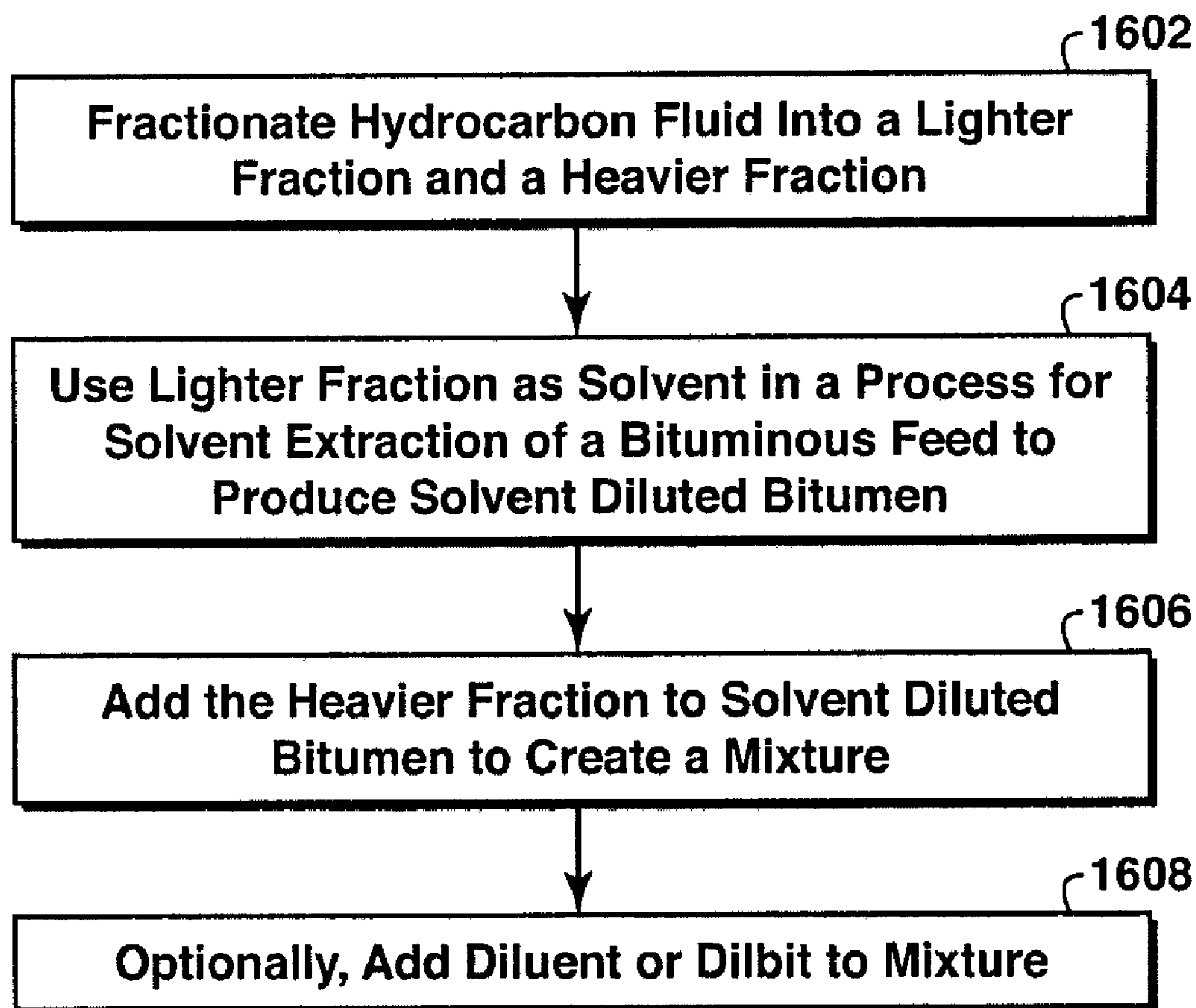




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(54) Titre : PROCÉDE ET SYSTEMES D'EXTRACTION AU SOLVANT DE BITUME A PARTIR DE SABLES BITUMINEUX  
(54) Title: PROCESSES AND SYSTEMS FOR SOLVENT EXTRACTION OF BITUMEN FROM OIL SANDS



(57) Abrégé/Abstract:

A process is described for extracting bitumen from bituminous feed, comprising fractionating hydrocarbon fluid into lighter and heavier fractions; extracting feed with the lighter fraction as solvent, producing solvent diluted bitumen; and combining the heavier



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

fraction with solvent diluted bitumen to form a high grade product. Extracting may involve combining the feed and first solvent as an initial slurry which is separated into fine and coarse streams; agglomerating the fine stream to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract; separating the extract therefrom; mixing a second solvent with the low solids bitumen extract to form a low solids mixture, the second solvent having a similar or lower boiling point than the first; separating the mixture into high and low grade bitumen extracts; and recovering solvent from the high grade extract, leaving high grade bitumen product. The first or second solvent may comprise the lighter fraction.

## ABSTRACT

A process is described for extracting bitumen from bituminous feed, comprising fractionating hydrocarbon fluid into lighter and heavier fractions; extracting feed with the lighter fraction as solvent, producing solvent diluted bitumen; and combining the heavier fraction with solvent diluted bitumen to form a high grade product. Extracting may involve combining the feed and first solvent as an initial slurry which is separated into fine and coarse streams; agglomerating the fine stream to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract; separating the extract therefrom; mixing a second solvent with the low solids bitumen extract to form a low solids mixture, the second solvent having a similar or lower boiling point than the first; separating the mixture into high and low grade bitumen extracts; and recovering solvent from the high grade extract, leaving high grade bitumen product. The first or second solvent may comprise the lighter fraction.

**PROCESSES AND SYSTEMS FOR SOLVENT EXTRACTION  
OF BITUMEN FROM OIL SANDS**

The present application is a divisional application of Canadian Patent Application Serial No. 2,724,806, filed December 10, 2010.

**FIELD**

**[0001]** Described herein are processes for hydrocarbon extraction from mineable deposits, such as bitumen from oil sands, and systems for implementing such processes.

**BACKGROUND**

**[0002]** Methodologies for extracting hydrocarbon from oil sands have required energy intensive processing steps to separate solids and water from the products having commercial value.

**[0003]** Previously described methodologies for solvent extraction spherical agglomeration (SESA), have not been commercially adopted. For a description of the SESA process, see Sparks et al., Fuel 1992(71); 1349-1353. Such processes 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 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 permits easy removal of the solids by sedimentation, screening or filtration.

**[0004]** Solvent recovery from the solids produced in previously described processes would be difficult, due to the nature of the solvent proposed for use in the extraction process. The proposed solvents in previously described 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. With such high boiling point solvents, the recovery would be energy intensive as significant energy is required to vaporize the residual hydrocarbon and to release hydrocarbon trapped within the agglomerates.

**[0005]** 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. While this may have resulted in a high recovery of bitumen, the energy intensity required for solvent recovery would be too high to be adopted in a commercial application.

**[0006]** 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.

**[0007]** 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.

**[0008]** 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. Although the method achieved low solids content in the resulting bitumen product with this approach, the solids content in the bitumen product fell short of optimal product quality of less than 400 ppm solids on a dry bitumen basis, especially for settling times less than 1 hour.

**[0009]** Others have proposed sequential use of two solvents in different solvent 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. However, it is not described or suggested that a second solvent could be effectively applied to a solvent extraction process with simultaneous solids agglomeration without upsetting the agglomeration process.

**[0010]** 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.

**[0011]** 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.

**[0012]** Canadian Patent Application 2,068,895 describes a method of incorporating a solvent extraction scheme into a water-based process flow sheet. The method involved a slurry conditioning process which allowed a hydrocarbon bitumen fraction, having high fines content, to be processed in a solvent extraction and solids agglomeration process to achieve higher overall bitumen recovery and reduced sludge volume.

**[0013]** The previously proposed process for agglomeration, as described by Govier and Sparks in "The SESA Process for the Recovery of Bitumen from Mined Oil Sands" (Proceedings of AOSTRA Oils Sands 2000 Symposium, Edmonton 1990, Paper 5), was of limited practicality partly due to the nature of the solvent which, when combined with tailings, made solvent recovery difficult. 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. As expected for such high boiling point solvents, bitumen recovery was consistently high. However, the energy intensity required for the solvent recovery was also high. There was no description in this document of the use of low boiling point solvents. Further, there was no suggestion in the Govier and Sparks process of how the process would have been adapted to employ a different solvent to more efficiently recover solvent, or of how appropriate feed slurry characteristics may have been achieved if a different solvent was employed.

**[0014]** 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. This would provide limited flexibility for sale or processing in a remote refinery.

**[0015]** The above-described agglomeration processes integrated solvent extraction and agglomeration within the same mixing vessel, which is inefficient because means of pre-conditioning and conveyance of the bituminous feed into the extraction / agglomerating unit is thus complicated. Conventional agglomeration units are large drums designed to integrate both the extraction and agglomeration aspects of the process, and are bulky and inefficient. Residence time in such agglomeration units would be lengthy, and process kinetics imposed restrictions on residence time. Dissolution time, the slow agitation required, limited slurry density, and the high containment volume required for extraction required the residence time in the agglomeration unit to be lengthy, and the process slow. Further, solvent recovery was not of concern in many previous processes, and is not addressed in most previously described processes.

**[0016]** 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.

**[0017]** 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.

**[0018]** 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.

**[0019]** It is desirable to provide processes and systems that increase the efficiency of oil sands extraction, reduce water use, and/or reduce energy intensity required to produce a commercially desirable bitumen product from oil sands. It is also desirable to produce a product

that is capable of meeting or exceeding requirements for downstream processing or pipeline transport.

**[0020]** Further, is desirable to provide systems for use in non-aqueous extraction processes to extract hydrocarbon from oil sands.

## **SUMMARY**

**[0021]** It is desirable to obviate or mitigate at least one disadvantage of previous processes and systems for hydrocarbon extraction from mineable deposits such as oil sands.

**[0022]** Solvent 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.

**[0023]** 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.

**[0024]** 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.

**[0025]** Advantageously, the inventive process permits 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.

**[0026]** As a result of the process, a high quality (or high grade) bitumen product is formed which is able to meet and/or exceed quality specifications of low water content and low solids content required for pipeline transport and downstream processing. The process permits premium, dry and clean bitumen to be obtained as well as a lower grade bitumen product to be obtained (which in certain cases may comprise primarily of asphaltenes) for various commercial uses. By using the process described herein, it is possible to achieve a high grade bitumen product, as well as lower grades of bitumen products. For example, a high grade bitumen product is considered to be one containing less than about 0.04 wt% solids (400 ppm), which may be

obtained according to the instant process. Further, such a product formed by the process described herein may contain about 0.5 wt% or less of water + solids of the dry bitumen product. Water content may be less than or equal to 200 ppm in the final high grade 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 Govier and Sparks process. Low grade bitumen products having more than 400 ppm solids, and more than 200 ppm water may additionally be obtained according to the process described herein. An exemplary low grade product formed according to the process described may be one having about 0.5 wt% of water + solids of the dry bitumen product.

**[0027]** A process for recovery of bitumen from oil sands is described herein. In the process, a first solvent is combined with a bituminous feed from oil sands to form an initial slurry. The initial slurry is separated into a fine solids stream and a coarse solids stream. Solids from the fine solids stream are agglomerated to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract. The low solids bitumen extract is then separated from the agglomerated slurry, and a second solvent is mixed with the low solids bitumen extract to form a solvent-bitumen low solids mixture. The second solvent is selected to have a similar or lower boiling point than the first solvent. The mixture is then subjected to gravity separation to produce a high grade bitumen extract and a low grade bitumen extract. The first and second solvent can be recovered from the high grade bitumen extract, leaving a high grade bitumen product.

**[0028]** Further, described herein is a process for recovery of bitumen from oil sands. The process involves combining a first solvent and a bituminous feed from oil sands to form an initial slurry. The initial slurry is then separated into a fine solids stream and a coarse solids stream. Solids from the fine solids stream are agglomerated to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract. A second solvent is then mixed with the agglomerated slurry to form a solvent-bitumen agglomerated slurry mixture, the second solvent having a similar or lower boiling point than the first solvent. This mixture is subjected to separation to produce a high grade bitumen extract and a low grade bitumen extract. The first and second solvent can then be recovered from the high grade bitumen extract, leaving a high grade bitumen product; and the first and second solvent can also be recovered from the low grade bitumen extract, leaving a low grade bitumen product.

**[0029]** Described herein is a further process for recovery of bitumen from oil sands comprising combining a first solvent and a bituminous feed from oil sands to form an initial slurry, which is then separated into a fine solids stream and a coarse solids stream. The first solvent is then recovered from the coarse solids stream. Solids are agglomerated from the fine solids

stream to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract, and the low solids bitumen extract is then separated from the agglomerated slurry. A second solvent is then mixed 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. The mixture is subjected to gravity separation to produce a high grade bitumen extract and a low grade bitumen extract; and the first and second solvent from the high grade bitumen extract, leaving a high grade bitumen product.

**[0030]** Additionally, a process is described herein for recovery of a bitumen product from oil sands. The process comprises combining a first solvent and a bituminous feed from oil sands to form an initial slurry, and separating the initial slurry into a fine solids stream and a coarse solids stream. The first solvent is recovered from the first coarse solids stream, and solids are agglomerated from the fine solids stream to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract. Further, mixing a second solvent with the agglomerated slurry to form a solvent-bitumen agglomerated slurry mixture is then conducted, the second solvent having a similar or lower boiling point than the first solvent. The mixture is then subjected to separation to produce a high grade bitumen extract and a low grade bitumen extract. The first and second solvent are then recovered from the high grade bitumen extract, leaving a high grade bitumen product; and the first and second solvent are also recovered from the low grade bitumen extract, leaving a low grade bitumen product.

**[0031]** Additionally, there is described herein a process for recovery of bitumen from oil sands comprising combining a first solvent and a bituminous feed from oil sands to form an initial slurry and agglomerating solids from the initial slurry to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract. The low solids bitumen extract is then separated from the agglomerated slurry. A second solvent is then mixed 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. The mixture is subjected to gravity separation to produce a high grade bitumen extract and a low grade bitumen extract; and the first and second solvent are then recovered from the high grade bitumen extract, leaving a high grade bitumen product. In this process, the ratio of first solvent to bitumen in the initial slurry is selected to avoid precipitation of asphaltenes during agglomeration.

**[0032]** Further, there is provided herein a process for recovery of a bitumen product from oil sands. The process involves combining a first solvent and a bituminous feed from oil sands to form an initial slurry, and agglomerating solids from initial slurry to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract. A second solvent is mixed with the

agglomerated slurry to form a solvent-bitumen agglomerated slurry mixture, the second solvent having a similar or lower boiling point than the first solvent. The mixture is then subjected to separation to produce a high grade bitumen extract and a low grade bitumen extract comprising substantially all solids and water. The first and second solvents are then recovered from the high grade bitumen extract, leaving a high grade bitumen product; and similarly, the first and second solvents are then recovered from the low grade bitumen extract, leaving a low grade bitumen product. In this instance, the ratio of first solvent to bitumen in the initial slurry is selected to avoid precipitation of asphaltenes during agglomeration.

**[0033]** A system is provided for recovery of bitumen from oil sands comprising a slurry system wherein a bituminous feed is mixed with 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.

**[0034]** Additionally, a system for recovery of bitumen from oil sands is described herein, comprising 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.

**[0035]** The system may further comprise a secondary solid-liquid separator for recovering additional bitumen product from the agglomerates and producing solvent-wet agglomerates, and at least one solvent recovery unit for recovering the first solvent from the solvent-wet agglomerates and other solids rejected from the system.

**[0036]** Advantageously, non-aqueous solvent extraction of oil sands, combined with particle enlargement through agglomeration can result in a reduction in fresh water withdrawal from nearby rivers or other water sources, and offers an opportunity for improved tailings management versus currently practiced water based extraction process.

**[0037]** There is described herein a system for recovery of bitumen from oil sands comprising a slurry system in which a bituminous feed is mixed with solvent to form an initial slurry; an agglomerator for mixing the initial slurry and a water-containing fluid to agglomerate the solids from the initial slurry, producing an agglomerated slurry; a separator unit for separating the agglomerated slurry into agglomerates and a low solids bitumen extract, said separator unit comprising a countercurrent washer for solvent washing of agglomerates with progressively cleaner solvent; a tailings solvent recovery unit for removing solvent from washed agglomerates; and a solvent recovery unit for separating solvent from the low solids bitumen extract.

**[0038]** There is described herein a system for recovery of bitumen from oil sands comprising: a mix box in which a bituminous feed is mixed with solvent to form an initial slurry; an agglomerator for mixing the initial slurry with a water-containing fluid to agglomerate the solids from the initial slurry, producing an agglomerated slurry; a screen to separate oversized rejects; a rejects dryer for receiving rejects and recovering solvent therefrom; a separator unit comprising a deep cone settler for separating agglomerates and a low solids bitumen extract from the agglomerated slurry, and a belt filter for receiving agglomerates from deep cone settler underflow and for solvent washing of agglomerates using countercurrent washing with progressively cleaner solvent; a tailings solvent recovery unit for recovering solvent from washed agglomerates; and a solvent recovery unit for separating solvent from the low solids bitumen extract.

**[0039]** There is described herein a system for recovery of bitumen from oil sands comprising: a slurry system in which a bituminous feed is mixed with solvent and optionally a water-containing fluid to form an initial slurry; one or more retention tank for receiving and agitating the initial slurry to agglomerate solids from the initial slurry to produce an agglomerated slurry; a separator unit for separating agglomerates and a low solids bitumen extract from the agglomerated slurry, said separator unit comprising a deep cone settler for separating a low solids bitumen extract, and a belt filter receiving agglomerates as underflow from the deep cone settler for solvent washing of agglomerates using countercurrent washing with progressively cleaner solvent; a tailings solvent recovery unit for removing solvent from washed agglomerates; and a solvent recovery unit for separating solvent from the low solids bitumen extract.

**[0040]** Processes and systems are described herein which involve the use of a lighter fraction of a hydrocarbon fluid, for example a diluent (e.g. natural gas condensate or naphtha), as a solvent source for solvent extraction of bitumen. The hydrocarbon fluid is fractionated into a heavier fraction and a lighter fraction. The lighter fraction (with a lower boiling point) is used as the solvent in the extraction (as described below, more than one solvent may be used in the extraction). The heavier fraction is recombined with the solvent diluted bitumen product (following

solvent extraction) to satisfy shipping viscosity, density and vapour pressure requirements. In addition, this solvent-extracted dilbit may be further combined with other diluents or dilbit sourced from nearby operations (product from water-based bitumen extraction, from an in situ bitumen recovery process such as SAGD, or even synthetic crude from nearby upgraders. Diluent and/or diluted bitumen can be added thereto as required to meet pipeline specifications.

**[0041]** Processes are described herein for extracting bitumen from a bituminous oil sands feed from oil sands. Such processes may comprise fractionating a hydrocarbon fluid into a lighter fraction and a heavier fraction; effecting solvent extraction of the bituminous feed with the lighter fraction as the solvent to produce solvent diluted bitumen; and combining the heavier fraction with the solvent diluted bitumen to form a high grade bitumen product.

**[0042]** Advantageously, an existing diluent pipeline accessing an existing site for use in water based extraction processes can be accessed for the diluent. In such an embodiment, transportation costs can be minimized, existing storage facilities may be utilized, and other efficiencies can be realized by integration of a solvent extraction process with a proximal water based extraction process.

**[0043]** The solvent extraction may be, but is not limited to, one described below or one described in the background section.

**[0044]** Other aspects and features 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**

**[0045]** Embodiments will now be described, by way of example only, with reference to the attached Figures.

**[0046]** **Figure 1** is a schematic representation of an embodiment of the process.

**[0047]** **Figure 2** illustrates an exemplary embodiment of the process consistent with the representation shown in **Figure 1**.

**[0048]** **Figure 3** is a schematic representation of an embodiment of the process.

**[0049]** **Figure 4** illustrates an exemplary embodiment of the process consistent with the representation shown in **Figure 3**.

**[0050]** **Figure 5** is a schematic representation of an embodiment of the process.

**[0051]** **Figure 6** illustrates an exemplary embodiment of the process consistent with the representation shown in **Figure 5**.

- [0052] **Figure 7** provides a schematic representation of an embodiment of the system described herein.
- [0053] **Figure 8** illustrates an exemplary system within the scope of the present disclosure.
- [0054] **Figure 9** illustrates an exemplary ore preparation and slurry system design for systems described herein.
- [0055] **Figure 10** illustrates an agglomerator for use with exemplary systems described herein.
- [0056] **Figure 11** illustrates an optional cone settler for agglomerates for systems described herein.
- [0057] **Figure 12** illustrates a filtration unit for embodiments of systems described herein.
- [0058] **Figure 13** illustrates an exemplary tailings solvent recovery unit for use with systems described herein.
- [0059] **Figure 14** illustrates a first embodiment of a system described herein.
- [0060] **Figure 15** illustrates a second embodiment of a system described herein.
- [0061] **Figure 16** is schematic representation of a process within the scope of the present disclosure.
- [0062] **Figure 17** illustrates an exemplary embodiment of a process consistent with the representation shown in **Figure 16**.
- [0063] **Figure 18** is a graph showing Thermo Gravimetric analysis (TGA) results of a sample described herein, in particular change in weight over time.
- [0064] **Figure 19** is a graph showing Thermo Gravimetric analysis (TGA) results of a sample described herein, in particular change in weight between 10 °C and 600 °C.
- [0065] **Figure 20** is a graph showing drying rate curve of cyclohexane agglomerates based on Thermo Gravimetric analysis (TGA) results of a sample described herein.
- [0066] **Figure 21** is a graph showing drying rate over a temperature range based on Thermo Gravimetric analysis (TGA) results of a sample described herein.
- [0067] **Figure 22** is a graph showing moisture content of water and solvent in agglomerates as a function of time based on Thermo Gravimetric analysis (TGA) results of a sample described herein, over a 10 minute period.

## DETAILED DESCRIPTION

- [0068] The description below is divided into three parts. **PART 1** describes processes and systems for recovery of bitumen from oil sands, **PART 2** describes systems for solvent extraction

of bitumen from oil sands, and **PART 3** describes processes for solvent extracting bitumen involving fractionating a diluent.

**[0069]        PART 1**

**[0070]        Processes and Systems for Recovery of Bitumen from Oil Sands.**

**[0071]**        Generally, there is provided herein a process and system for fines capture or agglomeration and solvent extraction of bitumen from oil sands. Processing oil sands according to the processes described herein may permit high throughput and improved product quality and value.

