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An agency of Industry Canada

CA 2852087 C 2016/04/12

(11)(21) **2 852 087**

(12) **BREVET CANADIEN**
CANADIAN PATENT

(13) **C**

(22) **Date de dépôt/Filing Date:** 2014/05/14

(41) **Mise à la disp. pub./Open to Public Insp.:** 2015/11/14

(45) **Date de délivrance/Issue Date:** 2016/04/12

(51) **Cl.Int./Int.Cl.** ***C10G 1/04*** (2006.01)

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(54) **Titre : PROCEDE INTEGRE DE REDUCTION DE SOLIDES A PARTIR DU PRODUIT D'EXTRACTION DE SOLVANT DES SABLES BITUMINEUX**

(54) **Title: INTEGRATED PROCESS FOR REDUCING SOLIDS FROM THE PRODUCT OF SOLVENT EXTRACTION OF OIL SANDS BITUMEN**

(57) **Abrégé/Abstract:**

A method is provided for producing a marketable bitumen product having low solids and essentially no water. The method can be integrated into existing solvent extraction processes for extracting bitumen from mined oil sand. A high-solids diluted bitumen is produced from a solvent extraction process and then mixed with a light solvent (LS) stream in at least a first mixer to produce a diluted bitumen-LS mixture. The diluted bitumen-LS mixture is subjected to separation in at least a first separator to produce low-solids diluted bitumen and high-solids asphaltene-rich tails. The LS is removed from the low-solids diluted bitumen to produce the marketable bitumen product.

ABSTRACT

A method is provided for producing a marketable bitumen product having low solids and essentially no water. The method can be integrated into existing solvent extraction processes for extracting bitumen from mined oil sand. A high-solids diluted bitumen is produced from a solvent extraction process and then mixed with a light solvent (LS) stream in at least a first mixer to produce a diluted bitumen-LS mixture. The diluted bitumen-LS mixture is subjected to separation in at least a first separator to produce low-solids diluted bitumen and high-solids asphaltene-rich tails. The LS is removed from the low-solids diluted bitumen to produce the marketable bitumen product.

DOCKET NO.: NS-506

INTEGRATED PROCESS FOR REDUCING SOLIDS FROM THE PRODUCT OF SOLVENT EXTRACTION OF OIL SANDS BITUMEN

FIELD OF THE INVENTION

The present invention relates generally to methods of reducing solids content in high-solids diluted bitumen produced by an existing solvent extraction process of mined oil sand.

BACKGROUND OF THE INVENTION

Oil sand deposits such as those found in the Athabasca Region of Alberta, Canada, generally comprise water-wet sand grains held together by a matrix of viscous heavy oil or bitumen. Bitumen is a complex and viscous mixture of large or heavy hydrocarbon molecules which contain a significant amount of sulfur, nitrogen and oxygen. Oil sands processing involves either Clark hot water extraction or solvent extraction to produce diluted bitumen which is further processed to produce synthetic crude oil and other valuable commodities. Clark hot water extraction technology or its variants require large amounts of water and generate a great quantity of wet tailings. Part of the wet tailings becomes mature fine tailings which contain approximately 30% fine solids and are a great challenge for tailings treatment. In addition, certain problem oil sands, often having high fines content, yield low bitumen recoveries in the water-based extraction process. This leads to economic losses and environmental issues with bitumen in wet tailings.

In contrast, solvent extraction of bitumen from mined oil sands uses little or no water, generates no wet tailings, and can achieve higher bitumen recovery than the exiting water-based extraction. Solvent extraction usually produces diluted bitumen product containing less than about 0.5 wt% water without any additional treatment step such as centrifugation or deasphalting. Solvent extraction is thus potentially more robust and more environmentally friendly than water-based extraction.

Solvent extraction is conducted using either a single solvent or mixture of solvents. One process uses paraffinic solvents and rejects a significant amount of asphaltene (see for example, Canadian Patent Application No. 2,715,301 and Canadian Patent Application No. 2,724,806). This process yields a low-solids product similar to a paraffinic froth treatment product, which contains less than about 0.1 wt% water and solids and is pipelinable and marketable. The diluted bitumen product is produced with low solids content through a fines capture process with asphaltene precipitation. Product of less than about 0.04 wt% (400 mg/kg) solids on dry bitumen basis with significant deasphalting has been reported. However, this process does not recycle the asphaltene-rich tails. Product of less than about 0.1 wt% (1000 mg/kg) solids on dry bitumen basis with significant deasphalting has also been reported. However, mixing the asphaltene-rich tails with the oil sand-solvent slurry causes the release of the captured fines back into the hydrocarbon product, defeating the purpose of product cleanup by deasphalting. The combined bitumen (maltene and asphaltene) recovery for solvent extraction processes with significant asphaltene rejection is estimated below about 88%, considering about 6% loss of bitumen in the extraction itself.

