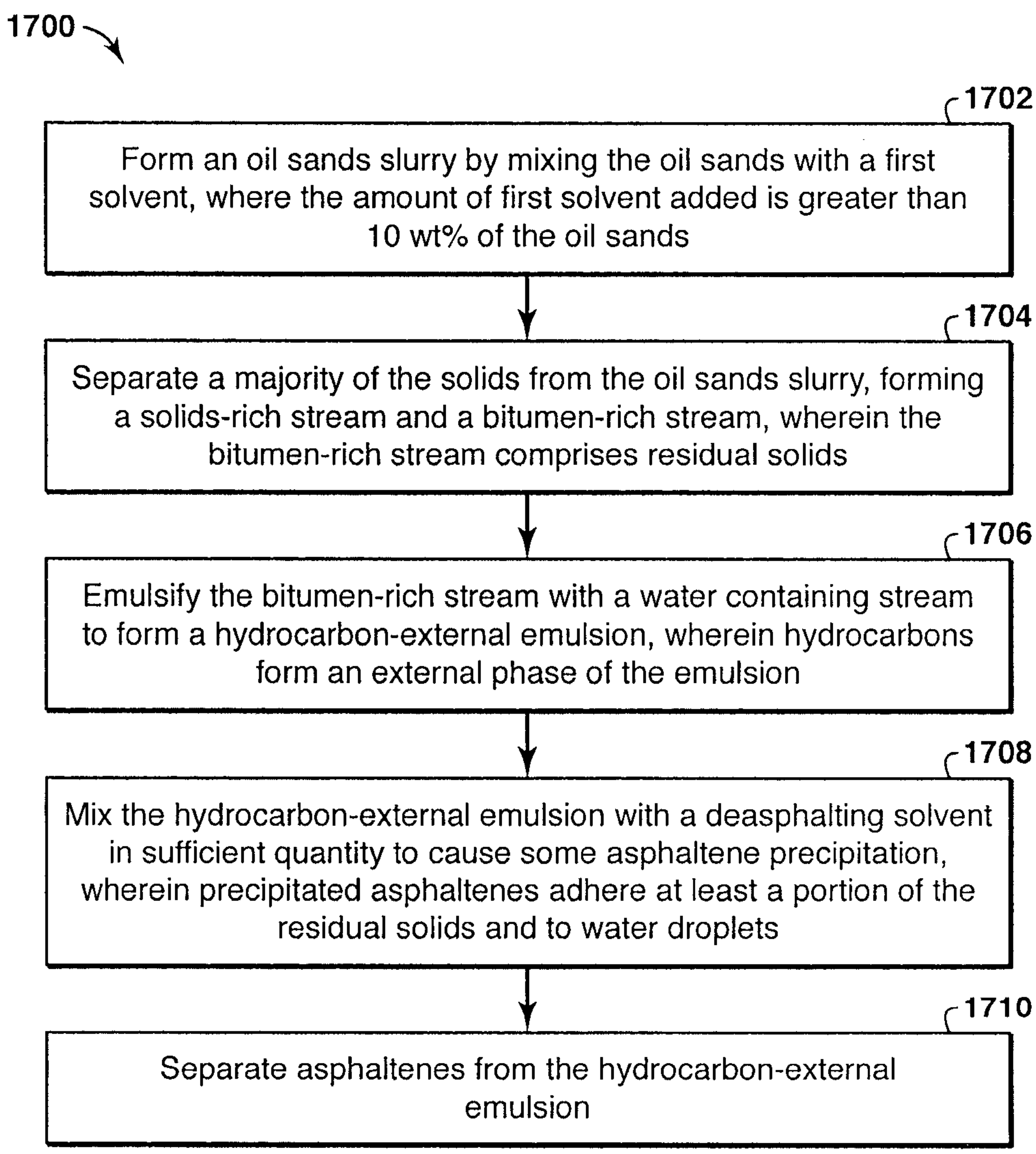

1700
1702
Form an oil sands slurry by mixing the oil sands with a first solvent, where the amount of first solvent added is greater than 10 wt% of the oil sands
1704
Separate a majority of the solids from the oil sands slurry, forming a solids-rich stream and a bitumen-rich stream, wherein the bitumen-rich stream comprises residual solids
1706
Emulsify the bitumen-rich stream with a water containing stream to form a hydrocarbon-external emulsion, wherein hydrocarbons form an external phase of the emulsion
1708
Mix the hydrocarbon-external emulsion with a deasphalting solvent in sufficient quantity to cause some asphaltene precipitation, wherein precipitated asphaltenes adhere at least a portion of the residual solids and to water droplets
1710
Separate asphaltenes from the hydrocarbon-external emulsion