**[0072]**        A process and system for recovery of bitumen from oil sands is provided herein.

**[0073]**        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 comprises 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 comprises bitumen that would otherwise not have been recovered, may be used as a bituminous feed. Such a bituminous feed may be also derived directly from oil shale, oil bearing diatomite or oil saturated sandstones.

**[0074]**        As used herein, the term "agglomerate" refers to conditions that produce a cluster, aggregate, collection or mass, such as nucleation, coalescence, layering, sticking, clumping, fusing and sintering, as examples.

**[0075]**        ***Embodiment In Which First Solvent Added Prior To Agglomeration, Second Solvent Added After Agglomerates Removed.*** In one embodiment of the process, a first solvent is added to a bituminous feed, to form an initial slurry and to dissolve bitumen. This initial slurry goes on to agglomeration. After the agglomerated slurry is formed within the agglomerator, a second solvent added to extract bitumen. This embodiment comprises combining a first solvent and a bituminous feed from oil sands to form an initial slurry. The initial slurry is then separated into a fine solids stream and a coarse solids stream. The fine solids stream is subjected to agglomeration to form an agglomerated slurry, which includes agglomerates and a low solids

bitumen extract. The low solids bitumen extract is separated from the agglomerated slurry, and subsequently mixed with a second solvent to form a solvent-bitumen low solids mixture. In this embodiment, the second solvent is one having a similar or lower boiling point than the first solvent. The mixture is subjected to gravity separation to produce a high grade bitumen extract and a low grade bitumen extract. The extracts are subjected to solvent recovery of both the first and second extracts, leaving a low grade bitumen product and a high grade bitumen product.

**[0076]        *Embodiment In Which Second Solvent Added Prior To Separating Low Solids Bitumen Extract From Agglomerated Slurry.*** An additional process for recovery of bitumen from oil sands is provided in which the second solvent is added prior to separating low solids bitumen extract and agglomerates from the agglomerated slurry. This embodiment involves combining a first solvent and a bituminous feed from oil sands to form an initial slurry, and subsequently separating the initial slurry into a fine solids stream and a coarse solids stream. Solids from the fine solids stream are agglomerated to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract. A second solvent is then mixed with the agglomerated slurry to form a solvent-bitumen agglomerated slurry mixture, the second solvent having a similar or lower boiling point than the first solvent. The mixture is then subjected to separation to produce a high grade bitumen extract and a low grade bitumen extract. The first and second solvent are then recovered from the high grade bitumen extract, leaving a high grade bitumen product. The first and second solvent are also recovered from the low grade bitumen extract, leaving a low grade bitumen product.

**[0077]**        In this embodiment of the process, the second solvent may be added prior to separating low solids bitumen extract from the agglomerated slurry. Thus, the second solvent will contact with the agglomerates and the low solids bitumen extract to form the solvent-bitumen agglomerated slurry mixture, which is processed further into high grade and low grade products, as described in further detail herein below.

**[0078]        *Embodiment In Which Coarse Solids are Processed Separately From Agglomeration Of Fine Solids Stream.*** Additionally, another embodiment comprises a process for recovery of bitumen from oil sands in which a first solvent and a bituminous feed from oil sands are combined to form an initial slurry. The initial slurry is then separated into a fine solids stream and a coarse solids stream. The first solvent is recovered from the coarse solids stream, and solids are agglomerated from the fine solids stream to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract. The low solids bitumen extract is separated from the agglomerated slurry, and mixed with a second solvent to form a solvent-bitumen low solids mixture. In this embodiment, the second solvent has a similar or lower boiling point than the first

solvent. The mixture is then subjected to gravity separation to produce a high grade bitumen extract and a low grade bitumen extract. The first and second solvent are recovered from the high grade bitumen extract, leaving a high grade bitumen product.

**[0079]** In this embodiment of the process, the coarse solids stream is processed separately from the fine solids stream, and will not optionally be included back into the mixture. Coarse solids are processed separately to remove the solvent therefrom, or are added back into the slurry system or separator, for subsequent processing in an iterative manner.

**[0080]** *Embodiment In Which Coarse Solids Are Processed Separately From Agglomeration Of Fine Solids Stream, And The Second Solvent Is Mixed With The Agglomerated Slurry.* A further embodiment comprises a process for recovery of a bitumen product from oil sands comprising: combining a first solvent 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; recovering the first solvent from the coarse solids stream; agglomerating solids from the fine solids stream to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract; mixing a second solvent with the agglomerated slurry to form a solvent-bitumen agglomerated slurry mixture, the second solvent having a similar or lower boiling point than the first solvent; subjecting the mixture to separation to produce a high grade bitumen extract and a low grade bitumen extract; recovering the first and second solvent from the high grade bitumen extract, leaving a high grade bitumen product; and recovering the first and second solvent from the low grade bitumen extract, leaving a low grade bitumen product.

**[0081]** In this embodiment of the process, the first solvent may be recovered from the coarse solids stream separately, and again there is no option to re-introduce the coarse solids stream into a downstream aspect of the process, for example, into the agglomerated slurry, as there would be in other embodiments of the process. This embodiment also involves combining the second solvent with the agglomerated slurry.

**[0082]** *Embodiment In Which Initial Slurry Is Directed To Agglomeration Without Separation Of Coarse Solids, And In Which Second Solvent Is Introduced After Agglomerates Are Removed.* A further embodiment of the process for recovery of bitumen from oil sands is described herein in which a first solvent is combined with a bituminous feed from oil sands to form an initial slurry. Solids in the initial slurry are agglomerated to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract. A low solids bitumen extract is separated from the agglomerated slurry. A second solvent is then mixed 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. The mixture is then subjected to

gravity separation to produce a high grade bitumen extract and a low grade bitumen extract. The first and second solvent are then recovered from the high grade bitumen extract, leaving a high grade bitumen product. In this embodiment, the ratio of first solvent to bitumen in the initial slurry is selected to avoid precipitation of asphaltenes during agglomeration.

**[0083]** In this embodiment of the process, the step of separating the initial slurry into a fine solids stream and a coarse solids stream is not conducted. Thus, the bituminous feed is combined with the first solvent to prepare the initial slurry, which can then be agglomerated without the requirement for further separation. In this embodiment, the first solvent is mixed with the bituminous feed, but the second solvent is not introduced until after the low solids bitumen extract has been separated from the agglomerates. In this way, the agglomerates need not come into contact with the second solvent.

**[0084]** ***Embodiment In Which Initial Slurry Is directed To Agglomeration Without Separation Of Coarse Solids, And In Which Second Solvent Is Introduced Prior To Removal Of Agglomerates.*** A further embodiment of the process is described herein for recovery of a bitumen product from oil sands. The embodiment comprises combining a first solvent and a bituminous feed from oil sands to form an initial slurry. Solids from the initial slurry are agglomerated to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract. A second solvent is then mixed with the agglomerated slurry to form a solvent-bitumen agglomerated slurry mixture, the second solvent having a similar or lower boiling point than the first solvent. The mixture is subjected to separation to produce a high grade bitumen extract and a low grade bitumen extract, in which the low grade extract comprises substantially all solids and water. The first and second solvents are then recovered from the high grade bitumen extract, leaving a high grade bitumen product. The first and second solvent are recovered from the low grade bitumen extract, leaving a low grade bitumen product. In this embodiment, the ratio of first solvent to bitumen in the initial slurry is selected to avoid precipitation of asphaltenes during agglomeration.

**[0085]** In this embodiment of the process, the step of separating the initial slurry into a fine solids stream and a coarse solids stream is not conducted. Thus, the bituminous feed is combined with the first solvent to prepare the initial slurry, which is then agglomerated without the requirement for further separation. In this embodiment, the first solvent is mixed with the bituminous feed, and later, the agglomeration of solids occurs. However, the second solvent is added to the agglomerated slurry, so as to form a mixture. In this embodiment, all components of the agglomerated slurry are contacted by both the first and the second solvent. Both solvents are then recovered from each of the high grade bitumen extract and the low grade bitumen extract.

**[0086]        *Embodiment Of A System In Which A Fine/Coarse Solids Separator And A Gravity Separator Are Employed.***

**[0087]**        A system is provided for recovery of bitumen from oil sands comprising a slurry system wherein a bituminous feed is mixed with a first solvent to form an initial slurry. A fine/coarse solids separator is included in the system, and is in fluid communication with the slurry system for receiving the initial slurry and separating a fine solids stream therefrom. The system additionally includes 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 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 the first solvent or the second solvent in a high grade bitumen extract arising from the gravity separator and for separating bitumen therefrom.

**[0088]**        In this embodiment of the system, both a fine/coarse solids separator, and a gravity separator are employed, consistent with the embodiment depicted and described previously in respect of **Figure 2**.

**[0089]        *Embodiment Of A System In Which There Is No Fine/Coarse Solids Separator Component Upstream Of The Agglomerator.***

**[0090]**        A further embodiment of a system for recovery of bitumen from oil sands is described herein comprising a slurry system wherein a bituminous feed is mixed with a first solvent to form an initial slurry. Further, the system includes an agglomerator for receiving the initial slurry, for agglomerating solids and producing an agglomerated slurry. A primary solid-liquid separator is used 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, 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 is also incorporated into the system.

**[0091]**        In this embodiment of the system, there is no requirement for a fine/coarse solids separator, and so both fines and coarse solids may be agglomerated together in the agglomerator.

**[0092]**        Additional process details are described below which are generally applicable to most embodiments listed above, with some exceptions.

**[0093]        *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. 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.

**[0094]** 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.

**[0095]** ***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.

**[0096]** ***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.

**[0097]        *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.

**[0098]**        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.

**[0099]**        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.

**[00100]**       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.

**[00101]** 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.

**[00102]** 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.

**[00103]** 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.

**[00104]** *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.

**[00105]** *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 10wt%, for example, less than 5wt%.

**[00106]      *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.

**[00107]**      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 bypass 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.

**[00108]**      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.

**[00109]**      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.

**[00110]      *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.

**[00111]      *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.

**[00112]**      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.

[00113] 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.

[00114] **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.

[00115] 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.

[00116] 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.

[00117] 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.

[00118] 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.

**[00119]** 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.

**[00120]** 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.

**[00121]** **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<sub>4</sub>-C<sub>9</sub> cyclic and/or open chain aliphatic solvents would be appropriate.

**[00122]** Exemplary cycloalkanes include cyclohexane, cyclopentane, or a mixture thereof.

**[00123]** 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.

**[00124]** A mixture of C<sub>4</sub>-C<sub>10</sub> cyclic and/or open chain aliphatic solvents would also be appropriate. For example, it can be a mixture of C<sub>4</sub>-C<sub>9</sub> cyclic aliphatic hydrocarbons and paraffinic solvents where the percentage of the cyclic aliphatic hydrocarbon in the mixture is greater than 50%.

**[00125]** **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 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.

**[00126]** 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<sub>2</sub> to C<sub>10</sub> 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.

**[00127]** *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.

**[00128]** *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.

**[00129]** 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.

**[00130]** ***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 conducted 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.

**[00131]** 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.

**[00132]** 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.

**[00133]** 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.

**[00134]** ***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 is entrained therein. Because an exemplary solvent:bitumen ratio in the agglomerator may be 2:1 or lower, it is acceptable to use recycled solvent containing bitumen to achieve this ratio. 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

**[00135]** 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.

**[00136]** 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.

**[00137]** 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 slurring 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.

**[00138]** 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.

**[00139]** 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.

**[00140]** 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.

**[00141]** ***Low and High Grade Bitumen Extracts and Products.*** Once solvent is removed from the low grade or high grade bitumen extracts, the resulting products may be used for commercial purposes. According to certain embodiments, the low grade bitumen extract is derived from gravity separation, and generally includes water and solids that may have settled into the underflow in the separation process together with bitumen and solvent. This underflow is removed and processed separately. This leaves a high grade extract as the overflow of the separation process.

The high grade bitumen extract is considered to be of a "high grade" in terms of bitumen products, as it meets and may even exceed pipeline specifications. It has been essentially de-watered, and does not contain solids removed by gravity separation, for example. The high grade bitumen product formed according to embodiments described herein, may have a low water content that is nearly undetectable, such as a content of  $\leq 200$  ppm. The high grade product may have a low solids content of  $\leq 400$  ppm or lower as a result of embodiments of the process. The low grade bitumen product may in fact be effectively similar to a "high grade" product, with very low water and solids content. This may be the case for embodiments where low water and low solids are present in the low grade bitumen extract emanating from solid-liquid separation. In some embodiments, the asphaltene content of the low grade bitumen product are high relative to the high grade bitumen product. For example, asphaltene content up to 98 wt% may be realized in the low grade bitumen product if the second solvent is paraffinic and the amount mixed with the low solids extract causes the precipitation of asphaltenes. In other embodiments, the asphaltene content of both products might in fact be similar but the low grade bitumen product is richer in polar components of the bitumen which are soluble in the solvent.

**[00142]** ***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.

**[00143]** 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.

**[00144]** *Dilution of Agglomerator Discharge to Improve Product Quality.* The first solvent or second solvent or mixtures thereof may be added to the agglomerated slurry for dilution of the slurry before discharge into the primary solid-liquid separator, which may be for example a deep cone settler. This dilution can be carried out in a staged manner to pre-condition the primary solid-liquid separator feed to promote higher solids settling rates and lower solids content in the solid-liquid separator's overflow. The solvent(s) with which the slurry is diluted may be derived from recycled liquids from the liquid-solid separation stage or from other sources within the process.

**[00145]** When dilution of agglomerator discharge is employed in this embodiment, the solvent to bitumen ratio of the agglomerator feed slurry is set to obtain from about 10 to about 90 wt% bitumen in the discharge, and a workable viscosity at a given temperature. In certain cases, these viscosities may not be optimal for the solid-liquid separation (or settling) step. In such an instance, a dilution solvent of equal or lower viscosity may be added to enhance the separation of the agglomerated solids in the clarifier, while improving the quality of the clarifier overflow by reducing viscosity to permit more solids to settle. Thus, dilution of agglomerator discharge may involve adding either the first or second solvent, or a separate dilution solvent, which may, for example, comprise an alkane.

**[00146]** **Figure 1** is a schematic representation of an embodiment of the process (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.

**[00147]** **Figure 2** outlines an embodiment of the process in which the second solvent is mixed with a low solids bitumen extract derived from separation of the agglomerated slurry in a clarifier.

**[00148]** 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, a pump or a 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.

**[00149]** 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.

**[00150]** The fine/coarse solids separator (206) may be a settling vessel, cyclone or screen, or any suitable separation device known in the art. 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.

**[00151]** 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).

**[00152]** The second solvent may be one having a low boiling point. The bitumen-containing mixture derived 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 directed either toward forming a high grade bitumen product (226) once the solvent has been extracted in a solvent recovery unit (228), or underflow 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.

**[00153]** 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).

**[00154]** 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% solid in dry bitumen. 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.

**[00155]** Advantageously, the process permits recovery of both the first solvent (209) and the second solvent (222). In one embodiment, the first solvent (209) 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.

**[00156]** 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.

**[00157]** 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.

**[00158]** 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.

**[00159]** **Figure 3** is a schematic representation of a further embodiment of the process (30) described herein. The combining (31) of a first solvent and a bituminous feed from oil sand to form 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.

**[00160]**        **Figure 4** illustrates an embodiment of the process 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.

**[00161]**        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.

**[00162]**        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.

**[00163]**        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.

**[00164]**        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.

**[00165]** 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.

**[00166]** 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.

**[00167]** 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) 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.

**[00168]** 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.

**[00169]** 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.

**[00170]** 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..

**[00171]** 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.

**[00172]** 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.

**[00173]** **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.

**[00174]** 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.

**[00175]** 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).

**[00176]** 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).

**[00177]** 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 (609c) 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.

**[00178]** 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).

**[00179]** 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).

**[00180]** 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.

**[00181]** 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.

**[00182]** 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.

**[00183]** 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 (609f) 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.

**[00184]**        **Figure 7** is a schematic representation of a system (70) according to an embodiment. 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.

**[00185]**        **PART 2**

**[00186]**        **Systems for Solvent Extraction of Bitumen from Oil Sands.**

**[00187]**        Generally, described herein are systems for use in fines capture or agglomeration and solvent extraction of bitumen from oil sands. Processing oil sands within systems according to those described herein permits high throughput and improved product quality and value.

**[00188]**        Using non-aqueous process for extraction of bitumen from oil sands with sequential agglomeration of fines contained therein requires specialized systems and equipment. Systems developed specifically for non-aqueous extraction will serve to simplify solid-liquid separation and produce bitumen with a quality specification of water content and low solids that exceeds downstream processing and pipeline transportation requirements.

**[00189]**        Described herein are various systems that can be used in non-aqueous processes for bitumen extraction. Systems are provided for processing crushed oil sand, which may include,

but are not limited to the following components: a ore preparation plant; a slurry system; an agglomerator which may include a discharge screening system; a primary solid-liquid separator; a secondary solid-liquid separator; a tailings solvent recovery unit; a rejects solvent recovery unit; a bitumen extract solvent recovery unit; a vent recovery system; supporting utilities and off site utilities; and/or an optional product cleaning plant.

**[00190]** A system is described herein for recovery of bitumen from oil sands. Such a system may comprise a slurry system in which a bituminous feed is mixed with solvent to form an initial slurry; an agglomerator for mixing the initial slurry and a water-containing fluid to agglomerate the solids from the initial slurry, producing an agglomerated slurry; a separator unit for separating the agglomerated slurry into agglomerates and a low solids bitumen extract, said separator unit comprising a countercurrent washer for solvent washing of agglomerates with progressively cleaner solvent; a tailings solvent recovery unit for removing solvent from washed agglomerates; and a solvent recovery unit for separating solvent from the low solids bitumen extract.

**[00191]** The separator unit may comprise a belt filter or a multi-stage counterflow cyclone for solvent washing agglomerates using progressively cleaner solvent. Further, the separator unit may include a gravity separator, cyclone, or screen, separating a low solids extract from the agglomerated slurry prior to solvent washing agglomerates. In certain embodiments, the separator unit may have a primary solid-liquid separator for receiving and separating the agglomerated slurry, as well as a secondary solid-liquid separator for receiving underflow from the primary solid-liquid separator. In some instances, the primary solid-liquid separator acts as a surge bin to smooth operating fluctuations in the composition of the agglomerated slurry for the secondary solid-liquid separator. The primary solid-liquid separator may be a deep cone settler, in which case the secondary solid-liquid separator may involve a filtration unit for receiving underflow from the deep cone settler for solvent washing of agglomerates.

**[00192]** The filtration unit, when present, may involve a belt filter for countercurrent washing of agglomerates.

**[00193]** The system may include a rejects dryer for recovering solvent from oversized rejects of the initial slurry.

**[00194]** The solvent recovery unit for separating solvent from the low solids bitumen extract may comprise a distillation unit, according to certain exemplary embodiments.

**[00195]** An optional steam source for pre-conditioning feed entering the slurry system may be incorporated into the system described herein.

**[00196]** Optionally, the slurry system may be a mixing unit in which the mixing of the initial slurry is effected. In such instances, the mixing unit could comprise for example: a mix box, a pump, or a combination thereof. The slurry may thus be permitted to flow by gravity from the mixing unit into the agglomerator.

**[00197]** The slurry system can optionally be maintained in a low oxygen environment. The low oxygen environment may comprises a gas blanket formed from a gas that is not reactive under process conditions. The gas may comprise nitrogen, methane, carbon dioxide, argon, steam, or a combination thereof.

**[00198]** The agglomerator may compriss one or more rotating drums in which the initial slurry is subjected to agitation, or one or more tanks through which the initial slurry is pumped. The agglomerator may have an inlet thereon for receiving the water-containing fluid to promote agglomeration of fines therein.

**[00199]** A further system for recovery of bitumen from oil sands is described herein, the components of which are outlined below. The system may include a mix box in which a bituminous feed is mixed with solvent to form an initial slurry; an agglomerator for mixing the initial slurry with a water-containing fluid to agglomerate the solids from the initial slurry, producing an agglomerated slurry; a screen to separate oversized rejects; a rejects dryer for receiving rejects and recovering solvent therefrom; a separator unit comprising a deep cone settler for separating agglomerates and a low solids bitumen extract from the agglomerated slurry, and a belt filter for receiving agglomerates from deep cone settler underflow and for solvent washing of agglomerates using countercurrent washing with progressively cleaner solvent; a tailings solvent recovery unit for recovering solvent from washed agglomerates; and a solvent recovery unit for separating solvent from the low solids bitumen extract.

**[00200]** Such an exemplary system may additionally comprise a filtration unit for washing oversized rejects to recover bitumen. An inlet may be included on the agglomerator for receiving water-containing fluids to promote the agglomeration of fines therein.

**[00201]** A further exemplary system for recovery of bitumen from oil sands is described herein which includes a slurry system in which a bituminous feed is mixed with solvent and optionally a water-containing fluid to form an initial slurry; one or more retention tank for receiving and agitating the initial slurry to agglomerate solids from the initial slurry to produce an agglomerated slurry; a separator unit for separating agglomerates and a low solids bitumen extract from the agglomerated slurry, said separator unit comprising a deep cone settler for separating a low solids bitumen extract, and a belt filter receiving agglomerates as underflow from the deep cone settler for solvent washing of agglomerates using countercurrent washing with

progressively cleaner solvent; a tailings solvent recovery unit for removing solvent from washed agglomerates; and a solvent recovery unit for separating solvent from the low solids bitumen extract. In certain embodiments, agitating the initial slurry in the retention tank occurs without rotating the tank. Such a system may additionally comprise a conduit from the retention tank to the slurry system, for recirculating a portion of the agglomerated slurry. A pump may be included, for directing the portion of the agglomerated slurry from the retention tank back to the slurry system for recirculation. The exemplary system may additionally comprise an inlet in the retention tank for including a water-containing stream to promote agglomeration of fines therein.

**[00202]** An exemplary system within the scope of the present disclosure, includes an ore preparation plant, a slurry system, an agglomerator, optionally a gravity separator, a filtration unit, a tailings solvent recovery unit, and an optional bitumen extract solvent recovery unit. Each component is described individually herein, followed by exemplary system embodiments.

**[00203] Ore Preparation Plant (OPP).** In an overall system, mine haul trucks deliver oil sands ore to a receiving hopper or dump pocket installed in the OPP area. The raw ore is then moved through a series of conveyors and crushers to eventually provide material of a maximum particle size to the slurry system. An exemplary crusher is a double roll crusher. Crushed ore is delivered to the slurry system via a surge bin which may be proximal to the location of the slurry system.