Another solvent extraction process uses aromatic and paraffinic solvents, and rejects little asphaltene (see for example, Canadian Patent Application No. 2,761,555 and Canadian Patent Application No. 2,751,719). Bitumen recovery greater than about 95% can be achieved. However, this process normally produces a high-solids product similar to a naphtha froth treatment product, which is not marketable without upgrading. The diluted bitumen product typically contains about 0.2-0.5 wt% of solids on dilbit basis and about 0.4-1 wt% on dry bitumen basis. The solids are almost exclusively fines which are difficult to remove by settling or centrifugation. Bitumen may be lost in the centrifuge tails. The product must be locally upgraded by coking to be pipelinable and marketable.

Accordingly, there is a need for a method of producing low-solids marketable bitumen at a reasonably high bitumen recovery.

SUMMARY OF THE INVENTION

The current application is directed to a method of producing a low solids, essentially water-free bitumen product from an oil sand/solvent slurry produced by an existing solvent extraction process of mined oil sand. It was surprisingly discovered that by conducting the method of the present invention, one or more of the following benefits may be realized:

(1) The invention may be integrated with an existing solvent extraction process in which diluted bitumen is extracted from oil sand using either a single solvent (e.g., a light solvent such as C_3-C_9 paraffinic solvent) or a combination of solvents (e.g., a high-flash point heavy solvent and a light solvent).

(2) The quality of the diluted bitumen product is enhanced by sufficient mixing. There is about 35% improvement of the product quality by using a high energy-dissipation impeller as compared to a low energy-dissipation impeller.

(3) High-solids asphaltene-rich tails produced by the invention are further treated without releasing captured fines in the solvent extraction process.

(4) Light solvent recovered by the invention is recycled in both the solvent extraction process and the bitumen solids content reduction process of the invention.

(5) One solvent extraction process uses a combination of a heavy solvent and a light solvent. Using the method of the invention, a low-solids, water-free stream is produced which comprises predominantly bitumen and heavy solvent which may be a light gas oil. The stream may contain less than about 500 mg/kg solids on dry bitumen basis. The stream may be pipelined either to a distillation unit for heavy solvent recovery prior to sale, or to market directly as "synthetic bitumen" or "synbit" including the heavy solvent as a diluent. The synbit has a filterable solids content of less than about 300 mg/kg which is considered fungible in refineries.

(6) One solvent extraction process uses only a light solvent. Using the method of the invention, a low-solids, water-free stream is produced which comprises predominantly bitumen.

Use of the present invention improves reduction of water and solids content in a final bitumen product, thereby in turn producing a low-solids marketable bitumen product with a reasonably high bitumen recovery. The bitumen recovery in the final bitumen product is generally greater than about 90% including the bitumen loss in the solvent extraction process.

Thus, broadly stated, in one aspect of the invention, a method of producing a marketable bitumen product having low solids and essentially no water from an oil sand/solvent slurry produced in a solvent extraction process of mined oil sand is provided, comprising:

- subjecting the oil sand/solvent slurry to solid-liquid separation to produce a high-solids diluted bitumen stream and a first solids stream;
- mixing the high-solids diluted bitumen with a light solvent (LS) stream in at least a first mixer to produce a diluted bitumen-LS mixture;
- subjecting the diluted bitumen-LS mixture to separation in at least a first separator to produce a low-solids diluted bitumen stream and high-solids asphaltene-rich tails;
- recovering the LS from the low-solids diluted bitumen in a diluent recovery unit to produce the marketable bitumen product;
- washing the high-solids asphaltene-rich tails with LS and combining the washed high-solids asphaltene-rich tails with the first solids stream to produce a second solid stream; and

- drying the second solid stream in a dryer to recover the LS and produce dry tailings.

In one embodiment, the LS is a paraffinic C_6-C_7 solvent. In one embodiment, wherein both a heavy solvent (HS) and a light solvent (LS) are used in solvent extraction, the LS to bitumen mass ratio ranges from about 2.5 to about 4.0.

In one embodiment, the LS is a paraffinic C_5-C_8 solvent. In one embodiment, wherein only LS is used in solvent extraction, the LS to bitumen mass ratio ranges from about 1.2 to about 2.0.

In one embodiment, the bitumen recovery is greater than about 90 wt%. In another embodiment, the bitumen recovery is greater than about 88 wt%.

BRIEF DESCRIPTION OF THE DRAWINGS

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

FIG. 1 is a diagram showing, in general, one embodiment of a bitumen solids content reduction process of the present invention.

FIG. 2 is a diagram showing, in general, one embodiment of a bitumen solids content reduction process of the present invention.

FIG. 3 shows two graphs of the solids concentration in dilbit (mg/kg) versus settling time (minutes).