FIG. 17

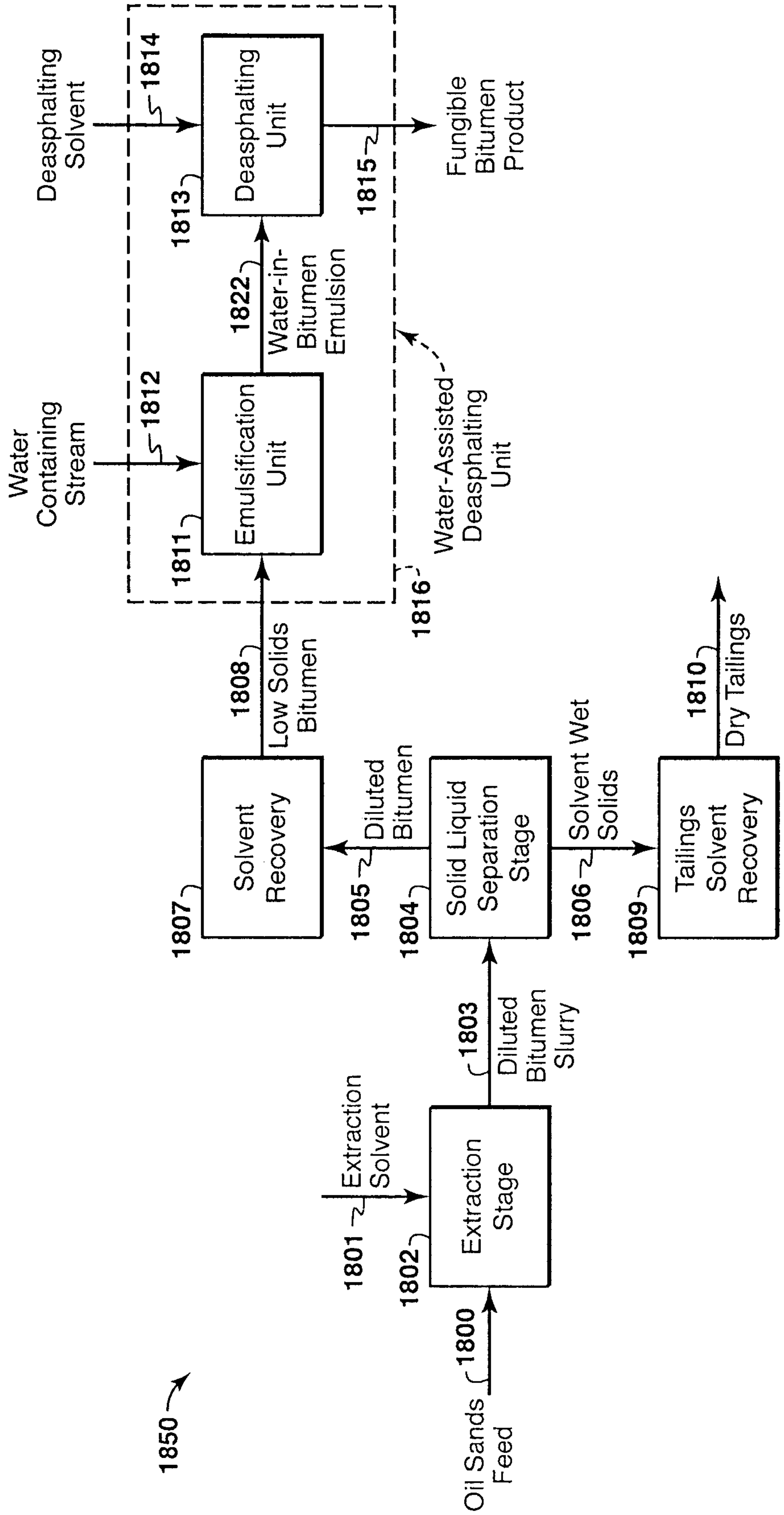

1850
Oil Sands Feed
1800
Extraction Solvent
1801
Extraction Stage
1802
Diluted Bitumen Slurry
1803
Solid Liquid Separation Stage
1804
Diluted Bitumen
1805
Solvent Wet Solids
1806
Solvent Recovery
1807
Low Solids Bitumen
1808
Tailings Solvent Recovery
1809
Dry Tailings
1810
Water Containing Stream
1812
Emulsification Unit
1811
Water-in-Bitumen Emulsion
1822
Deasphalting Solvent
1814
Deasphalting Unit
1813
Fungible Bitumen Product
1815
Water-Assisted Deasphalting Unit
1816