**[00204] Slurry System.** The slurry system receives crushed ore from the surge bin, and promotes mixing of the crushed ore with a non-aqueous solvent so as to form a slurry. Water may be added to the slurry system so as to achieve the appropriate water content for the agglomeration stage. The slurry system has a feed section which may comprise a hopper to receive crushed ore from the surge bin and conveyors to move the ore to a subsequent mixing unit. A low oxygen environment may be achieved in the feed section through use of a purge gas, such as natural gas, in the interests of excluding oxygen and avoiding explosive potential. Because a flowable slurry is formed within the mixing unit, the slurry may be pumped or otherwise conveyed in a flowable manner into the agglomerator. Thus, the slurry does not need to be further crushed or screw-fed into the subsequent agglomeration stage. Exemplary mixing units include a mix box, cyclofeeder, tumbler, rotary breaker, a stirred tank or other devices in which the mixing of solvent slurry can be effected. The mixing unit can be configured to feed the resulting slurry to one or more agglomerators using a pump or by gravity. Gravity may be used to deliver the slurry to the agglomerator(s) in any appropriate manner, such as via chutes with flow diverter gates. In an embodiment described herein, flow to the agglomerator is directed only by gravity, reducing the energy input required to pump flowable fluids.

**[00205]** Coarse solids or rejects, for example oversized solids which are not further broken down prior to entry within the slurry system, can enter the slurry system but can be separated and sent directly to filtration or solvent recovery instead of being forwarded on to the agglomeration stage. In this way, agglomeration can be optimized for appropriately sized fines and solids. The residence time in the mixing unit may be fixed such that complete or substantial bitumen dissolution occurs before the slurry is delivered to the agglomerator.

**[00206]** **Agglomerator.** Agglomeration of fines derived from the initial slurry occurs within an agglomerator. The initial slurry comprises bituminous components together with solids, fines and water. These components, together with the solvent, are subjected to agglomeration within the agglomerator by imparting agitation within the agglomerator. Agitation is imparted through such motion as tumbling, rotation, or directed flow. Within an agglomerator, purge gas may again be used so as to maintain a low oxygen environment within. An agglomerator may comprise a plurality of vessels, such as tanks or rotating drums, set up in parallel or in series. The use of vessels in parallel can advantageously be configured to any appropriate volume required at a given location. An exemplary amount of oil sand to be processed may be for example 5000 tonnes per hour per agglomerator vessel. Thus, in a system where two agglomerator vessels are configured in parallel, approximately 10,000 tonnes per hour can be processed.

**[00207]** The agglomerator may include a discharge screening system. After agglomeration, streams may be screened to separate agglomerates from solvent, and agglomerates are processed further for bitumen recovery, while solvent with bitumen entrained therein is further processed through solvent recovery steps.

**[00208]** Agglomeration may occur in a drum-style unit, or may occur in a shaker or within any alternative vessel into which agitation can be introduced. The agglomerator may have an integral trommel screen at the discharge which rotates with the agglomerator. The screen separates oversized reject materials, for example, solids greater than an average particle size of about 50mm as well as petrified wood, twigs or other material that can potentially upset downstream processing.

**[00209]** **Optional Primary Solid-Liquid Separator.** Following agglomeration, agglomerates may optionally be subjected to settling for primary separation of solids from liquid using a gravity separator, for example by using deep cone settling. Purge gas may be used to maintain a low oxygen environment. Overflow from such a settler can be further cleaned and the solvent removed. Underflow, including agglomerates, which settle out can be sent on to further cleaning through washing steps which may involve, for example, belt filtration and/or counter current washing with progressively cleaner solvent (with less and less bitumen entrained within the

solvent) so as to recover bitumen from agglomerates. Other exemplary gravity separators include a spiral classifier and a rake classifier.

**[00210]** The primary solid-liquid separator may act to reduce the load on the secondary solid-liquid separator. It may also act as a surge bin between the agglomerator and secondary solid-liquid separator so as to smooth out any operating fluctuations in the output of the agglomerator and thus improving the operation of the secondary solid-liquid separator.

Furthermore, in the embodiment where a filtration unit is used as the secondary solid-liquid separator, the primary solid-liquid separator may provide a more suitable feed to said secondary solid-liquid separator by increasing the solids concentration of the agglomerated slurry.

**[00211]** **Filtration Unit.** Following agglomeration, either directly or indirectly after a settling step in a primary solid-liquid separator, agglomerates can be drained and washed in a low oxygen, gas-tight filtration unit, such as a vacuum belt or pan filter. Agglomerates are conveyed on one or more belt filters and washed in a counter-current manner with progressively cleaner solvent. For example, four separate washing stages with progressively cleaner solvent may be employed as agglomerates progress along the belt. The final filter cake, which should be relatively free of bitumen may go on to further solvent removal steps before discarding as agglomerates with a low water content, and a residual hydrocarbon content that meets or exceeds environmental requirements.

**[00212]** In counter-current washing, solvent having bitumen entrained therein for the earlier stages washing can be obtained from later stages of the system. The drained solvent from the later stages of the counter-current washing, having entrained more bitumen therein from the washing step, can thus be used in earlier stages of the counter current washing. This action allows for washing stages to occur with progressively cleaner solvent, which results in a more efficient use of solvent..

**[00213]** **Tailings Solvent Recovery Unit (TSRU).** Following filtration, solvent still remaining in filter cake and from the rejects (separated before or after agglomeration) can be recovered within a tailings solvent recovery unit. By imposing a slight vacuum, or using a gas flow current to remove solvent vapor, the remaining amount of solvent in the solids is encouraged to evaporate. A purge gas may be used to create a low oxygen environment, and a flow of vent gas can serve the dual purpose of carrying solvent vapor away for recovery. Exemplary TSRU include a rotary drum dryer, a tray dryer, or a fluidized bed dryer, employing external heating and/or internal steam stripping. The tailings solvent recovery unit may employ separate equipment components. A "rejects solvent recovery unit", may be located upstream of the agglomerator, and is dedicated to solvent recovery from rejects and another equipment downstream of agglomeration

and filtration which is dedicated to recovery of solvent from washed agglomerates. In this way, more than one TSRU may be present at different stages or locations of the system. Following passage through the TSRU, dried tailings derived either from rejects or from the filter cakes, which are adequately dried for discharge, may be forwarded to discharge conveyors for disposal. Further drying steps can be employed if additional water or solvent removal is desired. Once drying is complete, dry tailings can be sent to disposal.

**[00214] Exemplary System Embodiments**

**[00215]** In a first embodiment of a system for implementing the non-aqueous extraction process, a feed derived from oil sands comprising bitumen is slurried in a slurry system with recycle solvent with some bitumen in it. Any water required for agglomeration may be added in the slurry system, and can be included as steam, or may be included in one of the feed components. The resulting slurry is transported to an agglomerator where particle enlargement through agglomeration occurs. By subjecting the slurry to mild agitation in the presence of water in the agglomerator, fines particles present in the slurry aggregate and form agglomerates. Upon discharge into a gravity separator, the agglomerates settle to the bottom of the vessel to produce the separator underflow. The diluted bitumen supernatant is collected as an overflow from the gravity separator and passes through a secondary clean-up stage, or may be transferred directly into a solvent recovery unit (SRU) where the non-aqueous solvent is recovered.

**[00216]** In this embodiment, the discharge slurry (or underflow) from the gravity separator is fed into a vacuum filtration unit and is washed counter-currently with progressively cleaner solvent. An appropriate residence time and filter arrangement is chosen to ensure that the agglomerates, are well drained and low in residual bitumen. The resulting solvent-wet filter cake is then passed into the TSRU where residual solvent is recovered and recycled to the wash stage of the process. Solvent is recovered from the agglomerated tailings in the TSRU by external heating and/or internal steam or gas stripping. The TSRU discharge may have about 15 wt% water or less, and residual solvent would be at levels that meet or exceed environmental requirements. The overall system, including the slurry system and the rejects handling unit is a unique system and is readily differentiated from systems and apparatuses used in conventional water based extraction processes.

**[00217]** In a further exemplary embodiment, a slurry system with re-circulation is employed. The system comprises a mixbox and at least one retention tank. Dry oil sand is mixed with solvent to form a slurry in the mixbox. The solvent used may or may not contain bitumen entrained therein. The resulting slurry is then directed into a retention tank. The slurry is mixed in

the tank at an appropriate mild agitation level to promote nucleation of the fines for agglomeration. The slurry exiting the tank may be divided into two streams, each directed to a respective conduit. One stream may be passed through a conduit into a separator while the other is directed by a conduit to be recirculated in the mixbox of the slurry system. The recirculating flow rate could be, for example, 0 to 60% of the nominal process flow rate. In this embodiment, the system is may be less maintenance intensive, as no rotating equipment is used in the agglomeration of solids. Capital cost savings may thus be realized due to savings in equipment costs and the reduction of building and foundation sizes. A steam heated filter cake conveyor located upstream of the TSRU dryer may be used to reduce the heating load of the system. Advantageously, the rejects drying drums may not be required in this embodiment.

**[00218]** Further embodiments of a system are described herein which integrate a variety of system components for use in a process for bitumen recovery from oil sands.

**[00219]** A non-aqueous solvent extraction process for recovery of bitumen from oil sands which incorporates embodiments of specialized systems described above is provided in detail below.

**[00220]** **Figure 8** illustrates an exemplary system (800) within the scope of the present disclosure, including a slurry system; an agglomerator; a separator unit comprising a countercurrent washer; a tailings solvent recovery unit (TSRU); and a solvent recovery unit (SRU). The separator unit may optionally comprise a deep cone settler to separate low solids bitumen (as overflow) from agglomerates (as underflow). The countercurrent washer may comprise a belt filter, or a multi-stage counterflow cyclone. In the depicted exemplary system (800), a feed (802) is provided to a slurry system (804), together with a non-aqueous solvent (814a) having bitumen (816b) entrained therein, and optionally together with steam (806) to either provide water content for later agglomeration and/or for the purpose of heating the feed to a temperature that is advantageous to further downstream processing in the system. The initial slurry (808) formed in the slurry system is fed to an agglomerator (810) by use of pumps or by gravity feed where the slurry may be combined with water (812a) and a solvent (814a) in which bitumen (816a) may be entrained.

**[00221]** Upon agglomeration in the system, the agglomerated slurry (818) is separated in a separator unit (819), which in this instance includes a deep cone settler (820), which separates a low solids bitumen extract (822) from the agglomerates. The agglomerates obtained through separation in the deep cone settler (820) may be classified as "separator underflow" (824) when obtained in this way, or may simply be referenced as "extracted solids", which can be further processed by washing in a countercurrent washer (826). The countercurrent washer in this

instance comprises a belt filter that incorporates countercurrent washing with solvent with progressively less bitumen entrained therein. From the countercurrent washer (826), solvent (814b) having bitumen (816b) entrained therein can be recycled for re-use in the slurry system (804).

**[00222]** After cleaning agglomerates in the countercurrent washer (826), wet, washed agglomerates (828) are further processed in a tailings solvent recovery unit (830). Solvent (814c) and water (812b) are recovered for re-use. Dry agglomerated tailings (832) derived from the tailings solvent recovery unit (830), are advantageously low in water content as well as very low in solvent content, thereby meeting or exceeding environmental standards for solvent content. The agglomerated tailings may be back-filled into a mine area. Solvent (814c) recovered from the tailings solvent recovery unit may be re-directed to the belt filter for use in counter-current washing, and may be combined with clean solvent (814d), having no bitumen entrained therein, to make up for any solvent volume losses in the system. Low solids bitumen extract (822) may be sent to a solvent recovery unit (834) and bitumen product (836) may be recovered therefrom. Further processing of the low solids bitumen extract with a solvent that may be the same as or different from the solvent introduced in the initial slurry can occur prior to solvent recovery, as described above.

**[00223]** In this system 800, the primary components comprise a slurry system (804); an agglomerator (810); a separator unit (819) comprising a deep cone settler (820) and a countercurrent washer (826); a solvent recovery unit (834) for removing solvent from low solids bitumen extract; and a tailings solvent recovery unit (830) to remove solvent from agglomerates.

**[00224]** A variety of modifications and optional component configurations are permitted and fall within the scope of the systems described herein. Exemplary system components are described below with respect to **Figure 9** to **Figure 13**. Further, **Figure 14** and **Figure 15** outline a variety of optional system configurations.

**[00225]** **Figure 9** illustrates an exemplary ore preparation and slurry system design (900) for systems described herein. Raw ore (902) obtained from oil sands mining may be processed at or near the site of the mine, or at a remote location by conveyance into a hopper (903) from which ore is conveyed on conveyor belts (905, 906) to a primary crusher (907). Further conveyance of crushed ore on a secondary conveyor belt (909) brings crushed ore to a secondary crusher (911), following which a conveyor belt (913) delivers crushed ore (915) into a surge bin (917), which may divide crushed ore into one or more crushed ore streams (919, 920), which are conveyed by conveyors (923, 924) to slurry system (927). In the depicted embodiment, the slurry system (927) comprises a hopper (928) for receiving crushed ore from the surge bin (917), conveyors (929,

930) for conveying ore to a mix box (933). Solvent (935), and optionally water (937), in the form of liquid or steam or a combination thereof, are combined in the mix box (933) with the crushed ore, and a vent gas (939) is provided to the mix box to create a low oxygen environment. The mixing within the mix box permits the crushed ore to take on the consistency of a pumpable slurry, referenced herein as the "initial slurry" (941). One or more pumps (943a, 944a) may be used to transport the initial slurry (941) into one or more agglomerator (943b, 944b).

**[00226]** **Figure 10** illustrates an agglomerator for use with exemplary systems described herein. It is understood that the agglomerator of the system described herein may take any number of forms, such as having one or more rotating drums or a series of tanks. The agglomerator (1000) depicted in **Figure 10** takes the form of a plurality of rotating drums. Initial slurry (941) received from the slurry system and optionally water (1020), in the form of liquid or steam or a combination thereof, are provided into rotating drums (1001, 1002), which are rotated to agglomerate fines therein. Effluent from the rotating drums will have agglomerated particles that may be subjected to screening for removal of oversized reject materials, for examples, solids greater than 50 mm as well as petrified wood, twigs or other materials that can potentially upset downstream processing. Screens (1003, 1004) are employed to filter out such oversized materials, which would be sized to permit passage of agglomerates therethrough. Oversized rejects in reject streams (1009, 1010) may be subjected to further processing, such as solvent removal (1026). Vent gas (1005, 1006) flowing out of the rotating drums (1001, 1002) may proceed to a vent gas recovery unit (1007) in order to recover vaporized solvent. The agglomerated slurry arising from the agglomerators (1001, 1002), having had oversized rejects removed with appropriately sized mesh screens (1003, 1004) which permit agglomerates to pass through, is optionally directed to a conveyor belt (1022) so that a stream of agglomerated slurry with rejects removed (1024) is directed over a distance, if required, for further processing in a separator unit, such as depicted in **Figures 11 and 12**.

**[00227]** **Figure 11** illustrates an optional component of the separator unit. In this embodiment, a deep cone settler (1103) is depicted for receiving agglomerated slurry (1009) from the agglomerator. The cone settler permits settling of agglomerated solids to the lower region (1105), while a low solids bitumen extract (1107) can be drawn off as overflow. A pump (1109) is used to convey the overflow to further cleaning or solvent removal in a solvent recovery unit. A vent gas (1111a, 1111b) is provided to and removed from the cone settler to provide a low oxygen environment therein. One or more pumps (1113, 1114, 1115) may be used to pump agglomerates (1117a, 1117b, 1117c) to a countercurrent washer (1119), which may be for example a belt filter for effecting solvent recovery from agglomerates.

**[00228]** Figure 12 illustrates a countercurrent washer (1200) which includes a belt filter system (1201) for washing of agglomerates (1117) derived from the agglomerators or optionally from a deep cone settler underflow. The agglomerates are conveyed along a conveyor belt (1203), in this instance progressing from left to right, while low solids bitumen extracts (1205a, 1205b, 1205c, 1205d) filter through the solid cake and filter media and collect within the tanks (1207a, 1207b, 1207c, 1207d). The low solids bitumen extracts in the tanks can be drawn off for re-use and pumped to an upstream stage of the belt filtration process by pumps (1209b, 1209c, 1209d).

**[00229]** The belt filter may consist of one or more drainage stages where a low solids bitumen extract is extracted from the agglomerate slurry. The wash stages of the belt filter may operate countercurrently where the direction in which the agglomerates (1117) are conveyed along the conveyor belt (1203) is counter to the direction in which the solvent is re-used for washing the agglomerates. Thus, the agglomerates are washed with progressively cleaner solvent when conveyed along the belt (1203). Cleaner solvent is interpreted as solvent with lesser bitumen entrained within. Fresh solvent, coming from storage or the solvent recovery units, has no or minimal amounts of bitumen within. In the depicted embodiment, agglomerates (1117) progress from left to right, while solvent used for washing becomes cleaner as agglomerates move from left to right.

**[00230]** The low solids extract (1205d) that is filtered at the end of the belt is the filtrate resulting from a final drainage stage used. Once washed in the countercurrent washing process, a solids agglomerate filter cake of minimum bitumen content is formed. The bitumen entrained within the extract (1205d) collected in the final tank (1207d) is preferably minimal. The extract (1205d) in the tank (1207d) is pumped back with pump (1209d) to an earlier region along the belt, and can be used again, optionally with the addition of fresh solvent (1220), to wash the agglomerates at an earlier region along the belt, for example region above the adjacent upstream tank (1207c). The resulting low solids extract that is filtered through the bed and filter media is collected within a tank 1207c to be used for the next countercurrent wash of the adjacent upstream region. Solvent with entrained bitumen accumulated from countercurrent washing of agglomerates, for example, as found in tank (1207a) may be directed via pump (1209a) to solvent recovery (1222).

**[00231]** Following the solvent washing of agglomerates and final drainage stage, The wet agglomerates (1211) can be conveyed by conveyor (1213) to further solvent removal in a tailings solvent recovery unit (1215) and once dried can subsequently be sent to storage. The wet agglomerates (1211) once subjected to solvent removal, have a low solvent content that meets or

exceeds requisite environmental standards. For this reason, the dried agglomerates can eventually be used as, for example, back-fill in a spent mine.

**[00232]** **Figure 13** illustrates an exemplary tailings solvent recovery unit (1300) for use in removing solvent from wet agglomerates. Following separation and washing in the separator unit, washed wet agglomerates (1211) can be dried in a tailings solvent recovery unit, which may comprise a TSRU drum (1313) comprising a dryer, an evaporator, a heater, and/or a blower in order to evaporate residual solvent from wet tailings. Dry agglomerates (1315) leave the drum (1313) and may be conveyed by means of a TSRU discharge conveyor (1317) to a dry tailings disposal location (1319), such as an oil sands mine location from which oil sand recovery is complete. Reject solids (1320), for example, oversized solids which may have been recovered earlier in the system, but which have been wetted with solvent may have been previously dried for solvent recovery in a rejects dryer (1321) may also be conveyed to dry tailings disposal (1319), optionally merging on a conveyor with dry agglomerates on the TSRU discharge conveyor (1317).

**[00233]** **Figure 13** also depicts a three phase separation unit (1310) for use in recovery of solvent derived from the TSRU drum (1313). In this instance, solvent derived from agglomerated tailings in the TSRU (1300) can be recovered and separated from water and vent gas in a separation unit (1327). Solvent (1323), and water (1325) can thus be separated and reused elsewhere in the system. The vent gas (1333) is sent to the vent gas recovery unit to recover any evaporated solvent. Pumps (1329, 1330) may be employed to convey solvent (1323) and water (1325) to other locations in the system. The tailing solvent recovery unit (1300) may operate under low oxygen conditions using an inert vent gas.

**[00234]** **Figure 14** illustrates a system (1400) commensurate with a first embodiment described herein. A bituminous feed (1401) is mixed with a solvent (1403) and optionally water in a mix box (1405), and a pumpable initial slurry is formed. The initial slurry is pumped by pump (1407) into an agglomerator (1409) having thereon a screen (1411) to screen for rejects. A water containing stream may optionally be injected into the agglomerator. Screened rejects may be dried and the solvent recovered in the rejects dryer (1413). The agglomerated slurry arising from the agglomerator may be pumped into a deep cone settler (1414) via a pump box (1445) in communication with a pump (1417). The overflow of the deep cone settler may be sent to a solvent recovery unit (1426) so as to remove bitumen from solvent, thereby forming a bitumen product. Underflow of the deep cone settler is pumped via pump (1419) to a belt filter (1421) where countercurrent washing is used to remove bitumen from agglomerates with washing along the length of the belt filter involving progressively cleaner solvent. The filter cake from the belt filter is conveyed by a conveyor (1423) to a TSRU dryer (1425). Solvent recovered in this TSRU

dryer may have bitumen light ends entrained therein, and may be used as is, or sent to a solvent recovery unit (1426), to remove bitumen light ends entrained therein. The dried agglomerates arising from the TSRU dryer (1425) may be conveyed via conveyor (1427) to a location for storage of dry tailings (1429), optionally together with dried rejects from the reject dryer (1413).

**[00235]**        **Figure 15** illustrates an exemplary embodiment of a system described herein. A system (1500) comprises a bituminous feed (1501) which is mixed with a solvent (1503) and optionally water in a mix box (1505), and an initial slurry is formed. Through mild agitation occurring within the slurry system (1506), the initial slurry becomes agglomerated as it is directed to a retention tank (1504) within the slurry system. Mild agitation causes agglomeration of fines. A water containing stream may optionally be injected into the retention tank to promote agglomeration of the fines therein. The initial slurry is held in the retention tank (1504) where it may be held and/or mixed for an appropriate residence time, such as 2 minutes, for example. Optionally, a portion (1510) of the agglomerated slurry leaving the retention tank (1504) may be directed to re-circulation via pump (1507) or by gravity flow, and is thus re-directed into the mix box (1505). Recirculation is depicted here with a dashed line to indicate the optional nature of this feature. Iterative recirculation may be helpful in breaking down size. The agglomerated slurry (1512) arising from the retention tank (1504) may be directed by a pump (1517), as depicted, or by gravity into a deep cone settler, or clarifier (1514). The overflow (1516) of the clarifier (1514) may be sent to a solvent recovery unit (1526) so as to remove bitumen from solvent, thereby forming a bitumen product. Underflow of the clarifier (1514) is pumped via pump (1519) to a belt filter (1521) where countercurrent washing is used to remove bitumen from agglomerates with washing along the length of the belt filter involving progressively cleaner solvent. The filter cake from the belt filter is then conveyed by conveyor (1523) to a TSRU dryer (1525). Solvent recovered in this TSRU dryer may have bitumen light ends entrained therein, and may be used as is, or sent to a solvent recovery unit (1526), to remove bitumen light ends entrained therein. The dried agglomerates arising from the TSRU dryer (1525) may be conveyed via conveyor (1527) to a location for storage of dry tailings (1529).

**[00236]**        **PART 3**

**[00237]**        **Processes for Solvent Extracting Bitumen Involving Fractionating a Diluent.**

**[00238]**        Generally, the processes and systems described herein involve the use of a lighter fraction of an available hydrocarbon fluid as a solvent source for solvent extraction of bitumen. The available hydrocarbon fluid may comprise a diluent (e.g. gas condensate or naphtha). The hydrocarbon fluid is fractionated into a heavier fraction and a lighter fraction. Upon fractionation,

the lighter fraction, which has a lower boiling point, is used as a solvent in the extraction. As described herein, more than one solvent may be used in the extraction. The heavier fraction, having a higher boiling point, is recombined with the diluted bitumen product (following solvent extraction) to satisfy shipping requirements. Shipping requirements may, for example, require a particular viscosity, vapour pressure, or other measurable parameter to be met, which can be achieved by addition of the heavier fraction. Further, additional diluent and/or diluted bitumen can be added, if needed, in order to meet shipping requirements consistent with pipeline specifications.

**[00239]** Diluted bitumen is also referred to as “dilbit” herein. Dilbit is bitumen diluted by a diluent, for example a natural gas condensate or naphtha. The bitumen is diluted for easier transport by pipeline.

**[00240]** A process is described herein for extracting bitumen from a bituminous feed from oil sands. The process comprises fractionating a hydrocarbon fluid into a lighter fraction and a heavier fraction; effecting solvent extraction of the bituminous feed with the lighter fraction as the solvent to produce solvent diluted bitumen; and combining the heavier fraction with solvent diluted bitumen to form a high grade bitumen product.

**[00241]** The hydrocarbon fluid may be, for example, a diluent, a natural gas condensate, naphtha, a C5+ natural gas condensate, mixtures of these, and optionally other fluids that may possess appropriate qualities under certain temperature and pressure conditions.

**[00242]** The lighter fraction may have a boiling point of less than 100°C, and/or may comprise hydrocarbons with a boiling point less than 100 °C, but greater than 50 °C. The lighter fraction may comprise one or more C5 to C8 hydrocarbons, and in certain embodiments may comprises a single hydrocarbon. The lighter fraction comprises a C4 or lighter hydrocarbon, for example under certain circumstances or conditions. For example, if fractionating is conducted under pressure and temperature conditions permitting the lighter fraction to remain liquid, then C4 or lighter hydrocarbons could comprise the lighter fraction.

**[00243]** Dilbit or diluent may be combined with the high grade bitumen product to form a mixed product. If used, the dilbit may be derived from any appropriate source, such as from a water-based bitumen extraction operation. The dilbit may be derived from a paraffinic froth treatment operation, for example. Further, the dilbit may be derived from an in situ bitumen production operation, such as SAGD, SA-SAGD, LASER, or CSS. Optimally, the dilbit, when used, has less than 300 ppm filterable solids on a bitumen basis.

**[00244]** The mixed product produced according to the process is advantageously fungible. For example, the mixed product may have less than 300 ppm filterable solids on a bitumen basis.

**[00245]** In the process, effecting solvent extraction may comprise agglomerating solids. Further, effecting solvent extraction may comprise recycling the solvent.

**[00246]** In the process described, fractionating may comprise solvent removal by vaporizing and condensing the lighter fraction, flashing to create a pressure drop and vaporize the lighter fraction. Optionally, using membrane separation based on solvent molecular size would be a possible method of fractionating. Further, fractionating may involve solvent removal by vaporization followed by condensation of the lighter fraction at or below the boiling point of the lighter fraction.

**[00247]** Effecting solvent extraction may comprise combining a first solvent and the bituminous feed 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 the high grade bitumen product; wherein the first solvent or the second solvent comprises the lighter fraction.

**[00248]** Optionally, effecting solvent extraction may comprise combining a first solvent and the bituminous feed 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; mixing a second solvent with the agglomerated slurry to form a solvent-bitumen agglomerated slurry mixture, the second solvent having a similar or lower boiling point than the first solvent; subjecting the mixture to separation to produce a high grade bitumen extract and a low grade bitumen extract; recovering the first and second solvent from the high grade bitumen extract, leaving the high grade bitumen product; and recovering the first and second solvent from the low grade bitumen extract, leaving a low grade bitumen product; wherein the first solvent or the second solvent comprises the lighter fraction.

**[00249]** Additionally, effecting solvent extraction may comprise combining a first solvent and the bituminous feed to form an initial slurry; separating the initial slurry into a fine solids stream and a coarse solids stream; recovering the first solvent from the 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 the high grade bitumen product; wherein the first solvent or the second solvent comprises the lighter fraction.

**[00250]** Optionally, the effecting of solvent extraction may comprise combining a first solvent and the bituminous feed to form an initial slurry; separating the initial slurry into a fine solids stream and a coarse solids stream; recovering the first solvent from the coarse solids stream; agglomerating solids from the fine solids stream to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract; mixing a second solvent with the agglomerated slurry to form a solvent-bitumen agglomerated slurry mixture, the second solvent having a similar or lower boiling point than the first solvent; subjecting the mixture to separation to produce a high grade bitumen extract and a low grade bitumen extract; recovering the first and second solvent from the high grade bitumen extract, leaving the high grade bitumen product; and recovering the first and second solvent from the low grade bitumen extract, leaving a low grade bitumen product; wherein the first solvent or the second solvent comprises the lighter fraction.

**[00251]** The effecting of solvent extraction may optionally comprise combining a first solvent and the bituminous feed 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 the 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; wherein the first solvent or the second solvent comprises the lighter fraction.

**[00252]** The effecting of solvent extraction may comprise combining a first solvent and the bituminous feed to form an initial slurry; agglomerating solids from initial slurry to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract; mixing a second solvent with the agglomerated slurry to form a solvent-bitumen agglomerated slurry mixture, the second solvent having a similar or lower boiling point than the first solvent; subjecting the mixture to separation to produce a high grade bitumen extract and a low grade bitumen extract comprising

substantially all solids and water; and recovering the first and second solvent from the high grade bitumen extract, leaving the high grade bitumen product; and recovering the first and second solvent from the low grade bitumen extract, leaving a low grade bitumen product; wherein the ratio of first solvent to bitumen in the initial slurry is selected to avoid precipitation of asphaltenes during agglomeration; wherein the first solvent or the second solvent comprises the lighter fraction.

**[00253]** Other methods of solvent extraction, in addition to or as an alternative to those mentioned above may be used in the process, such as prior methods described herein in the background section.

**[00254]** The first solvent and the second solvent, if used in effecting solvent extraction may comprise the lighter fraction. The first solvent and the second solvent may comprises at least 50% by weight of the lighter fraction. Further, the first solvent and the second solvent may comprises at least 90% by weight of the lighter fraction. Optionally, the ratio of the first solvent to bitumen in the initial slurry may be less than 2:1, and can be selected to limit precipitation of asphaltenes during agglomeration.

**[00255]** The initial slurry described in the solvent extraction steps described above may be formed in a low oxygen environment under a gas blanket. Optionally, the first solvent used in solvent extraction may have a boiling point of less than 100°C. The second solvent, when used in solvent extraction, may have a boiling point of less than 100°C. Indeed, it is envisioned that the first solvent and the second solvent are possibly the same solvent, and may comprise the lighter fraction.

**[00256]** Where applicable, the agglomerated slurry may be separated into low solids bitumen extract and agglomerates in a solid-liquid separator. The solid-liquid separator may comprise a gravity separator, a cyclone, a screen, a belt filter or a combination thereof. Further, the solid-liquid separator may comprise a secondary stage for countercurrently washing the agglomerates separated from the agglomerated slurry. Where applicable, the secondary stage for countercurrently washing the agglomerates may comprise a gravity separator, a cyclone, a screen, a belt filter, or a combination thereof.

**[00257]** The process for solvent extracting bitumen involving fractionating a diluent may be used with a process or system described in **PART 1**, or **PART 2** above, but need not be limited to these processes or systems. The processes described herein may be used with another process or system of solvent extraction including, but not limited to, those described in the background section.

**[00258]** Processes and systems are described herein which involves the use of a lighter fraction of a hydrocarbon fluid, for example a diluent (e.g. gas condensate or naphtha), as a

solvent source for solvent extraction of bitumen. The diluent stream is fractionated into a heavier fraction and a lighter fraction. The lighter fraction (with a lower boiling point) is used for as the solvent in the extraction (as described below more than one solvent may be used in the extraction). The heavier fraction is recombined with the diluted bitumen product (following solvent extraction) to satisfy shipping viscosity requirements and diluent and/or dilbit can be added thereto as required to meet pipeline specifications.

**[00259]      *Fractionation.*** Fractionation may involve separating of fluids according to any appropriate methodology. Fractionating may comprise vaporizing a liquid, and subsequently condensing specific boiling point ranges to separate different hydrocarbons, or different hydrocarbon mixtures according to a pre-selected boiling point. In addition, similar separation might be achieved through flashing (pressure drop - some light ends turn to vapor); or even membrane separation, where separation is based on molecular size, which may give similar results to fractionation based on boiling points.

**[00260]      **Figure 16**** is schematic representation of an exemplary process within the scope of the present disclosure where the solvent is obtained from fractionating a hydrocarbon fluid. The process of shown in **Figure 16** involves fractionating the hydrocarbon fluid into a lighter fraction and a heavier fraction (1602). It is conceivable for more than two fractions to be formed. The lighter fraction is used as the solvent in a solvent extraction process for extracting bitumen from a bituminous feed, so as to produce solvent diluted bitumen (1604). The heavier fraction is added to the solvent diluted bitumen stream (1606) to create a mixture. Optionally, diluent and/or dilbit or synthetic crude may be added to the mixture of the heavier fraction and the solvent diluted bitumen (1608), if desired, to meet fungible requirements.

**[00261]** As discussed further below, the hydrocarbon fluid may be a diluent, for example natural gas condensate or naphtha. A primary criteria of the hydrocarbon fluid is that it must be capable of being fractionated to produce at least a fraction suitable for use as a solvent in solvent extraction of bitumen. Suitable solvents include, but are not limited to, those described above in **PART I** and those previously described or known, such as those described in the background section.

**[00262]      **Figure 17**** illustrates a system where solvent is sourced from a diluent stream and used in the solvent extraction process. In this embodiment, diluent (1702) from a diluent pipeline (1704) is fractionated in a fractionation unit (1706). A lighter fraction (1708) and a heavier fraction (1710) are formed. The lighter fraction (1708) is used as the solvent in solvent extraction of bitumen (1712). The bitumen feed (1713) is also shown. The solvent extraction (1712) may be as described above in **PART I**, or may be another solvent extraction process including, but not limited

to, those described in the background section. Solvent extraction (1712) includes the associated solvent recycling (not shown). From the solvent extraction (1712), a solvent diluted bitumen with low levels of fine solids (1714) is obtained. The heavier fraction (1710) and the solvent diluted bitumen (1714) are combined to form product (1715). If the product (1715) has a filterable solids content that is higher than a desirable level, the product (1715) may be combined with diluent and/or dilbit (1716) to form a mixed product (1718). A product requirement where the filterable solids content, on a bitumen basis, must not exceed a level of 300 ppm of filterable solids can be met according to the process described. This requirement may be one typically needed for downstream refineries. Thus, by adding a diluent containing bitumen but having a solids content measurably less than 300 ppm, the resulting product stream can result in an overall solids content below the 300 ppm level. By combining such streams, the solids content is reduced to a level that can meet the 300 ppm limit and render the stream appropriate for downstream refineries.

**[00263]** The dilbit may be from a water-based extraction process, for example PFT or an in situ operation, such as SAGD. The dilbit (1716) has less than 300ppm filterable solids on a bitumen basis. The mixed product (1718) is more likely achieve its fungibility requirement of less than 300 ppm of filterable solids in cases where the mass of bitumen in dilbit (1716) available from a water-based extraction operation exceeds the mass of bitumen from product (1715) by a significant amount, so that the combination of streams results in an appropriate result. For example, a level factor of from at least a 2-fold different, for example, a 2-fold, 3-fold, 4-fold, or 5-fold minimum difference in filterable solids is appropriate, thus making it quite simple to produce a mixed product (1718) that meets fungible requirements. An example of this is when the filterable solids content of a product is 1000 ppm, but it is desirable to reduce to 300 ppm. The dilbit used may have a filterable solids content of 100 ppm, resulting in a 10-fold difference between the filterable solids content of the two streams.

**[00264]** A "diluent" as used herein means a hydrocarbon fluid that could be used to dilute bitumen or heavy oil to reduce its viscosity for easier transportation. Natural gas condensate is one common diluent. Natural gas condensate is a low-density mixture of hydrocarbon liquids that are present as gaseous components in the raw natural gas produced from natural gas fields. The condensate condenses out of the raw gas if the temperature is reduced to below the hydrocarbon dew point temperature of the raw gas. Natural gas condensate is also referred to as simply condensate, or gas condensate, or sometimes natural gasoline because it comprises hydrocarbons within the gasoline boiling range. Another common diluent is naphtha. Naphtha is a mixture of C5 to C13 hydrocarbons which may include about 15 to 40 wt.% of C6 to C11 aromatic compounds and the balance mostly a mixture of C5 to C11 aliphatic hydrocarbons,

including mixed paraffins and mixed olefins. Naphtha may have a final boiling point of around 175 °C.

**[00265]** In one embodiment, the diluent is a C5+ gas condensate with at least five carbons including, among other components, pentane and hexane. The diluent may have similar properties to heptane. C5+ gas condensates are hydrocarbon mixtures predominantly comprising C5, C6, and heavier hydrocarbons, are often produced in natural gas processing plants, and can be sold as commodity as such condensates can often be processed to transportation fuels.

**[00266]** The lighter fraction, while composed primarily of C5 to C8 molecules may optionally employ C4 and lighter molecules, should the process temperature and pressure allow for such hydrocarbon components remain as liquid. For example, in one embodiment, the lighter fraction may have a boiling point of from 30 to 50 °C, or may comprise hydrocarbons having a boiling point in this range. For example, if pressurized systems are employed, such lower boiling point liquids (below 50 °C) may be used, such as butane (C4).

**[00267]** In the PFT process, which is water-based, diluent may be used to dilute the bitumen product after removal of solvent, thus making the product of a PFT extraction operation easier to transport. Therefore, in such a PFT process, diluent is on hand. Using this diluent in a nearby solvent extraction operation would be advantageous since an independent solvent source would not be required. An example of where diluent is used to dilute the product of a PFT process will now be provided. Processes for extracting bitumen from mined oil sands commonly employ the steps of bitumen extraction, bitumen froth separation, and froth treatment. An example of such a process will now be provided, although different processes exist. Oil sand is supplied from a mine, mixed with water, and separated from rocks and debris. The slurry is conditioned by adding air, and optionally chemical additives such as caustic (sodium hydroxide). The slurry is sent to a primary separation cell/vessel (PSV) where the aerated bitumen droplets separate from most of the solids to form bitumen froth. The bitumen froth comprises bitumen, water and fine solids (also referred to as mineral solids). A typical composition of bitumen froth is about 60 wt% bitumen, 30 wt% water, and 10 wt% solids. A paraffinic solvent is combined with the bitumen froth and further separation occurs in a Froth Separation Unit (FSU). The lighter fraction from the FSU is sent to a Solvent Recovery Unit (SRU) to recover solvent for reuse. The bitumen product stream from the SRU is combined with a diluent to form dilbit for transport. The dilbit formed in the water-based extraction process described above may be combined with the dilbit formed in the solvent-bases extraction process.

**[00268]** Where a stand alone solvent extraction operation is envisioned, the expensive PFT process could be replaced by additional gravity separation vessels such as inclined plate settlers.

The solvent extraction bitumen product will contain almost no water, removing some separation considerations such as solids stabilized emulsions.

**[00269]** The combination of higher diluent use and blending with a diluted water-based extraction product (dilbit) enables the product of the solvent extraction to be shipped without additional product cleaning. A range of blending options can be used. For example, a very high diluent amount could be used with the solvent extracted bitumen to have very low density and viscosity, allowing particles to easily settle. Less diluent would be required in the water-based dilbit stream, as the combined stream could still meet shipping requirements

**[00270]** In the solvent-based extraction process described above in the background section, the proposed solvent was naphtha having a final boiling point of about 180-220°C. With such high boiling point solvents, the recovery of solvent from the solvent-washed ore would be energy intensive as all of the water would necessarily be evaporated in order to recover all the solvent. However, if a lighter solvent is used, as proposed herein, the boiling point will be lower, and therefore the energy requirements to remove the solvent can potentially be less

**[00271]** In a solvent-based process, recovering high boiling point solvent requires that water be first evaporated, which adds to the cost. On the other hand, if a lighter fraction is used in a solvent extraction process, recovering the solvent can be less energy intensive. As an example, water requires 2257 kJ/kg to change phase at 100 °C; while a light hydrocarbon (for instance cyclohexane, boiling point = 80.7 °C) would require approximately 356 kJ/kg. As a result, use of lower boiling point solvents reduces both the sensible heat required to raise the temperature of the solids and fluid to a high final boiling point, as well as giving a significant reduction in the heat of vaporization required by keeping the required temperature below 100 °C. For example, a temperature of about 80°C can be used to remove the bulk of the solvent without evaporating water that would be present in an aqueous extraction process, thereby reducing costs. Some hydrocarbon liquids are known to form azeotropes with water (requires that water and hydrocarbon both boil at the same temperature, which may be lower than 100 °C). Tailoring the fractionation operation to produce low boiling point solvents that do not form an azeotrope in the operating range is a further enhancement of the process.

**[00272]** Thermo Gravimetric Analysis (TGA) can be used to determine changes in weight in relation to change in temperature of a sample of unwashed tailings (low grade ore - agglomerated) with cyclohexane. The method was 600/10C, 30', Air, 10-21689 #2 Air. The results are shown in **Figure 18** to **Figure 21**. The initial weight of the sample was 62.40193 mg. The solvent free mass was estimated to be 60.34511 mg (no mass spectrometry analysis was

performed, but rather a guess was made as to when all the solvent left the sample). The final weight of the sample was 57.71024 mg.

**[00273]** **Figure 18** is a graph showing Thermo Gravimetric analysis (TGA) results of a sample in which a sample of unwashed tailings changes in weight over time. The lines representing the solvent free mass and the final weight are indicated as dashed lines on the chart.

**[00274]** **Figure 19** is a graph showing Thermo Gravimetric analysis (TGA) results of the same sample, illustrating change in weight relating to change in temperature from 10 to 600 °C.

**[00275]** **Figure 20** is a graph showing a drying rate curve for cyclohexane agglomerates based on Thermo Gravimetric analysis (TGA) results of the sample. The chart illustrates the rate of change (mg/minute) depending on the ratio "X", which is free solvent (mg)/dry solids (mg). In this instance,  $X_c$  appears to be about 0.01 mg/mg.  $X_e$  appears to be negligible (about 0.0 mg/mg). The rate of about 1 mg solvent per minute is employed in a constant rate regime. The  $k_d$  is about 121 (mg solvent/min)/(mg solvent/mg dry solid) for these conditions.

**[00276]** **Figure 21** is a graph showing drying rate based on Thermo Gravimetric analysis (TGA) results of the sample, showing rate (mg/min) changes over a temperature range.

**[00277]** **Figure 22** is a graph showing the moisture content of water and solvent remaining within agglomerates as a function of time based on Thermo Gravimetric Analysis (TGA) results. These data illustrate that at a point in time following 8 minutes of drying, the agglomerates reached the desired 400 ppm (0.04%) of residual solvent with only about 60% of its initial water content being lost. At the 8 minute point, solvent content was reduced from about 5% to about 0.04%, while water content was reduced from about 5% to about 2%, representing a reduction of about 60%. The reduction in solvent content over that period of time was considerably greater. Values are expressed on a weight basis.

**[00278]** Another specification that may be used on the light solvent is to limit the vapour pressure or lower boiling point so that the extraction can operate without the need for pressurization. The boiling point must be higher than the desired operating temperature, but lower than 100 °C to avoid excess water evaporation.

**[00279]** In **PART I**, a first solvent and a second solvent are discussed and it is mentioned that they may be the same solvent. The lighter fraction as discussed herein in **PART 3** may be the first solvent, the second solvent, both, or part of one of both of the first and second solvents. The higher boiling point cut from the fractionator may be used as the second solvent, or as a diluent for shipping requirements.

**[00280]        EXAMPLES**

**[00281]**        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 necessarily required in practice.

**[00282]**        The examples below describe embodiments intended to exemplify only certain embodiments. Alterations, modifications and variations can be effected to the particular embodiments by those of skill in the art without departing from the scope of the invention, which is defined solely by the claims appended hereto.

**[00283]        Example 1**

**[00284]**        Approximately 500 g of low grade oil sands (comprising 22 wt% fines) was mixed with 300 g cyclohexane as a first solvent (loaded with bitumen up to 40 wt%) using an impeller in a mixing vessel at 30 °C. Sand grains greater than 1 mm were removed by screening. The remaining slurry was passed into an agglomerator where 30 ml of water was added. Agglomerates of sizes ranging from 0.1 mm to 1 cm were formed. The agglomerated slurry was allowed to settle for 30 minutes and a first supernatant was collected for water and solids content analysis. Solids content determined by ashing ranged between 5,000 – 20,000 ppm on a dry bitumen basis for this first supernatant while water content by Karl Fischer analysis was generally less than 1000 ppm. Portions of the first supernatant were mixed with normal pentane as a second solvent above the critical solvent to bitumen ratio to effect precipitation of asphaltene at 30 °C. After settling for 30 minutes, a second supernatant was collected and analyzed for solids and water content. The sediment from the settling test comprised predominantly of asphaltenes and less than 20 wt% solids and was treated as the lower grade bitumen extract. Solids and water contents of the second supernatant were determined to be less than 400 ppm and 200 ppm on a dry bitumen basis, respectively. The second supernatant was a dry, clean and partially de-asphalted bitumen product suitable for transportation via a common carrier pipeline and processing in a remote refinery.

**[00285]        Example 2**

**[00286]**        In another experiment similar to the one described in Example 1, a mixture of 30% cyclohexane and 70% heptane, by volume, was used in agglomeration as the first solvent. For the

first supernatant, solids content determined by ashing range between 5,000 – 10,000 ppm on a dry bitumen basis while water content by Karl Fischer analysis was generally less than 1,000 ppm. Portions of the first supernatant were mixed with normal pentane as a second solvent above the critical solvent to bitumen ratio to effect precipitation of asphaltene at room temperature. The solids and water content of the resulting second supernatant was determined to be less than 400 ppm and 200 ppm on a dry bitumen basis after 30 minutes of settling.