FIG. 18

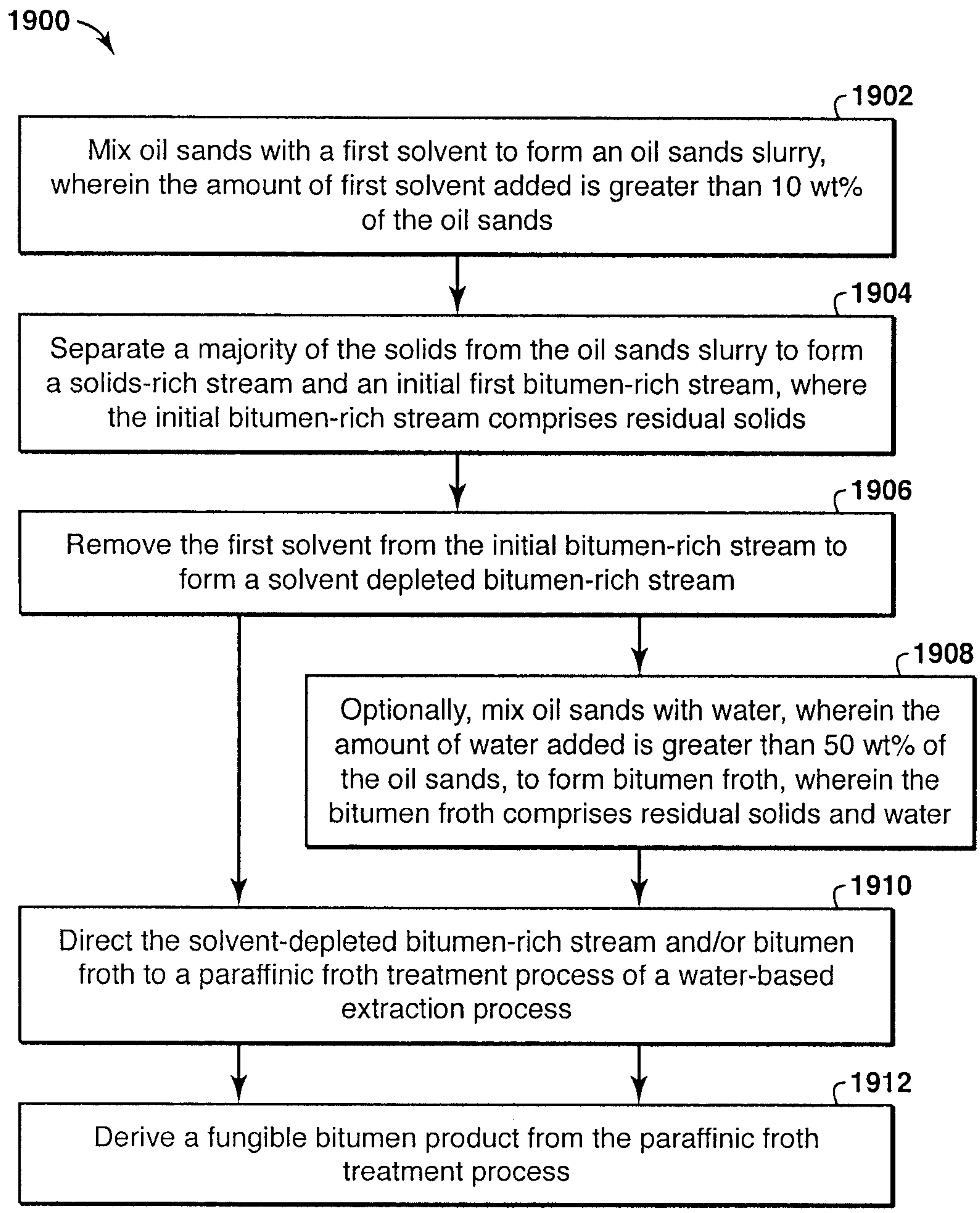

1900
1902
Mix oil sands with a first solvent to form an oil sands slurry, wherein the amount of first solvent added is greater than 10 wt% of the oil sands
1904
Separate a majority of the solids from the oil sands slurry to form a solids-rich stream and an initial first bitumen-rich stream, where the initial bitumen-rich stream comprises residual solids
1906
Remove the first solvent from the initial bitumen-rich stream to form a solvent depleted bitumen-rich stream
1908
Optionally, mix oil sands with water, wherein the amount of water added is greater than 50 wt% of the oil sands, to form bitumen froth, wherein the bitumen froth comprises residual solids and water
1910
Direct the solvent-depleted bitumen-rich stream and/or bitumen froth to a paraffinic froth treatment process of a water-based extraction process
1912
Derive a fungible bitumen product from the paraffinic froth treatment process