**[00287]        Example 3**

**[00288]**        In another experiment similar to the one described in Example 1, normal heptane loaded with 40 % bitumen was used as extraction solvent (the first solvent). Solids content of the first supernatant was determined to be less than 400 ppm on a dry bitumen basis after 30 minutes of settling. Water content was less than 200 ppm. The resulting product, having less than 400 ppm of filterable solids was a high grade bitumen product.

**CLAIMS:**

1. A process for extracting bitumen from a bituminous oil sands feed from oil sands, comprising:
  - fractionating a hydrocarbon fluid into a lighter fraction and a heavier fraction;
  - effecting solvent extraction of the bituminous oil sands feed with the lighter fraction as a solvent to produce solvent diluted bitumen; and
  - combining the heavier fraction with the solvent diluted bitumen to form a high grade bitumen product.
2. The process of claim 1, wherein the hydrocarbon fluid is a diluent.
3. The process of claim 1, wherein the hydrocarbon fluid is a natural gas condensate.
4. The process of claim 1, wherein the hydrocarbon fluid is naphtha.
5. The process of claim 1, wherein the hydrocarbon fluid is a C5+ natural gas condensate.
6. The process of any one of claims 1 to 5, wherein the lighter fraction has a boiling point of less than 100 °C.
7. The process of any one of claims 1 to 6, wherein the lighter fraction comprises hydrocarbons with a boiling point less than 100 °C, but greater than 50 °C.
8. The process of any one of claims 1 to 7, wherein the lighter fraction comprises one or more C5 to C8 hydrocarbons.
9. The process of claim 8, wherein the lighter fraction comprises a single hydrocarbon.
10. The process of any one of claims 1 to 6, wherein the lighter fraction comprises a C4 or lighter hydrocarbon and fractionating is conducted under pressure and temperature conditions permitting the lighter fraction to remain liquid.

11. The process of any one of claims 1 to 10, wherein dilbit or diluent is combined with the high grade bitumen product to form a mixed product.
12. The process of claim 11, wherein the dilbit is from a water-based bitumen extraction operation.
13. The process of claim 11 or 12, wherein the dilbit is from a paraffinic froth treatment operation.
14. The process of claim 11, wherein the dilbit is from an in situ bitumen production operation.
15. The process of claim 14 wherein the in situ operation is SAGD, SA-SAGD, LASER, or CSS.
16. The process of any one of claims 11 to 15, wherein the dilbit has less than 300 ppm filterable solids on a bitumen basis.
17. The process of any one of claims 11 to 16, wherein the mixed product is fungible.
18. The process of any one of claims 11 to 17, wherein the mixed product has less than 300 ppm filterable solids on a bitumen basis.
19. The process of any one of claims 1 to 18, wherein effecting solvent extraction comprises agglomerating solids.
20. The process of any one of claims 1 to 19, wherein effecting solvent extraction comprises recycling the solvent.
21. The process of any one of claims 1 to 20, wherein fractionating comprises removing the solvent by vaporizing and condensing the lighter fraction, flashing to create a pressure drop and vaporize the lighter fraction, or membrane separation based on solvent molecular size.

22. The process of claim 21, wherein fractionating comprises removing the solvent by vaporization followed by condensation of the lighter fraction at or below the boiling point of the lighter fraction.
23. The process of any one of claims 1 to 22, wherein effecting solvent extraction comprises:  
 combining a first solvent and the bituminous oil sands feed 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 the high grade bitumen product;  
 wherein the first solvent or the second solvent comprises the lighter fraction.
24. The process of any one of claims 1 to 22, wherein effecting solvent extraction comprises:  
 combining a first solvent and the bituminous oil sands feed 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;  
 mixing a second solvent with the agglomerated slurry to form a solvent-bitumen agglomerated slurry mixture, the second solvent having a similar or lower boiling point than the first solvent;  
 subjecting the mixture to separation to produce a high grade bitumen extract and a low grade bitumen extract;  
 recovering the first and second solvent from the high grade bitumen extract, leaving the high grade bitumen product; and

recovering the first and second solvent from the low grade bitumen extract, leaving a low grade bitumen product;

wherein the first solvent or the second solvent comprises the lighter fraction.

25. The process of any one of claims 1 to 22, wherein effecting solvent extraction comprises:
- combining a first solvent and the bituminous oil sands feed to form an initial slurry;
  - separating the initial slurry into a fine solids stream and a coarse solids stream;
  - recovering the first solvent from the 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 the high grade bitumen product;

wherein the first solvent or the second solvent comprises the lighter fraction.

26. The process of any one of claims 1 to 22, wherein effecting solvent extraction comprises:
- combining a first solvent and the bituminous oil sands feed to form an initial slurry;
  - separating the initial slurry into a fine solids stream and a coarse solids stream;
  - recovering the first solvent from the coarse solids stream;
  - agglomerating solids from the fine solids stream to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract;
  - mixing a second solvent with the agglomerated slurry to form a solvent-bitumen agglomerated slurry mixture, the second solvent having a similar or lower boiling point than the first solvent;
  - subjecting the mixture to separation to produce a high grade bitumen extract and a low grade bitumen extract;
  - recovering the first and second solvent from the high grade bitumen extract, leaving the high grade bitumen product; and

recovering the first and second solvent from the low grade bitumen extract, leaving a low grade bitumen product;

wherein the first solvent or the second solvent comprises the lighter fraction.

27. The process of any one of claims 1 to 22, wherein effecting solvent extraction comprises:
- combining a first solvent and the bituminous oil sands feed 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 the 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;
  - wherein the first solvent or the second solvent comprises the lighter fraction.

28. The process of any one of claims 1 to 22, wherein effecting solvent extraction comprises:
- combining a first solvent and the bituminous oil sands feed to form an initial slurry;
  - agglomerating solids from initial slurry to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract;
  - mixing a second solvent with the agglomerated slurry to form a solvent-bitumen agglomerated slurry mixture, the second solvent having a similar or lower boiling point than the first solvent;
  - subjecting the mixture to separation to produce a high grade bitumen extract and a low grade bitumen extract comprising substantially all solids and water; and
  - recovering the first and second solvent from the high grade bitumen extract, leaving the high grade bitumen product; and
  - recovering the first and second solvent from the low grade bitumen extract, leaving a low grade bitumen product;

wherein the ratio of first solvent to bitumen in the initial slurry is selected to avoid precipitation of asphaltenes during agglomeration;

wherein the first solvent or the second solvent comprises the lighter fraction.

29. The process of any one of claims 23 to 28, wherein the first solvent and the second solvent comprise the lighter fraction.

30. The process of claim 29, wherein the first solvent and the second solvent comprises at least 50% by weight of the lighter fraction.

31. The process of claim 29, wherein the first solvent and the second solvent comprises at least 90% by weight of the lighter fraction.

32. The process of any one of claims 23 to 31, wherein a ratio of the first solvent to bitumen in the initial slurry is less than 2:1, and is selected to limit precipitation of asphaltenes during agglomeration.

33. The process of any one of claims 23 to 31, wherein the initial slurry is formed in a low oxygen environment under a gas blanket.

34. The process of any one of claims 23 to 33, wherein the first solvent has a boiling point of less than 100 °C.

35. The process of any one of claims 23 to 34, wherein the second solvent has a boiling point of less than 100 °C.

36. The process of any one of claims 23 to 35, wherein the first solvent and the second solvent are the same and comprise the lighter fraction.

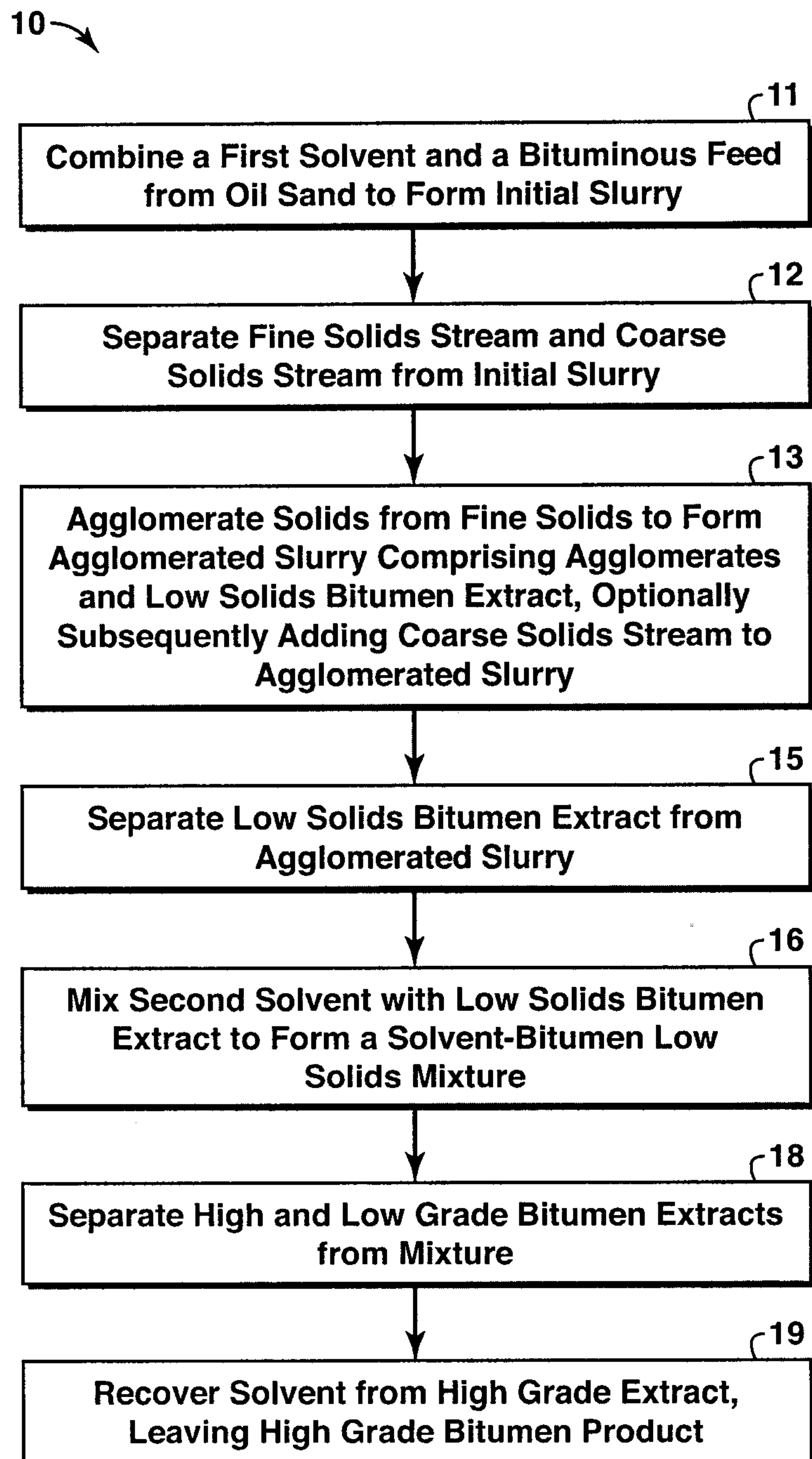
37. The process of any one of claims 23 to 36, wherein the agglomerated slurry is separated into low solids bitumen extract and agglomerates in a solid-liquid separator.

38. The process of claim 37, wherein the solid-liquid separator comprises a gravity separator, a cyclone, a screen, a belt filter or a combination thereof.

39. The process of claim 37 or claim 38, wherein the solid-liquid separator comprises a secondary stage for countercurrently washing the agglomerates separated from the agglomerated slurry.

40. The process of claim 39, wherein the secondary stage for countercurrently washing the agglomerates comprises a gravity separator, a cyclone, a screen, a belt filter, or a combination thereof.

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**FIG. 1**

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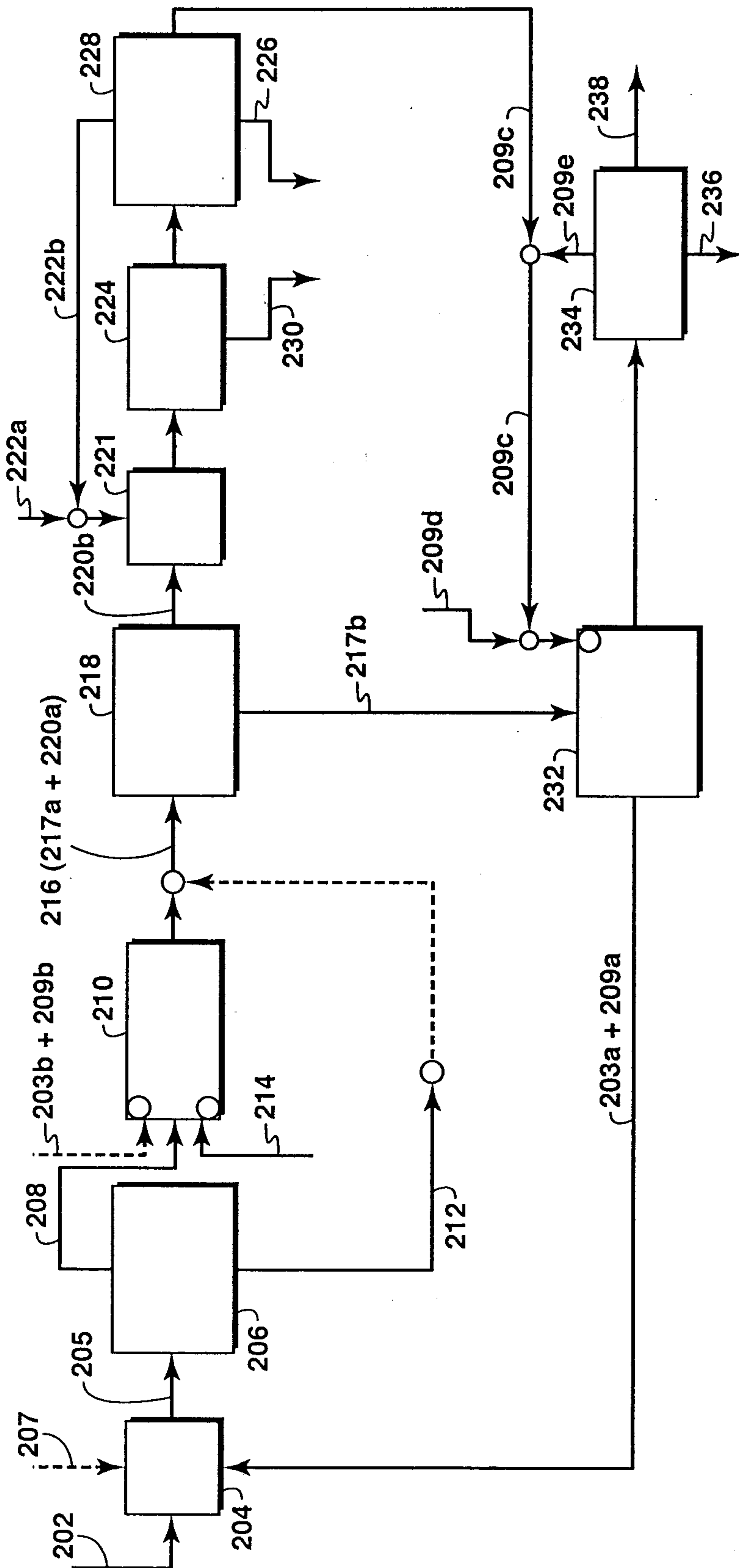


FIG. 2

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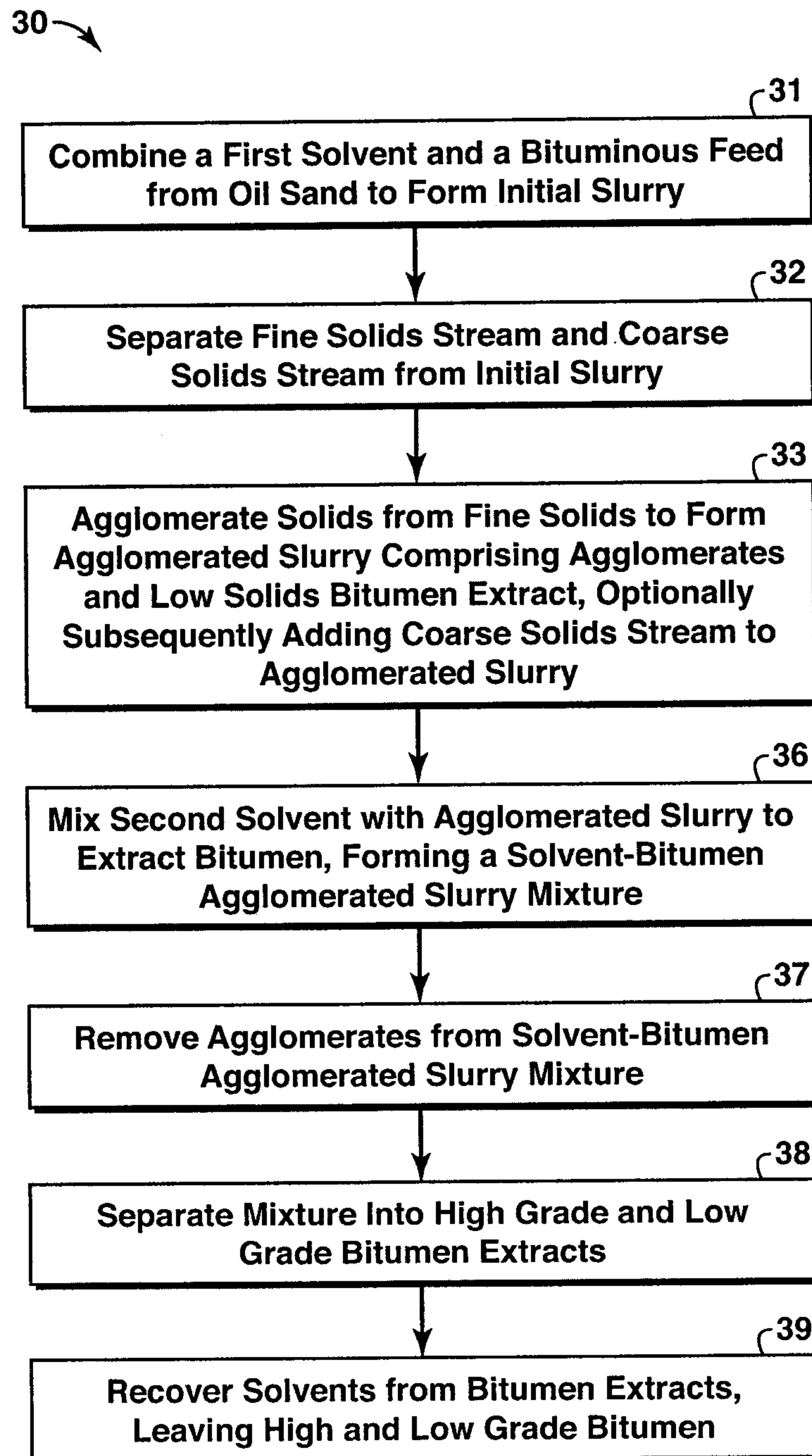


FIG. 3

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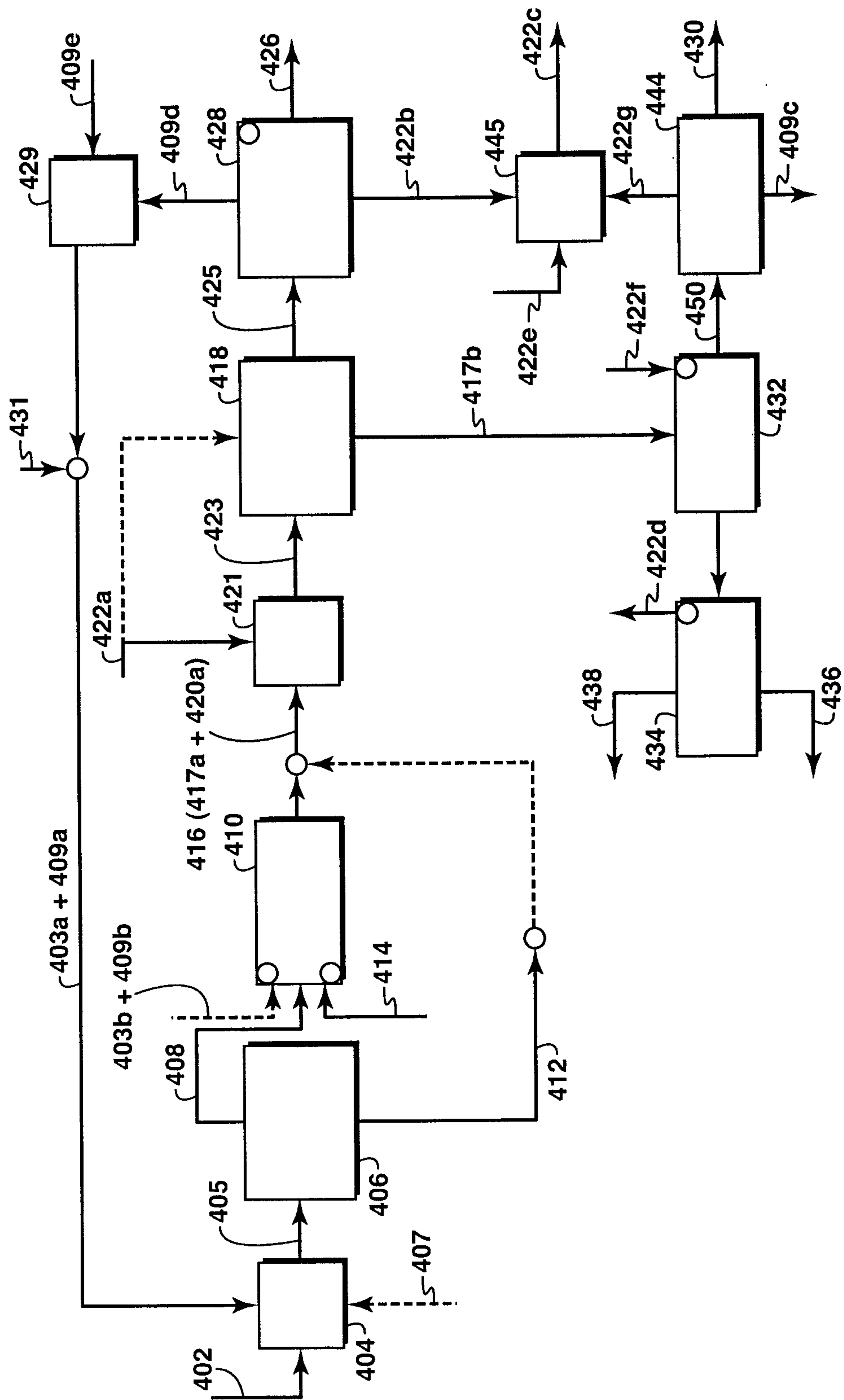


FIG. 4

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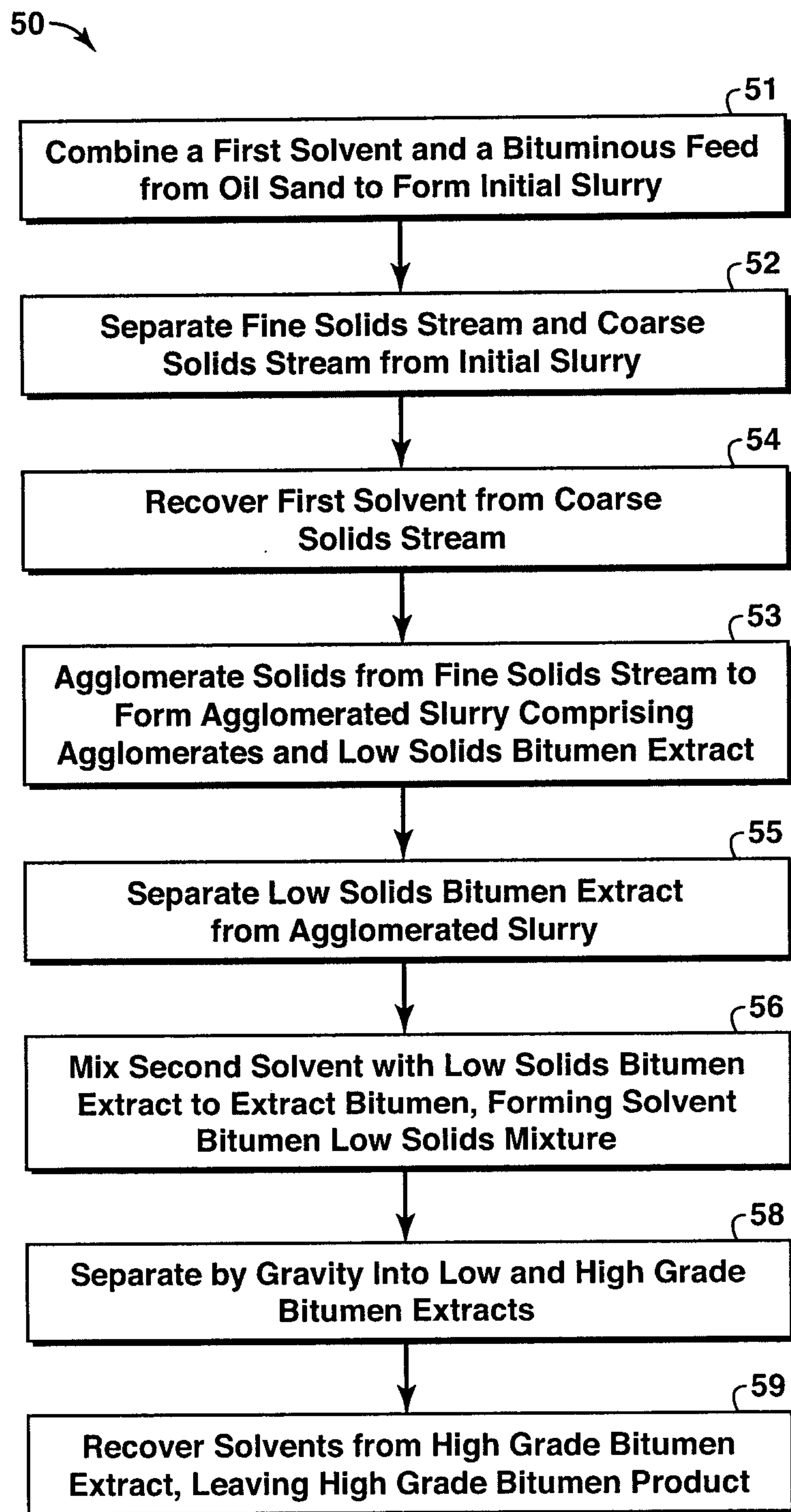


FIG. 5

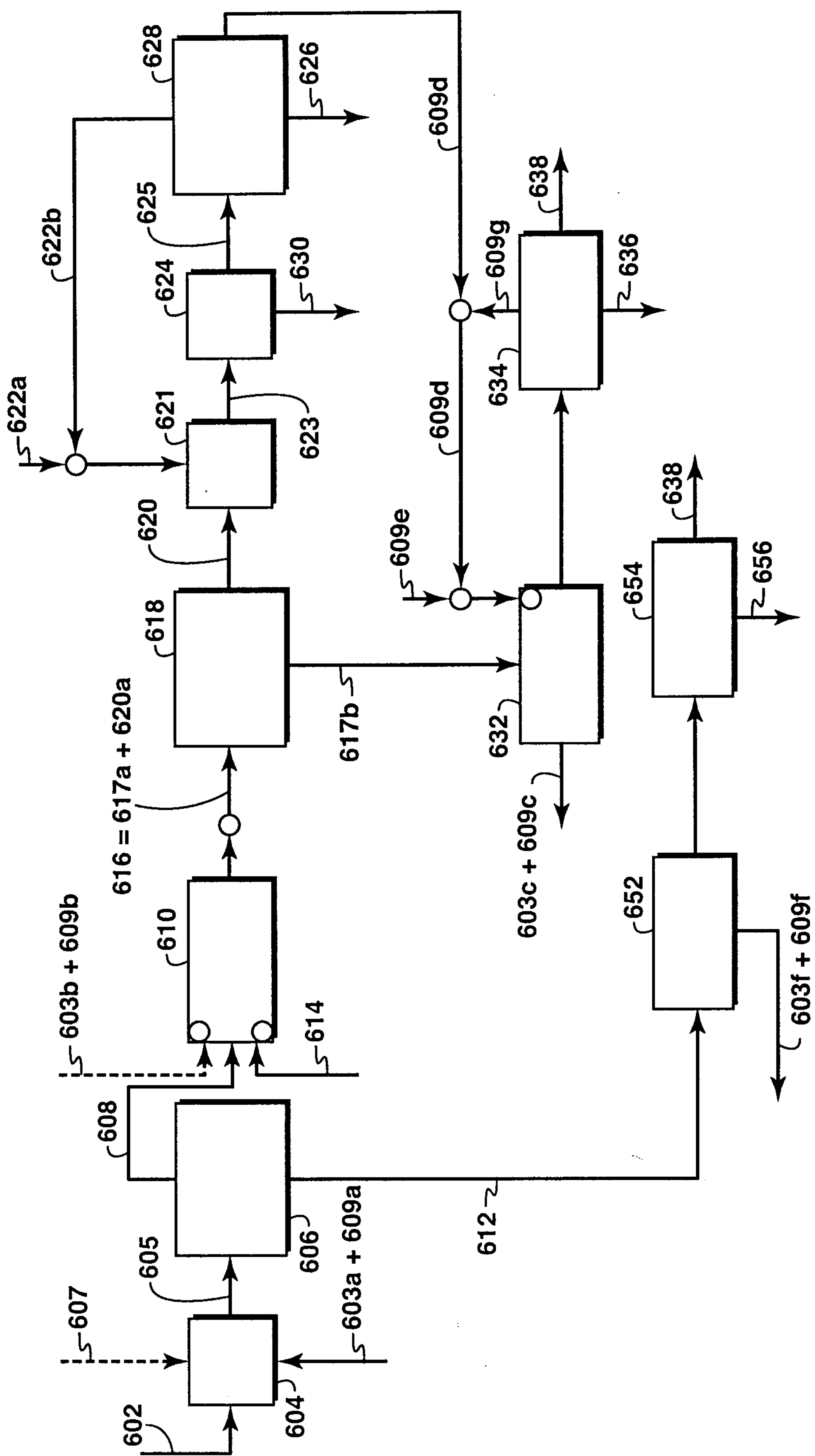


FIG. 6

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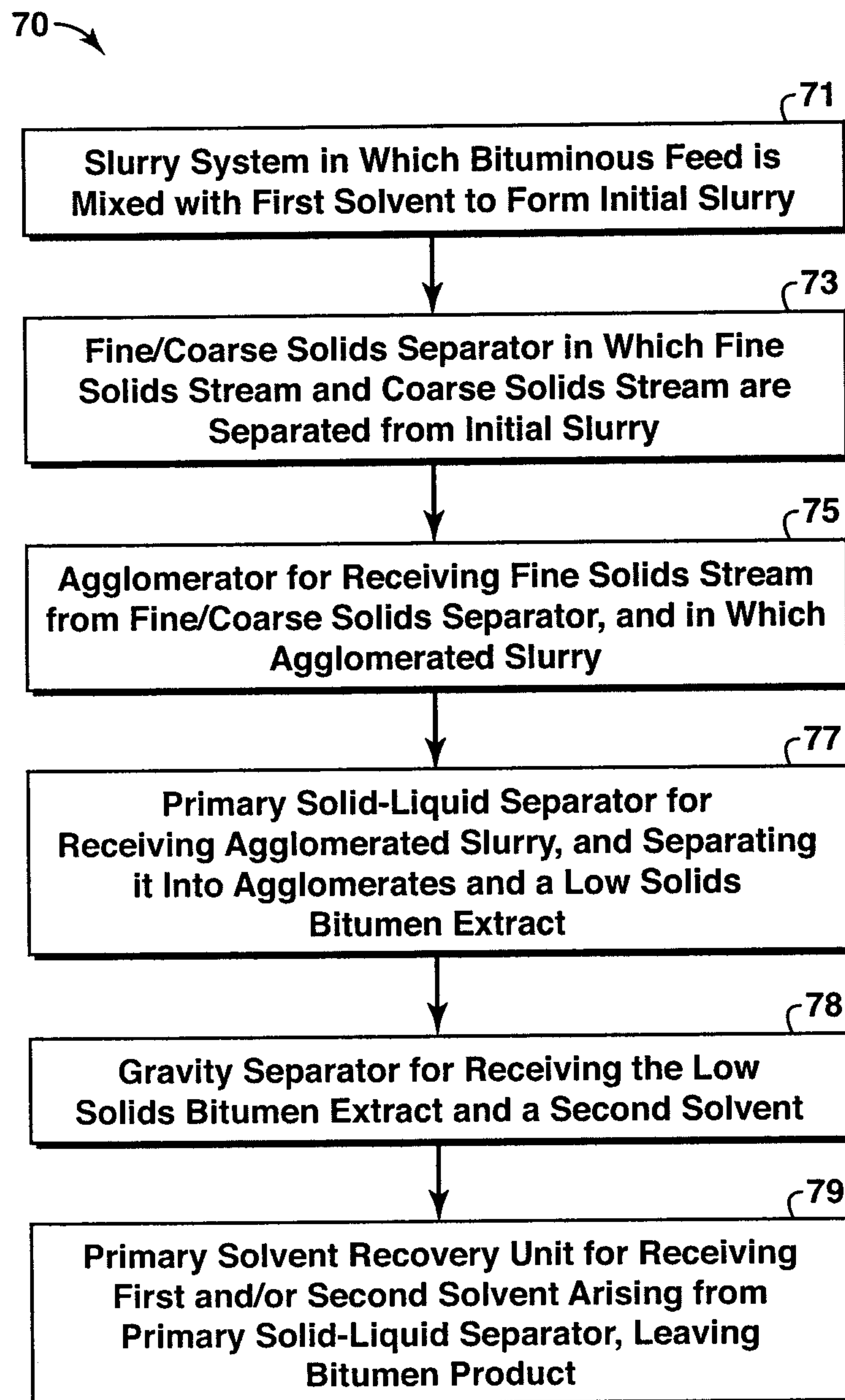


FIG. 7

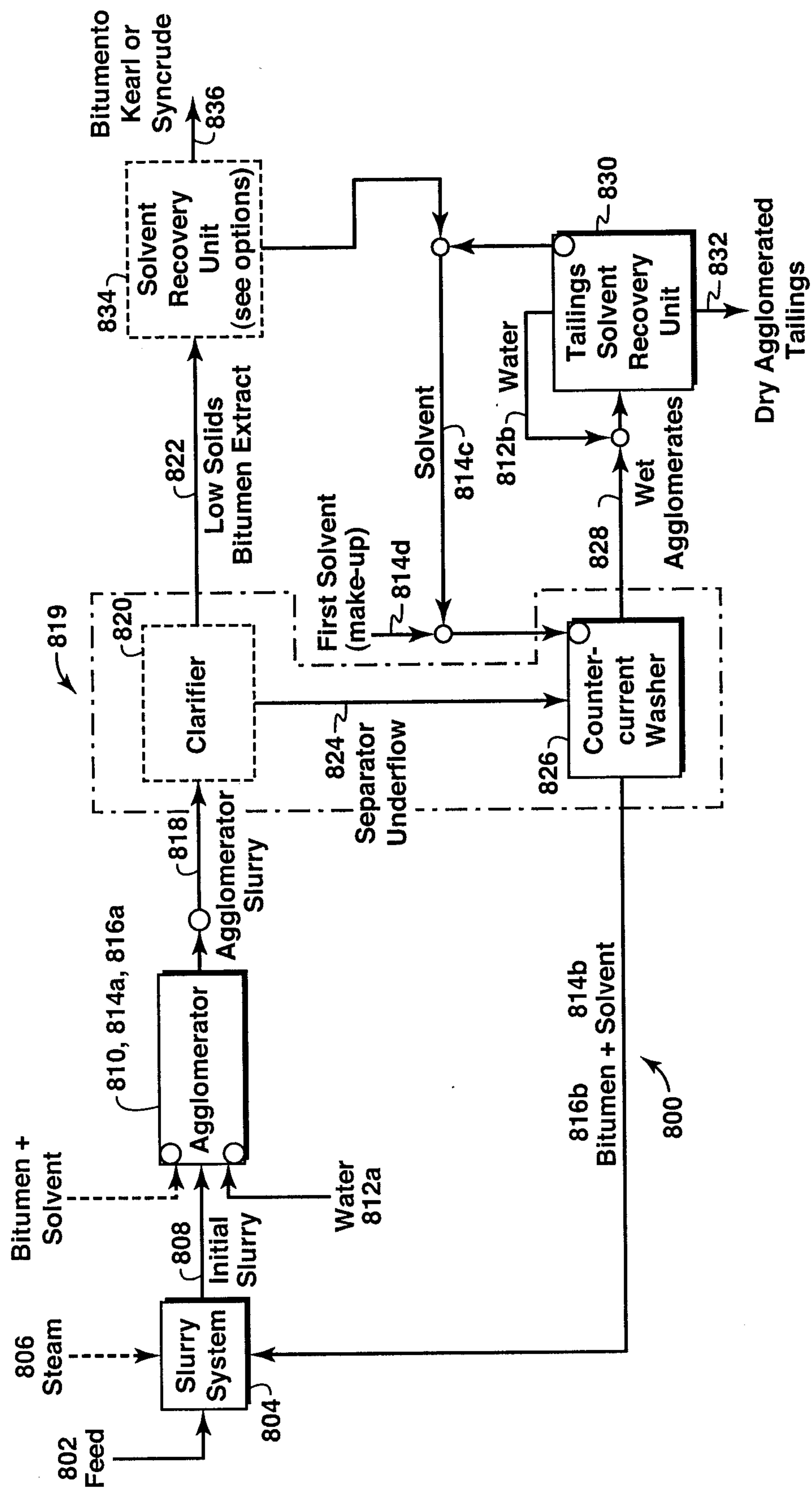


**FIG. 8**

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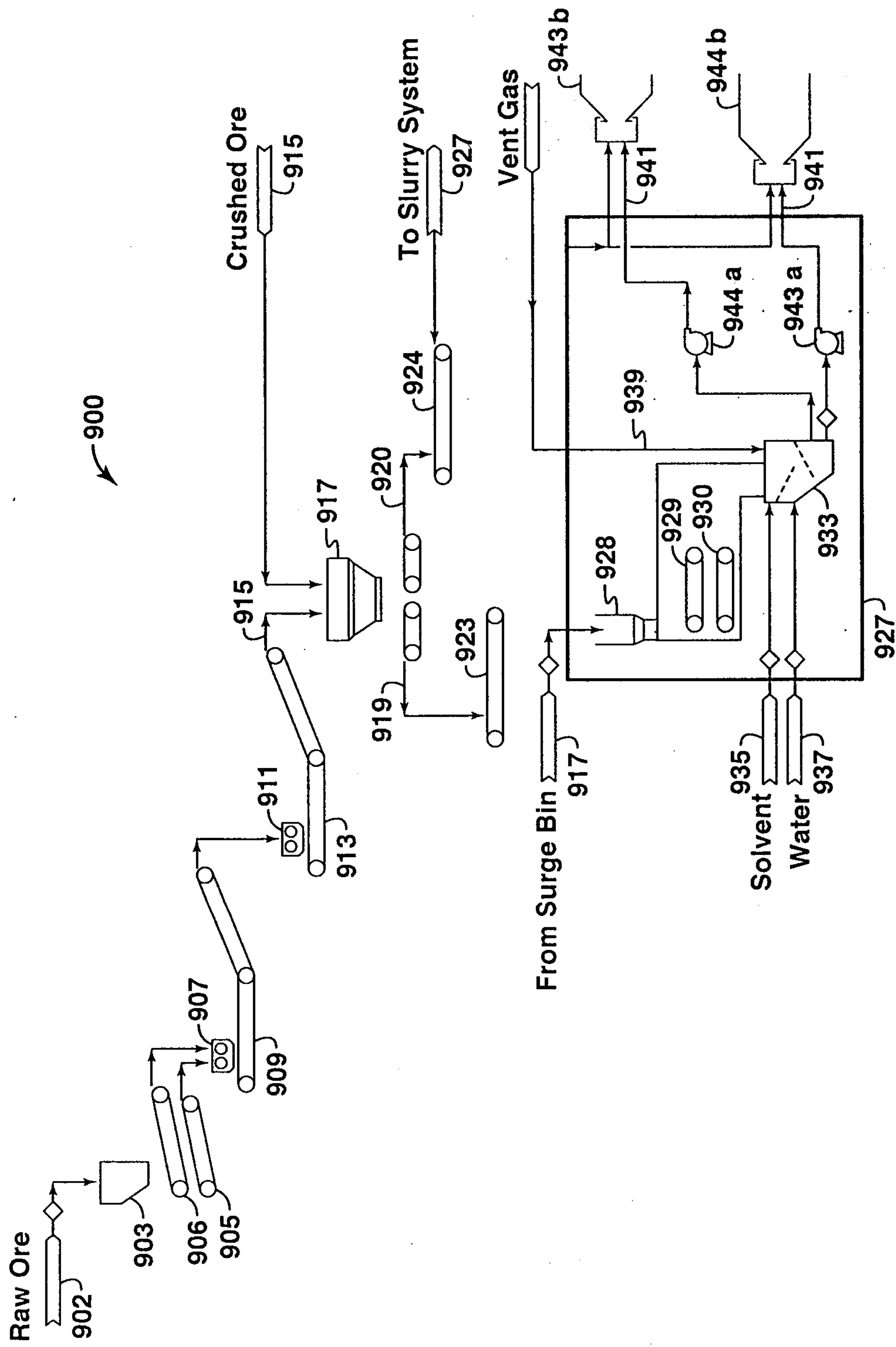


FIG. 9

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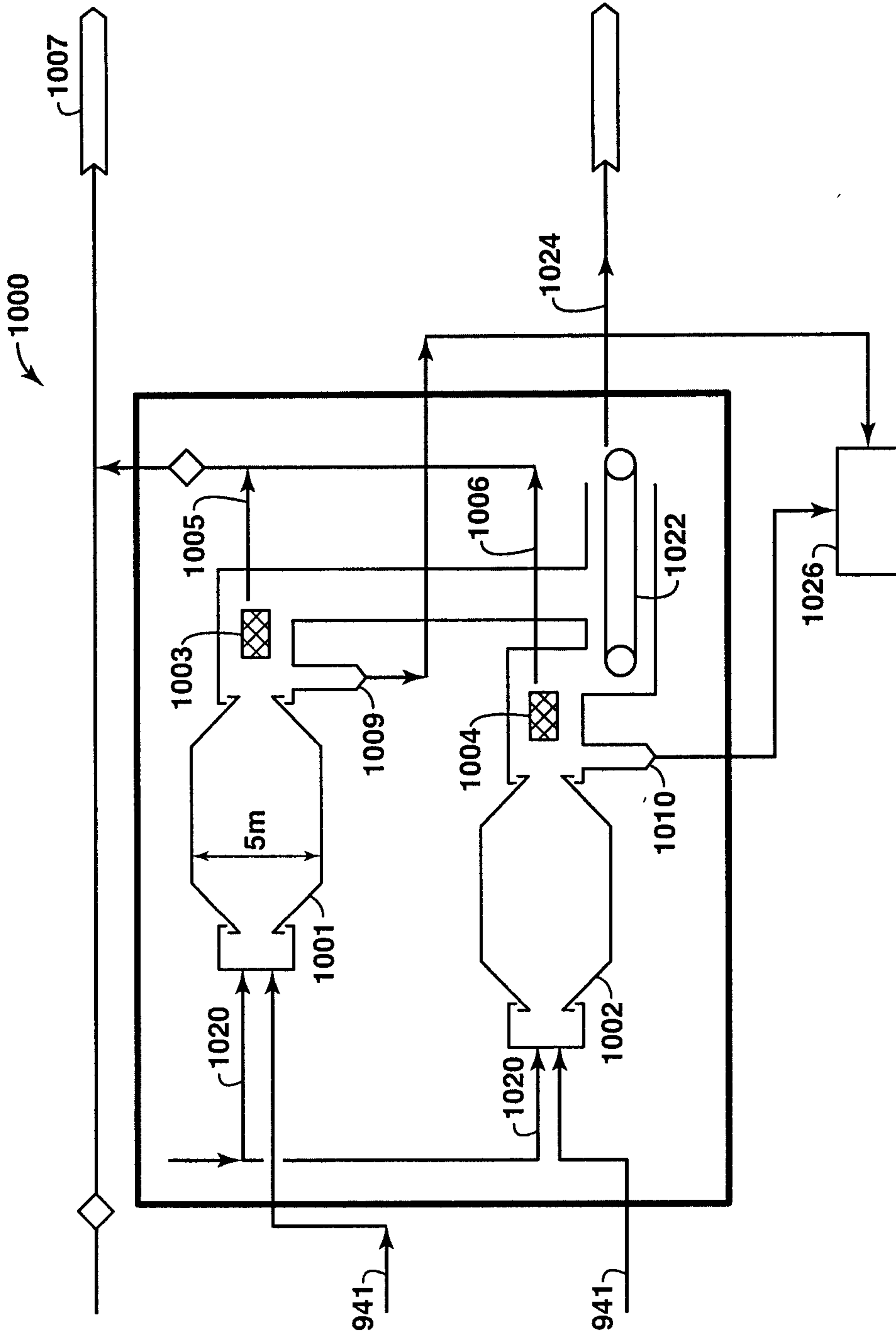