FIG. 19

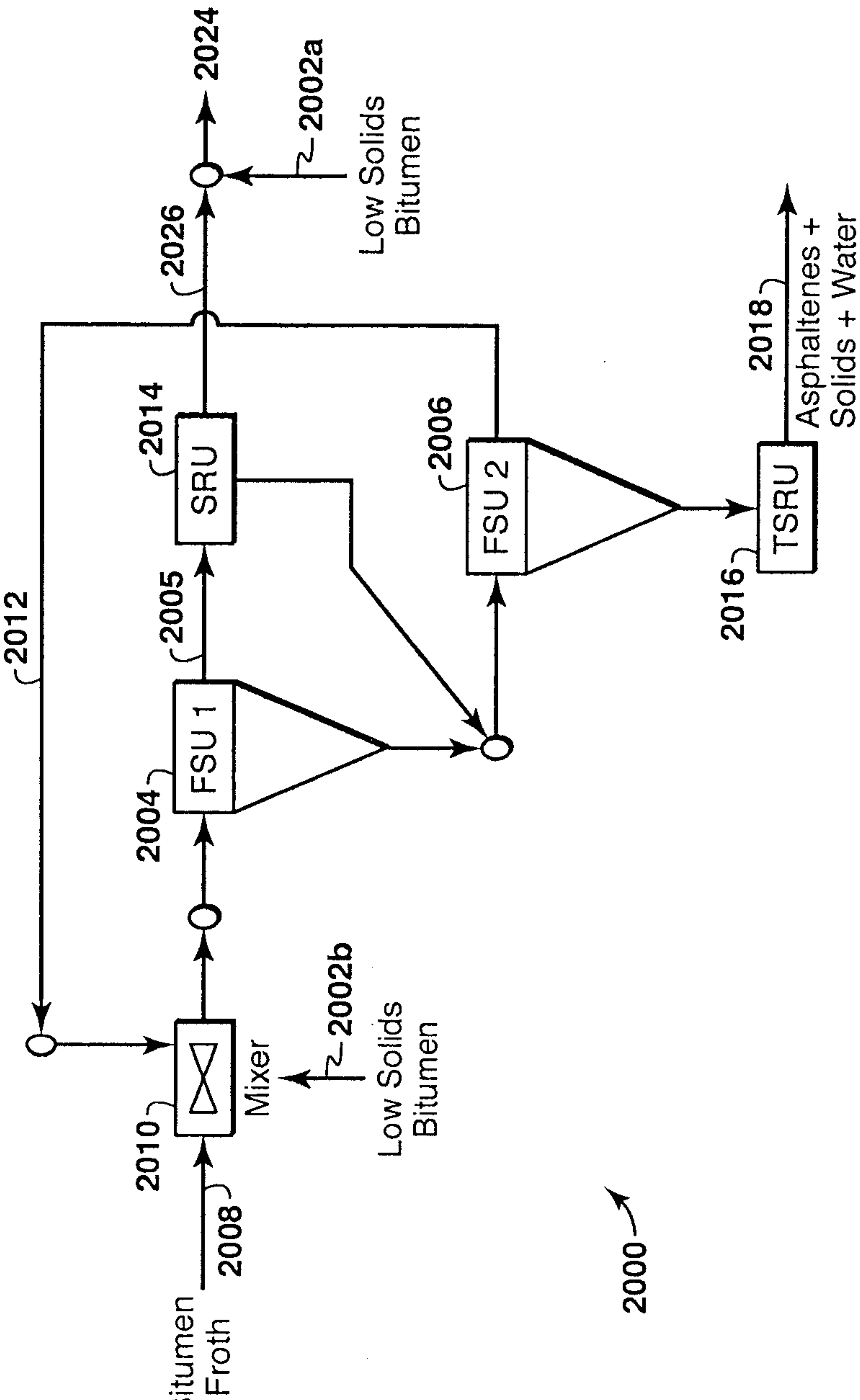

2024
2002a
Low Solids
Bitumen
2026
2012
2014
SRU
2005
FSU 1
2004
2006
FSU 2
2018
Asphaltenes +
Solids + Water
TSRU
2016
Mixer
2010
2002b
Low Solids
Bitumen
Bitumen
Froth
2008
2000