FIG. 10

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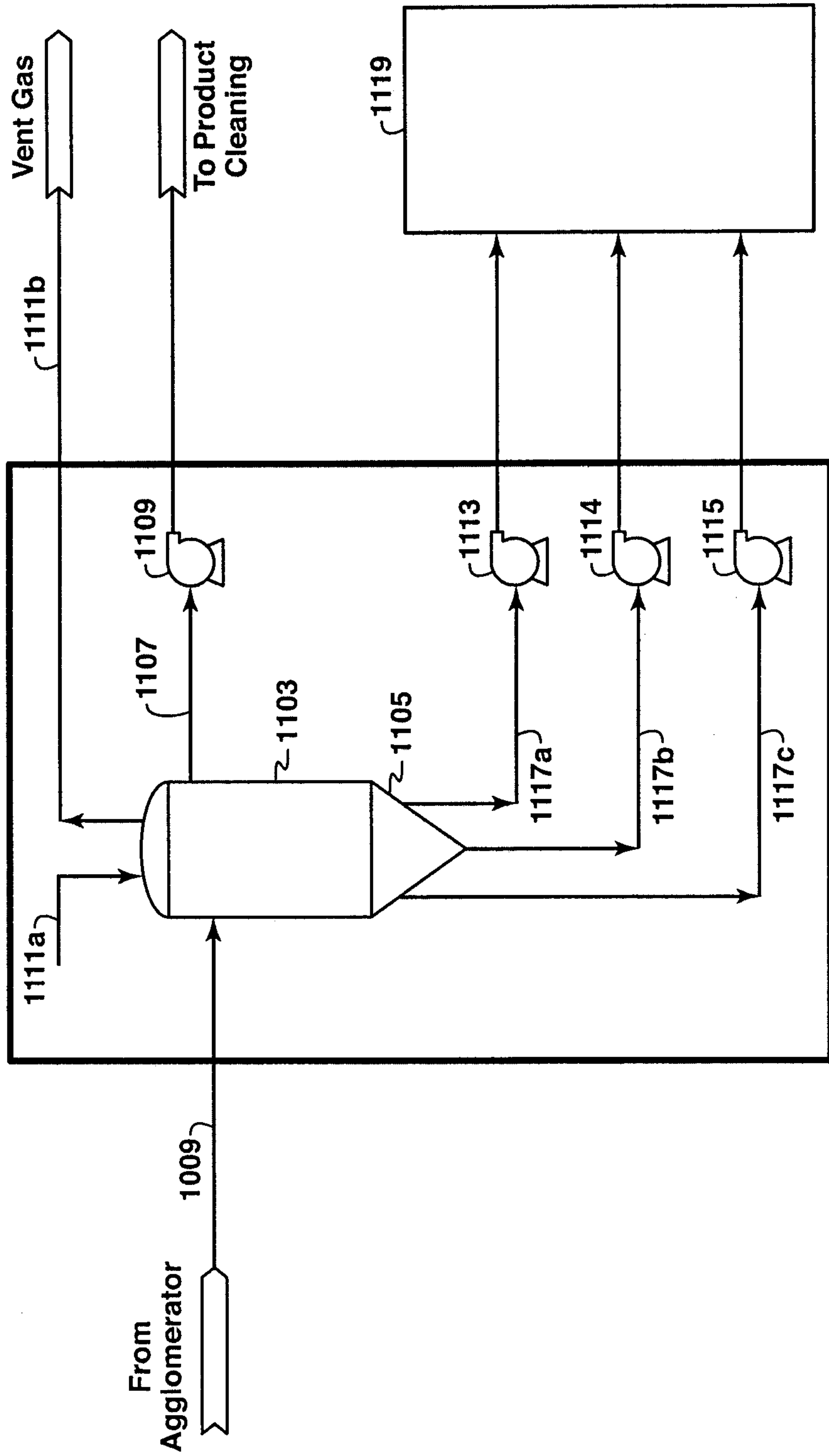


FIG. 11

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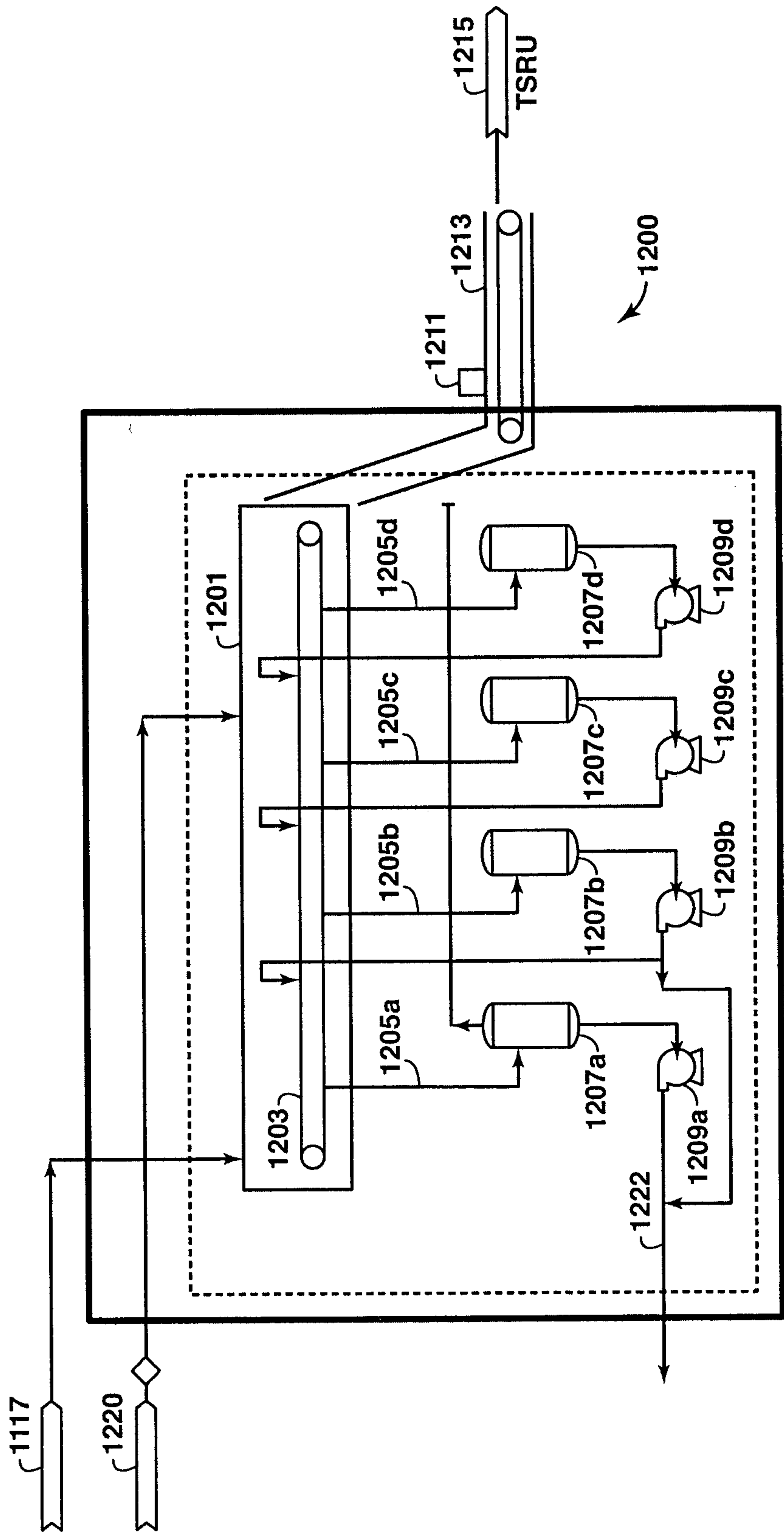


FIG. 12

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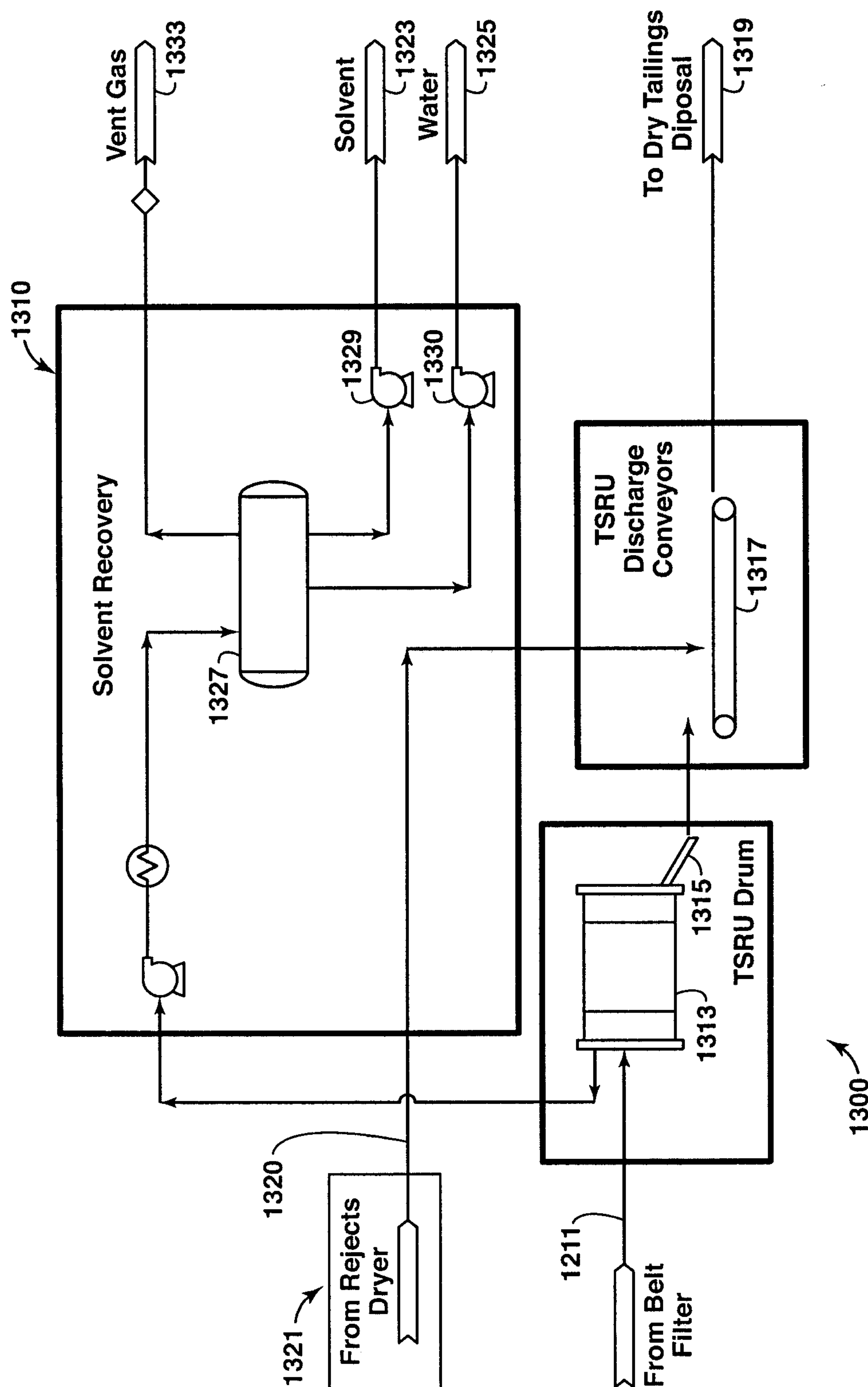