FIG. 20

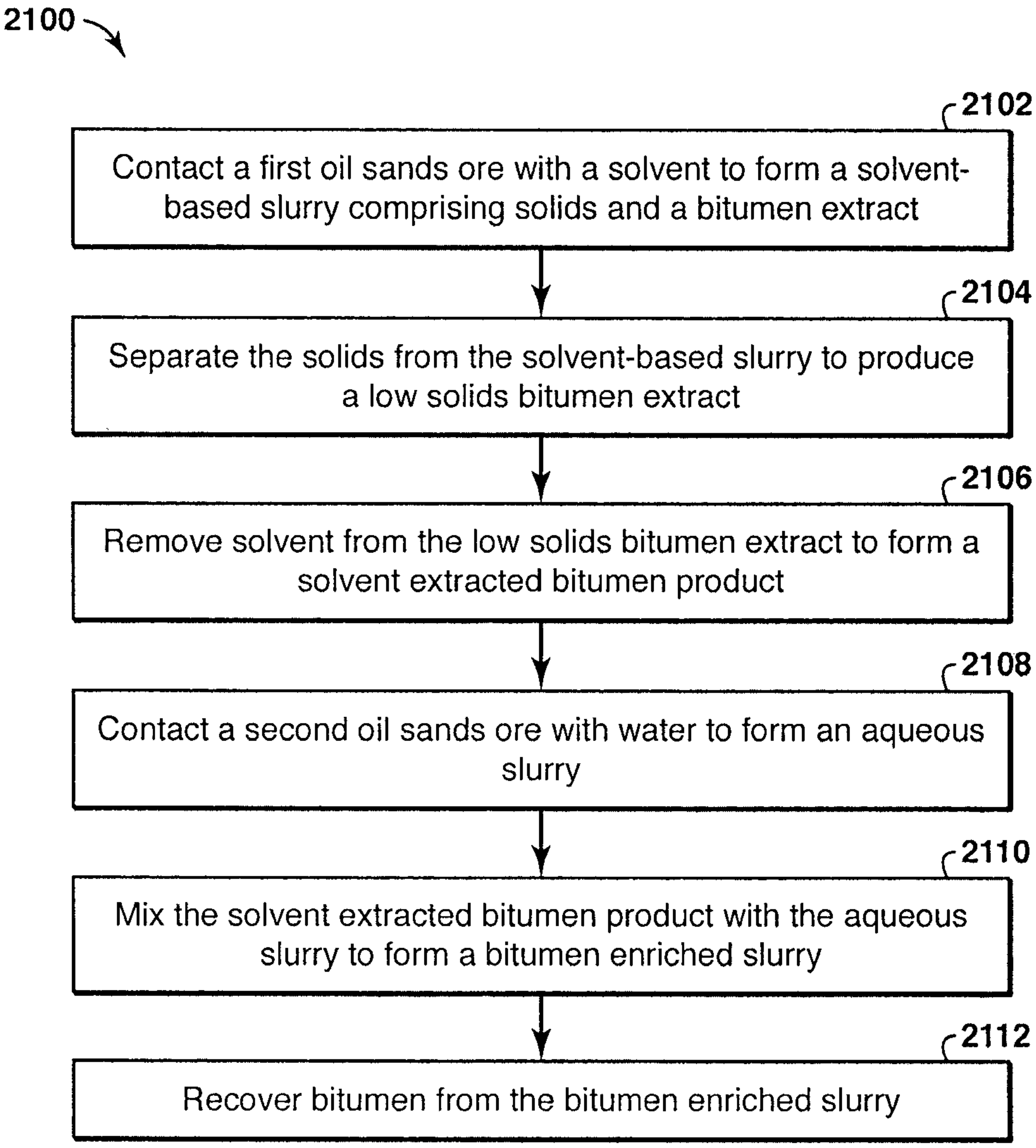

2100
2102
Contact a first oil sands ore with a solvent to form a solvent-based slurry comprising solids and a bitumen extract
2104
Separate the solids from the solvent-based slurry to produce a low solids bitumen extract
2106
Remove solvent from the low solids bitumen extract to form a solvent extracted bitumen product
2108
Contact a second oil sands ore with water to form an aqueous slurry
2110
Mix the solvent extracted bitumen product with the aqueous slurry to form a bitumen enriched slurry
2112
Recover bitumen from the bitumen enriched slurry

FIG. 21

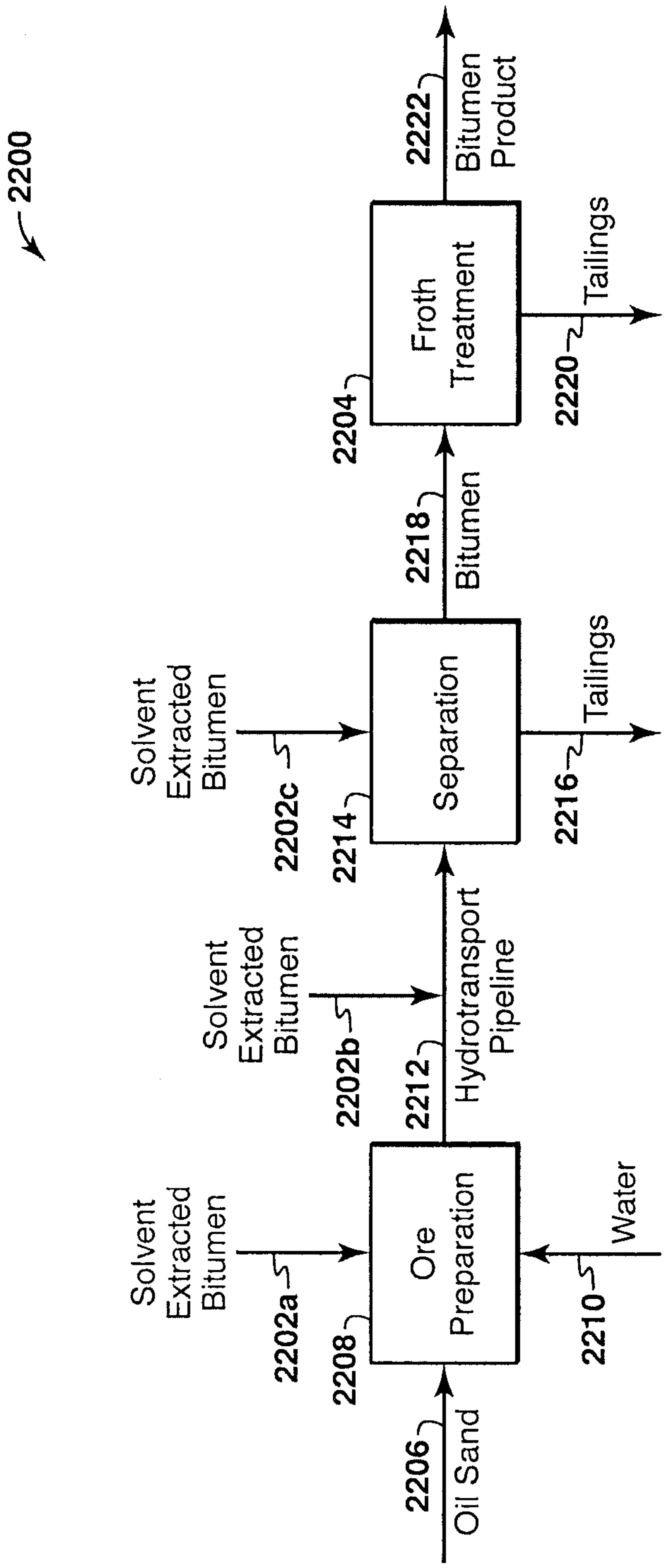

2200
Oil Sand
2206
Ore Preparation
2208
Solvent Extracted Bitumen
2202a
Water
2210
Hydrotransport Pipeline
2212
Solvent Extracted Bitumen
2202b
Separation
2214
Solvent Extracted Bitumen
2202c
Tailings
2216
Bitumen
2218
Froth Treatment
2204
Tailings
2220
Bitumen Product
2222

FIG. 22

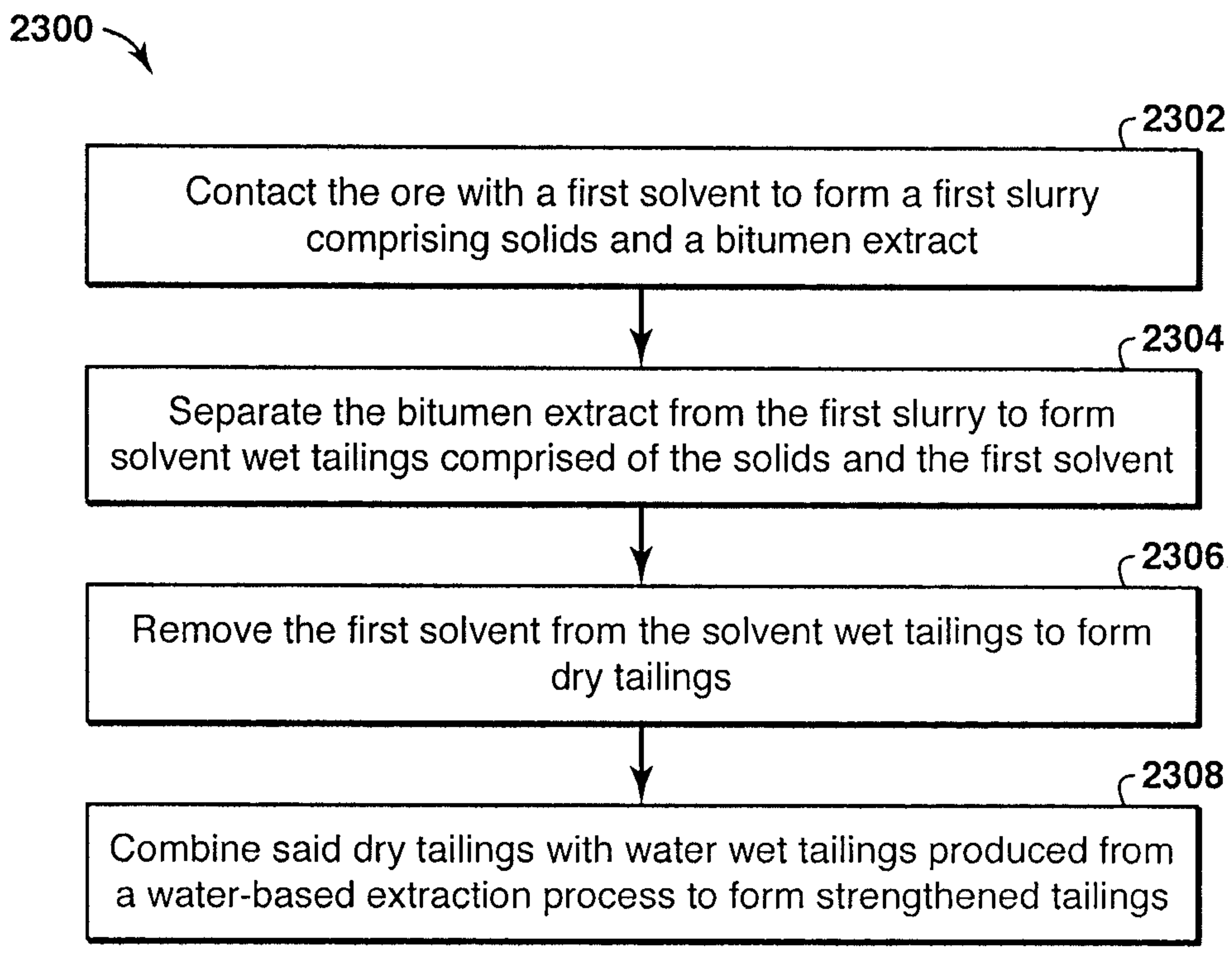

2300
2302
Contact the ore with a first solvent to form a first slurry comprising solids and a bitumen extract
2304
Separate the bitumen extract from the first slurry to form solvent wet tailings comprised of the solids and the first solvent
2306
Remove the first solvent from the solvent wet tailings to form dry tailings
2308
Combine said dry tailings with water wet tailings produced from a water-based extraction process to form strengthened tailings