FIG. 13

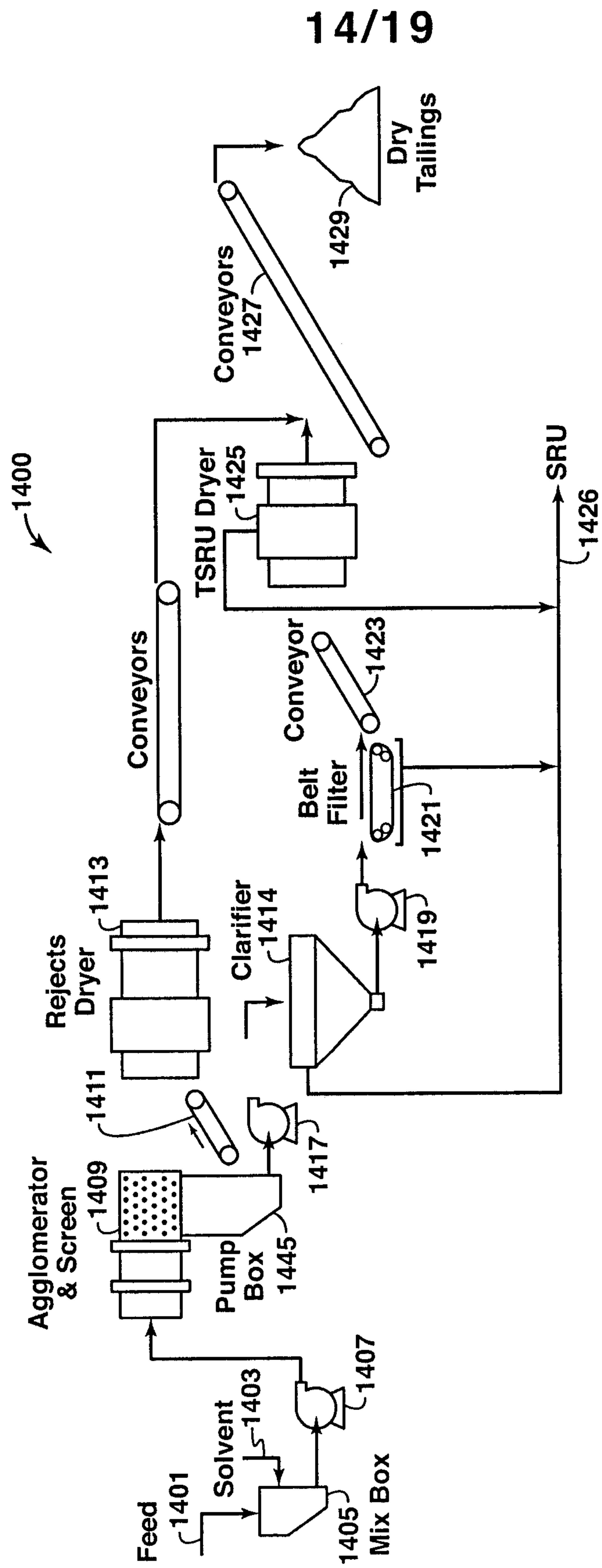


FIG. 14

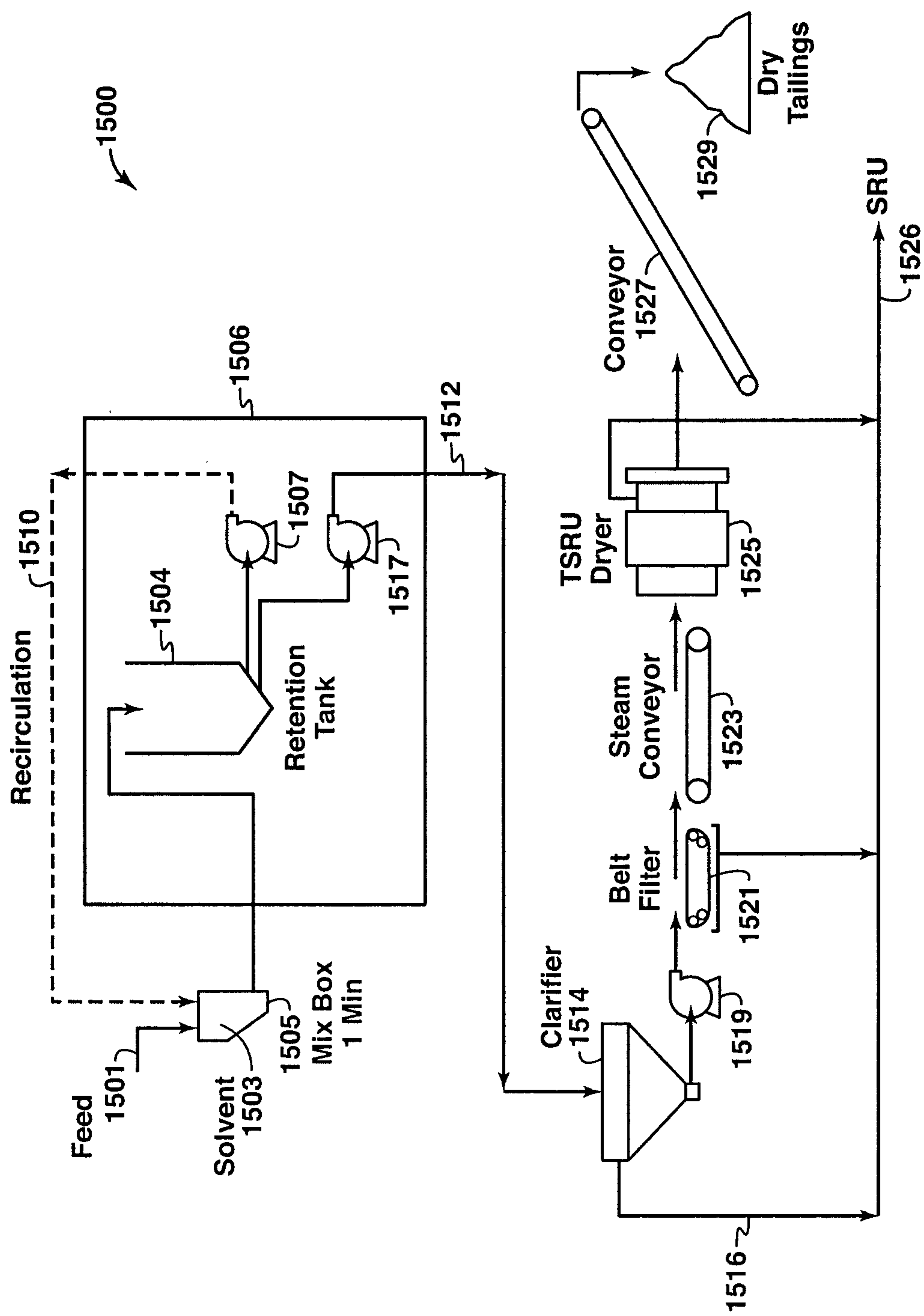
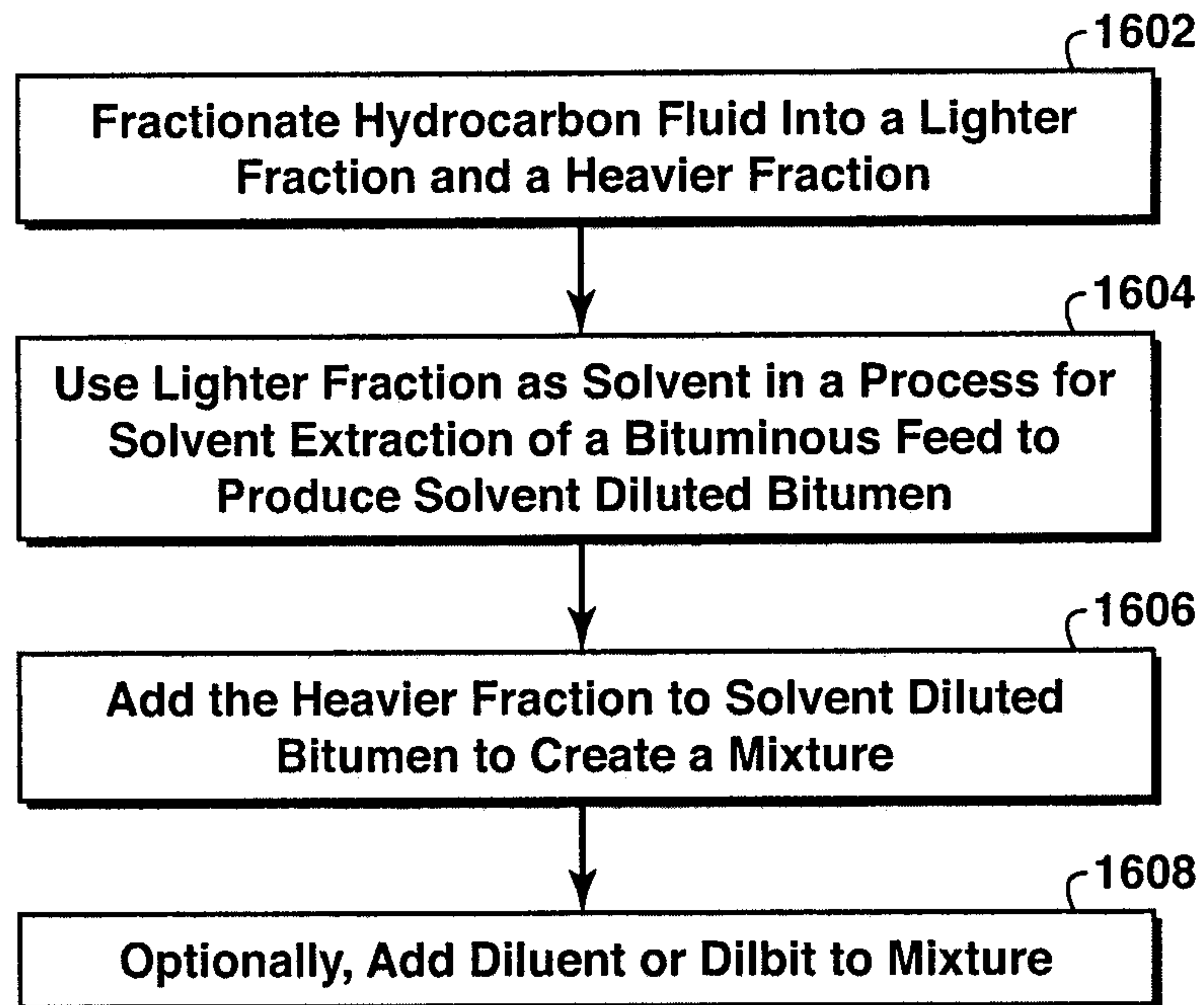
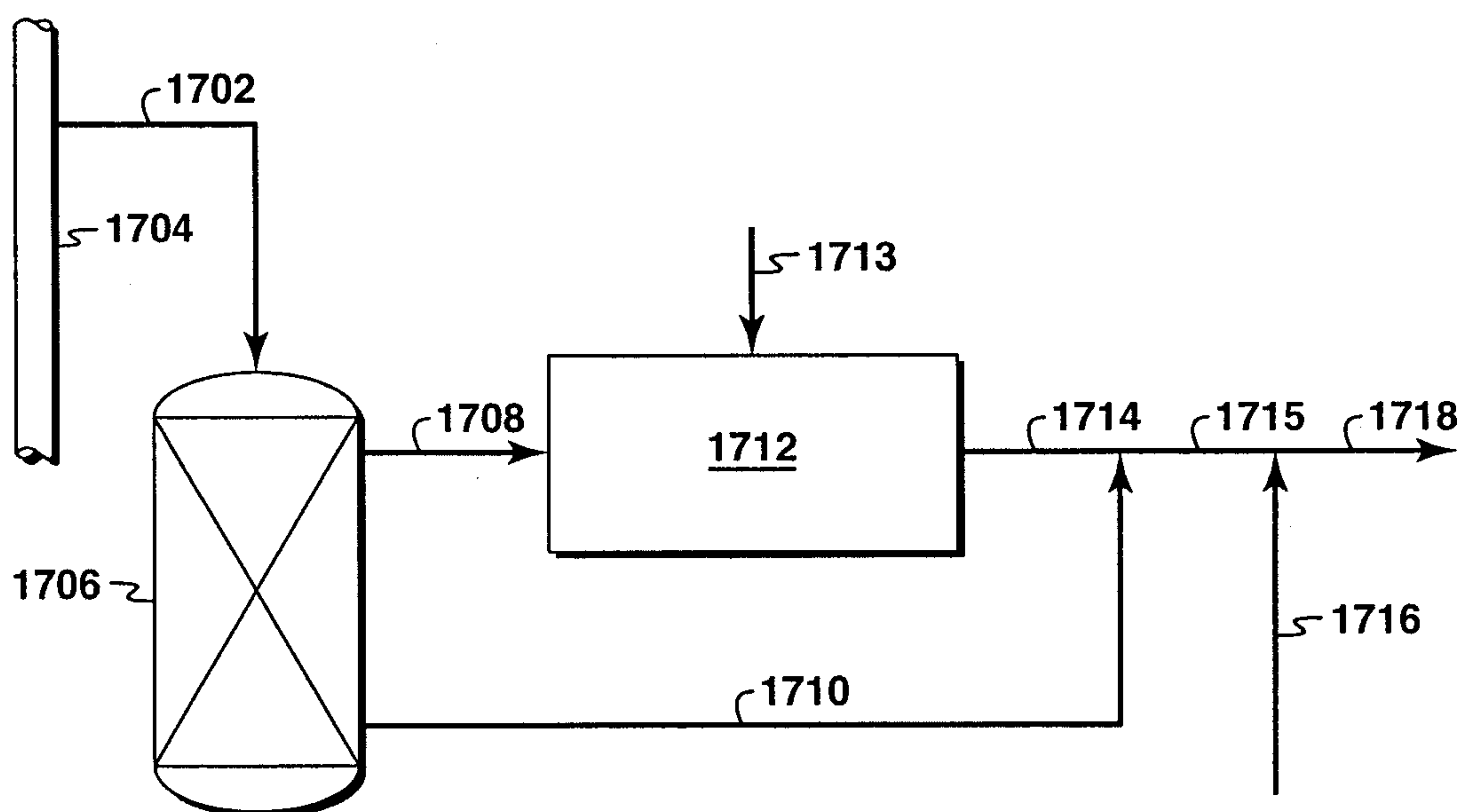
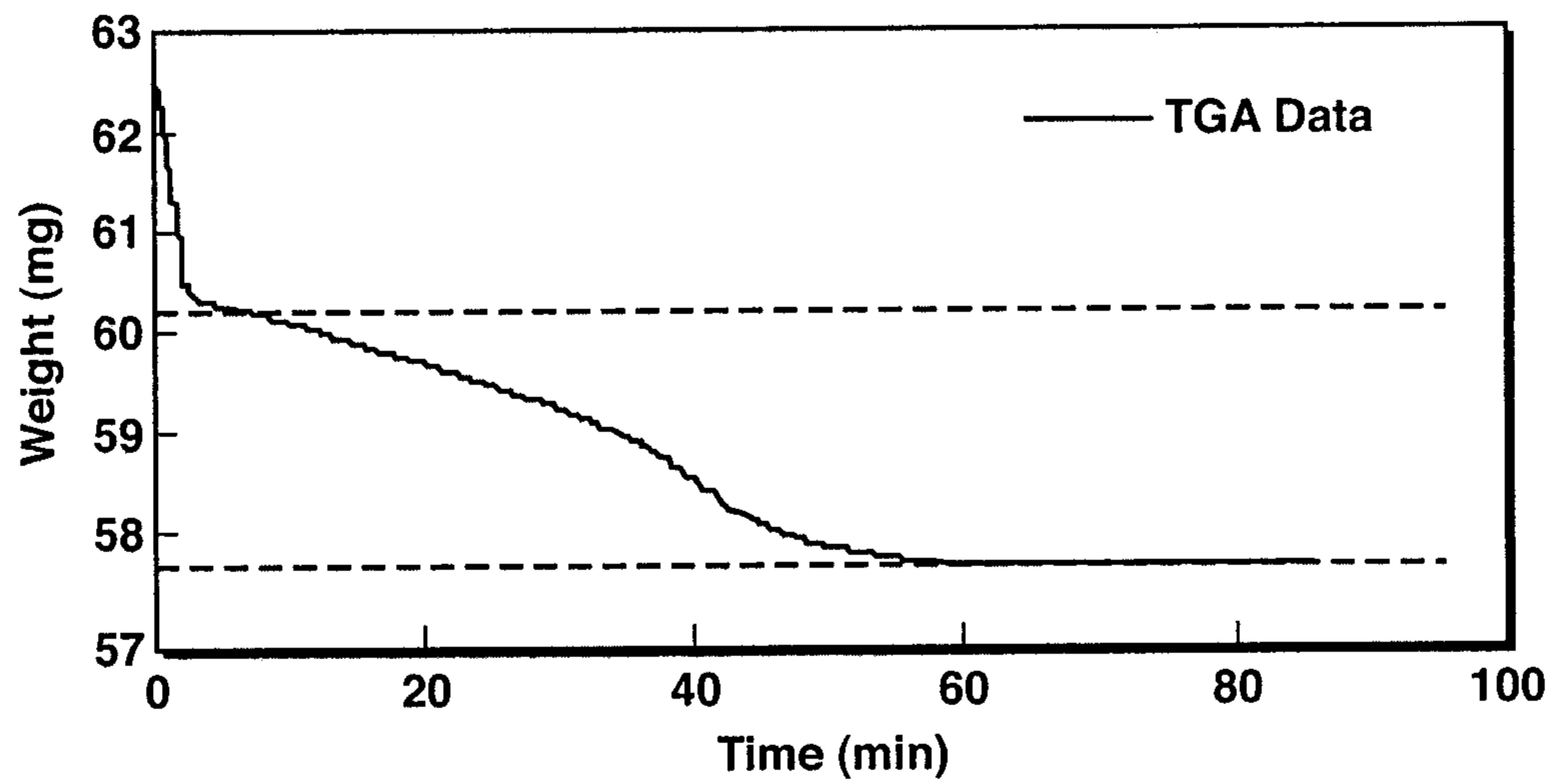
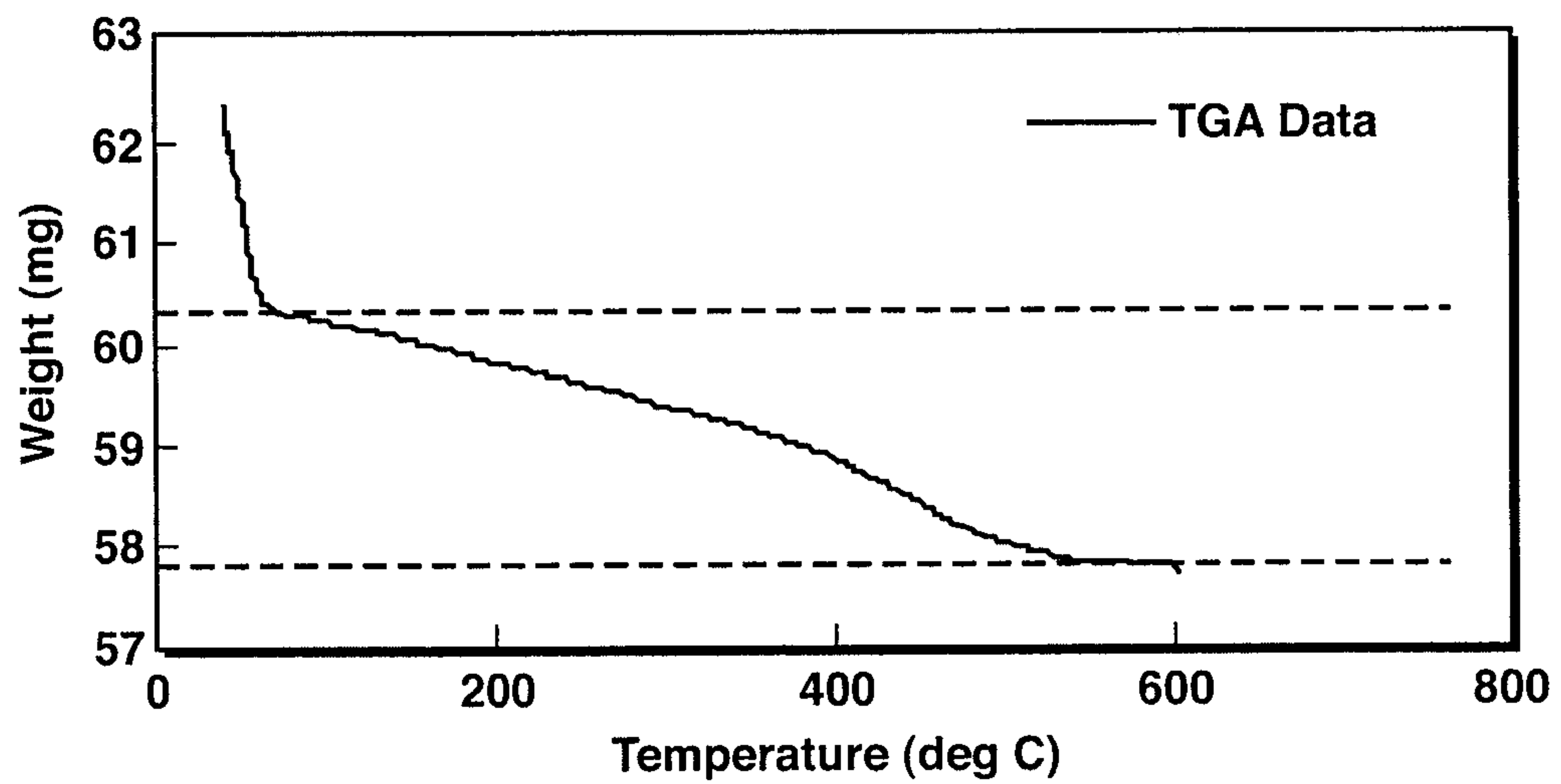


FIG. 15

**16/19****FIG. 16****FIG. 17**

**17/19****FIG. 18****FIG. 19**

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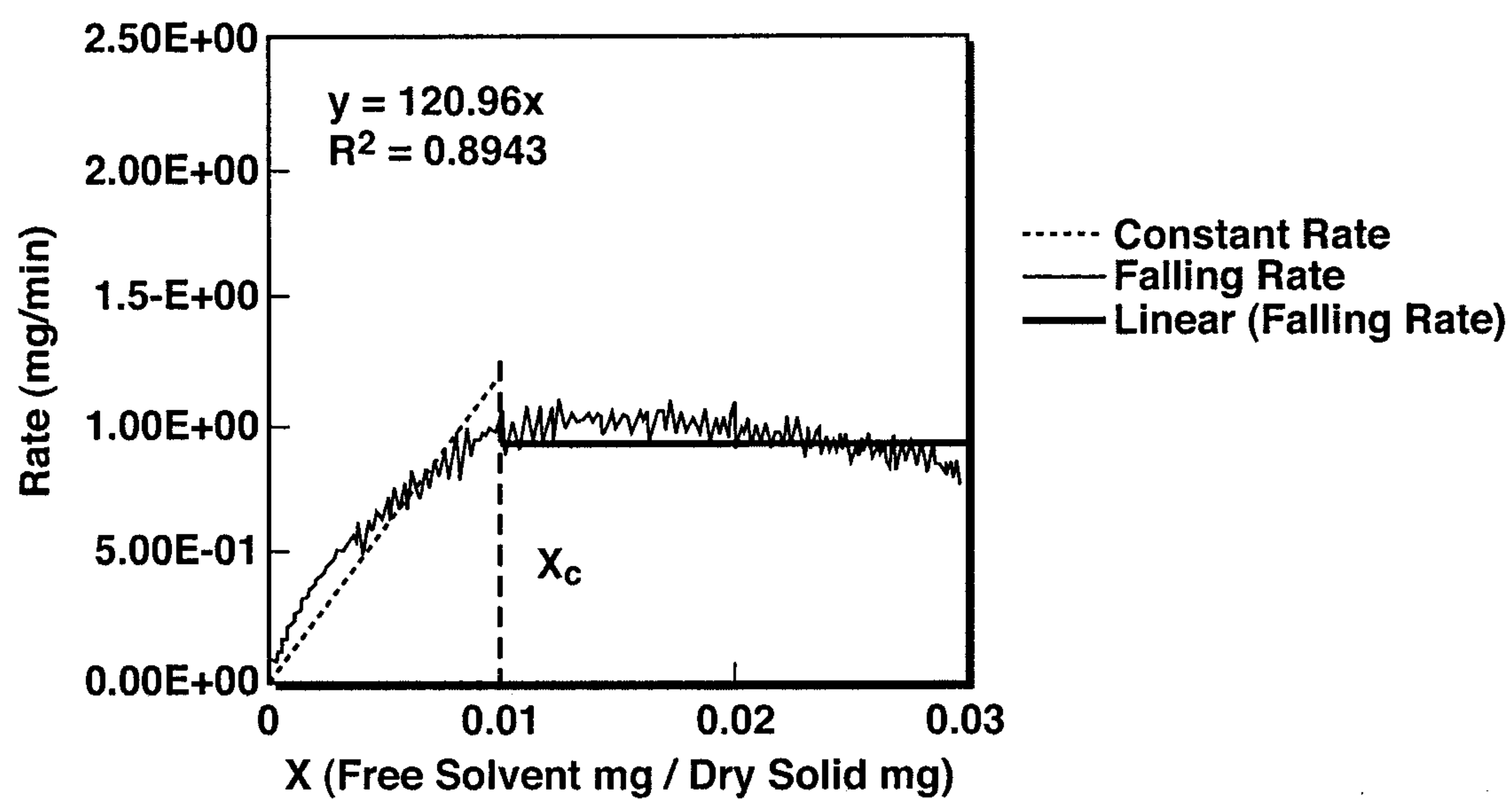


FIG. 20

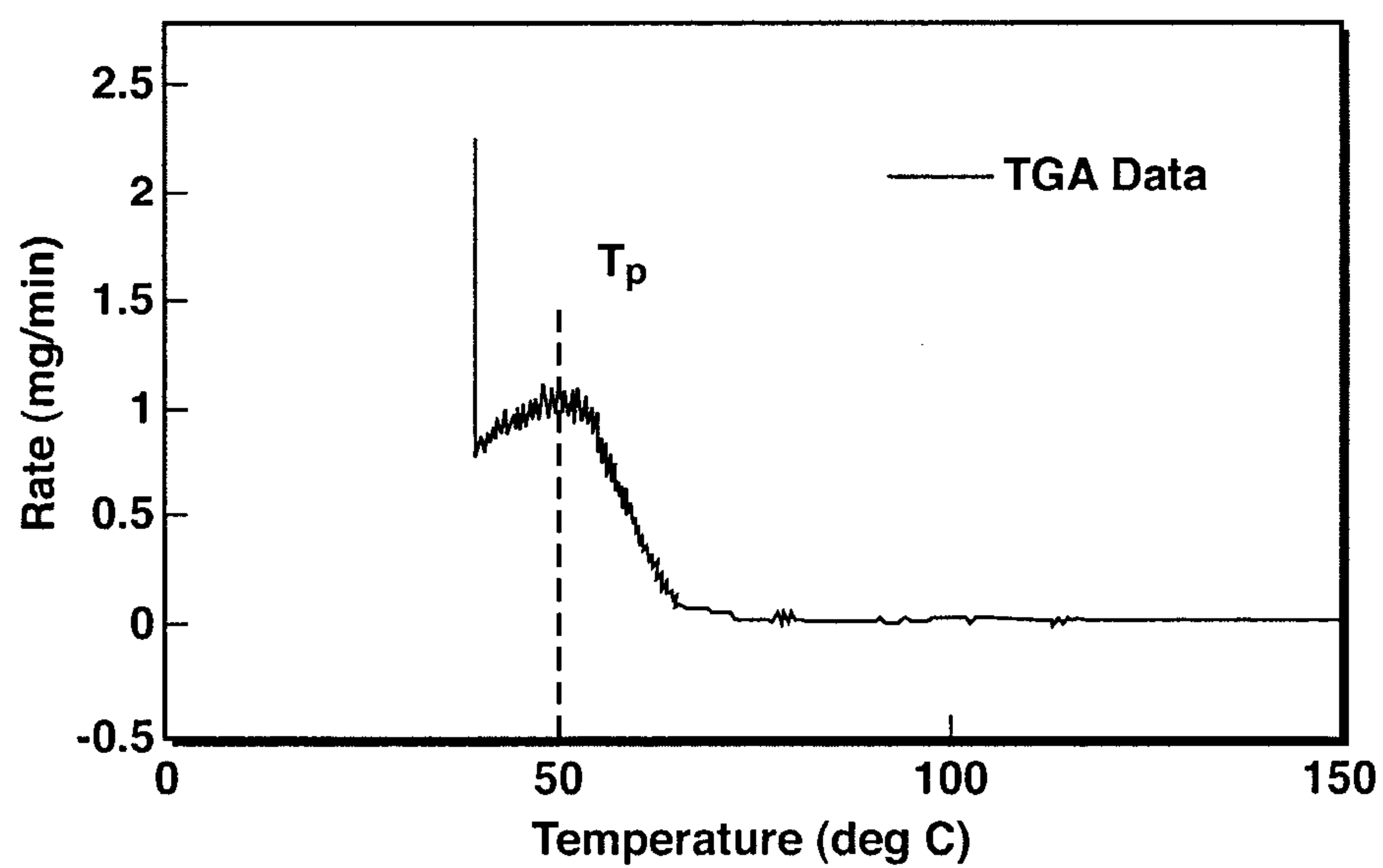
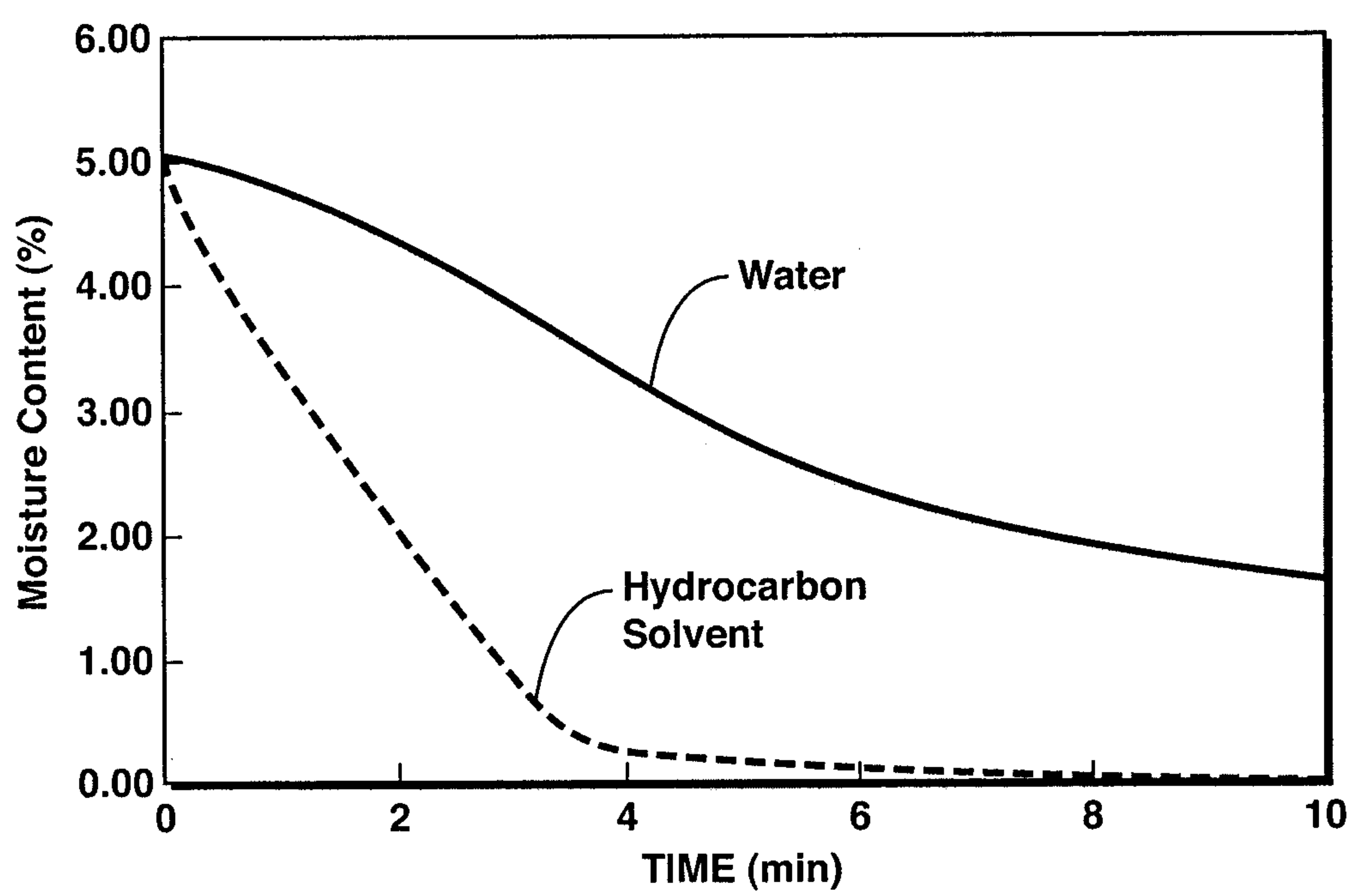


FIG. 21

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**FIG. 22**

1602

**Fractionate Hydrocarbon Fluid Into a Lighter Fraction and a Heavier Fraction**



1604

**Use Lighter Fraction as Solvent in a Process for Solvent Extraction of a Bituminous Feed to Produce Solvent Diluted Bitumen**



1606

**Add the Heavier Fraction to Solvent Diluted Bitumen to Create a Mixture**



1608

**Optionally, Add Diluent or Dilbit to Mixture**