FIG. 23

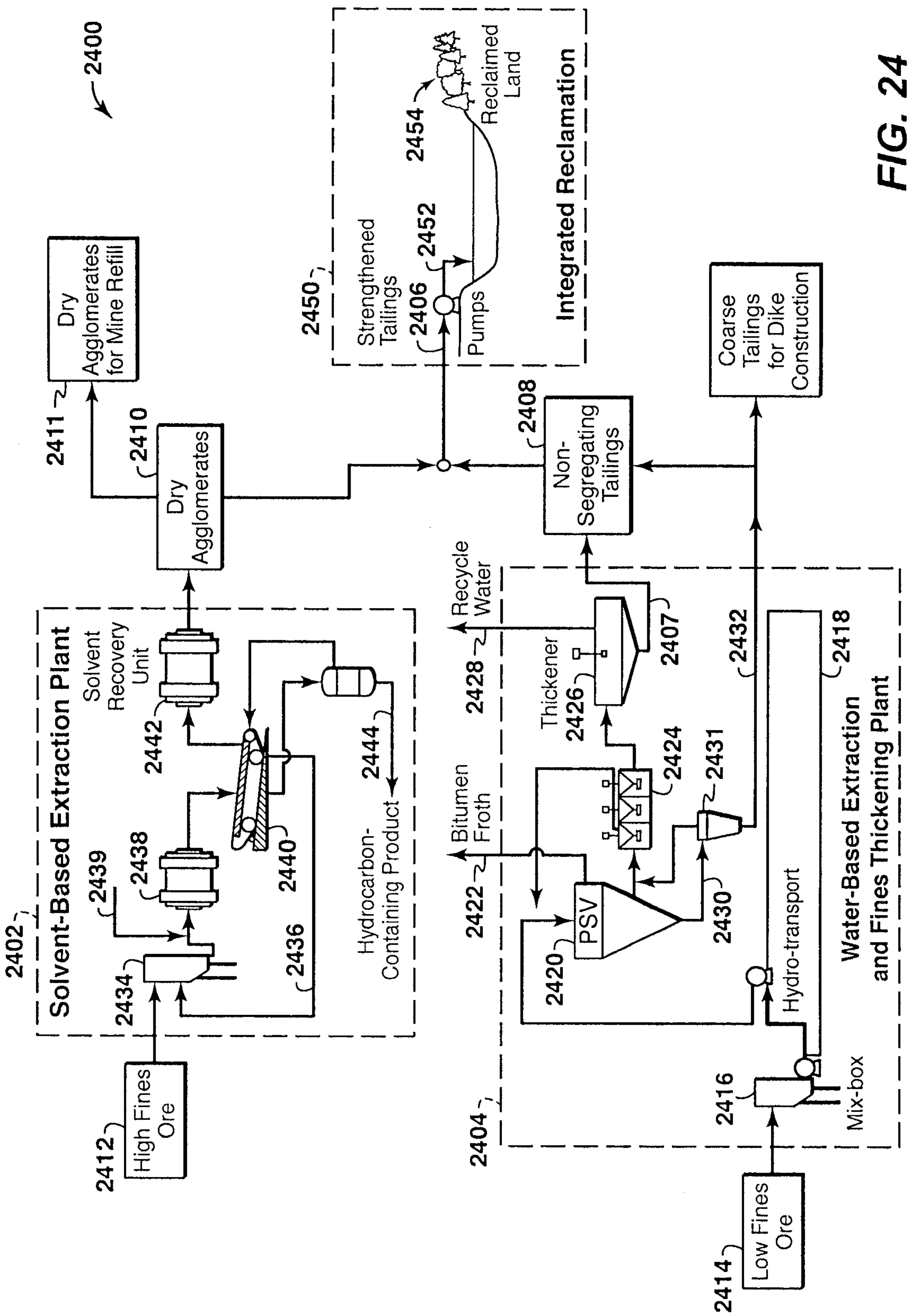
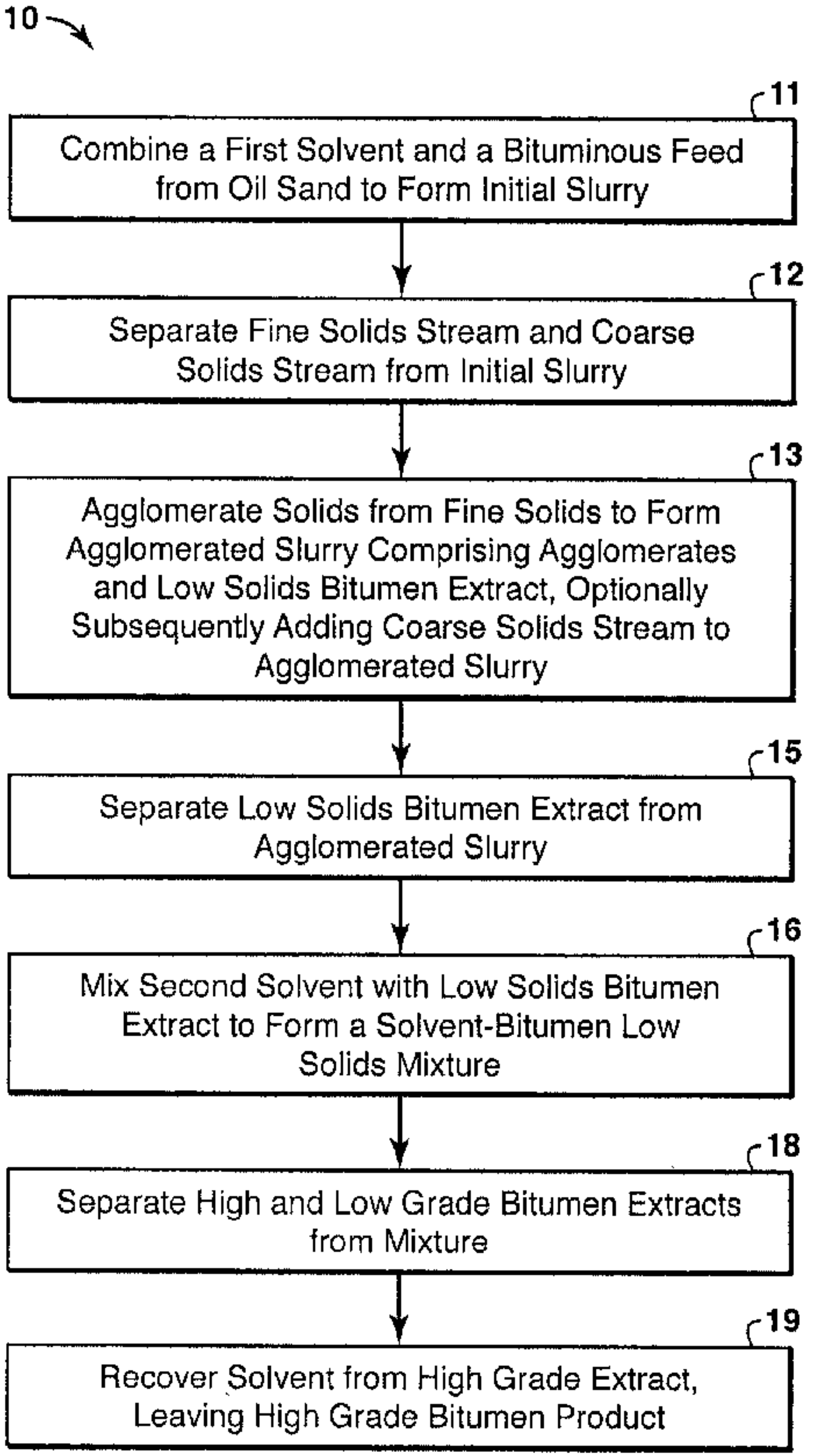

2400
Solvent-Based Extraction Plant
2402
High Fines Ore
2412
2434
2436
2439
2438
2440
2442
Solvent Recovery Unit
2444
Hydrocarbon-Containing Product
Dry Agglomerates
2410
2411
Dry Agglomerates for Mine Refill
Integrated Reclamation
2450
Strengthened Tailings
2406
Pumps
2452
2454
Reclaimed Land
Non-Segregating Tailings
2408
Coarse Tailings for Dike Construction
Water-Based Extraction and Fines Thickening Plant
2404
Low Fines Ore
2414
2416
Mix-box
Hydro-transport
2418
2420
PSV
2422
Bitumen Froth
2430
2431
2424
2426
Thickener
2428
Recycle Water
2407
2432

FIG. 24


10
11
Combine a First Solvent and a Bituminous Feed from Oil Sand to Form Initial Slurry
12
Separate Fine Solids Stream and Coarse Solids Stream from Initial Slurry
13
Agglomerate Solids from Fine Solids to Form Agglomerated Slurry Comprising Agglomerates and Low Solids Bitumen Extract, Optionally Subsequently Adding Coarse Solids Stream to Agglomerated Slurry
15
Separate Low Solids Bitumen Extract from Agglomerated Slurry
16
Mix Second Solvent with Low Solids Bitumen Extract to Form a Solvent-Bitumen Low Solids Mixture
18
Separate High and Low Grade Bitumen Extracts from Mixture
19
Recover Solvent from High Grade Extract, Leaving High Grade Bitumen Product