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

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

The present invention relates generally to a method of reducing solids content in high-solids diluted bitumen produced by solvent extraction of mined oil sand. Reduction of bitumen water and solids content improves bitumen product quality, thereby in turn producing a low-solids marketable bitumen product with a reasonably high bitumen recovery. The method of the present invention is integrated with an existing solvent extraction process. High-solids asphaltene-rich tails produced by the method of the invention are further treated without releasing captured fines in the solvent extraction process. Light solvent recovered by the method of the invention is reused in the solvent extraction process and in the bitumen solids content reduction process of the invention. The method of the invention thus imparts environmental and economic benefits.

Several embodiments of the method for reducing solids content in high-solids diluted bitumen produced by an existing solvent extraction process are described herein. The solvent extraction process may be, but is not limited to, one described below or one described in the background section. The embodiment of the invention shown in FIG. 1 integrates the solvent extraction process as described in Canadian Patent Application No. 2,751,719, wherein bitumen is extracted from oil sand using a combination of high-flash point heavy solvent (HS) and light solvent (LS). The embodiment of the present invention shown in FIG. 2 integrates a solvent extraction process wherein bitumen is extracted from oil sand using only LS.

As used herein, the term "heavy solvent" or "HS" refers to a solvent with a typical boiling range of 177-480°C and generally includes hydrocarbon liquids in the C_{10} to C_{30} range such as light gas oil and diesel.

As used herein, the term "light solvent" or "LS" means a solvent with a typical boiling range of 36-126°C and generally includes hydrocarbon liquids in the C_5 to C_8 range such as pentane, hexane, cyclohexane, heptanes and octane.

FIG. 1 shows one embodiment of the method of the present invention integrated with an existing solvent extraction process which uses a combination of HS and LS. The solvent extraction process is shown separated with a dashed line in FIG. 1. The oil sand is delivered in a dry form from a mine to a slurry preparation and conditioning unit (e.g., a tumbler/crusher circuit) which is located in an extraction plant. The oil sand is prepared, conditioned, crushed, and mixed with a HS and a LS-rich in two stages to form an oil sand/solvent slurry 100. As used herein, a "LS-rich stream" is defined as a stream containing more than about 50 wt% LS. The oil sand/solvent slurry 100 is passed through a first solid-liquid separator 10, e.g., a filter, to produce a high-solids diluted bitumen stream or high-solids "dilbit" 105 and a filter cake 101.

The filter cake 101 is fed to a repulper 11 in which it is vigorously mixed with a LS-dominant stream pumped into the repulper 11. As used herein, a "LS-dominant stream" is defined as a stream containing more than about 80 wt% LS. The repulper 11 may be a baffled tank agitated with impellers. After repulping, the repulped filter cake 102 is passed through a second solid-liquid separator 12, e.g., a top-loading filter, to produce a first filtrate stream 130 and a first filter cake 103a. The first filter cake 103a is then washed with a pure LS stream and a second filtrate stream 132 and a second filter cake 103b are separated from the second solid-liquid separator 12. It is understood that the second filtrate stream 132 and second filter cake 103b could be produced in a third, separate, solid-liquid separator. The first filtrate stream 130 and the second filtrate stream 132 may be recycled back to the solvent extraction process as the LS-rich stream to produce the oil sand/solvent slurry and the repulper 11 as the LS-dominant stream, respectively. The filter cake 103b is dried in a solids dryer 13 to recover the LS and to produce dry tailings 104 for disposal.

The high-solids diluted bitumen 105 contains about 1 wt% solids on dry bitumen basis. The high-solids diluted bitumen 105 is sufficiently mixed with a LS stream 110 in a suitable mixer 14 to produce a diluted bitumen-LS mixture 106. In one embodiment, the LS stream 110 comprises C_6-C_7 paraffins. In another embodiment, the LS stream 110 comprises C_5-C_8 paraffins.

The flow rate of LS stream 110 is adjusted so that the mass ratio of LS stream 110 to high-solids diluted bitumen 105 is controlled to be in the range of about 0.5 to about 1.0. Since the high-solids diluted bitumen 105 in this embodiment already contains LS, the mass ratio of LS to bitumen is about 2.5 to about 4.0 in the diluted bitumen-LS mixture 106. At such a ratio, only moderate asphaltene precipitation occurs due to the presence in high-solids diluted bitumen 105 of an aromatics-rich HS, a light gas oil fraction produced from an oil sand bitumen upgrading unit.

In one embodiment, the diluted bitumen-LS mixture 106 is fed to a separator 15 in which it is subjected to separation to produce low-solids diluted bitumen 107 and high-solids asphaltene-rich tails stream 108. Since the solids and asphaltene from the diluted bitumen-LS mixture 106 settle in the separator 15, the low-solids diluted bitumen 107 may contain less than about 500 mg/kg filterable solids and about 1000 mg/kg water on dry bitumen basis. In one embodiment, separator 15 is a gravity settler. In another embodiment, separator 15 is a general solid-liquid separator that includes a bank of centrifuges.

The low-solids diluted bitumen 107 is fed to a diluent recovery unit 16 to recover the LS stream 110. Any manner of recovering the LS stream 110 from the low-solids diluted bitumen 107 may be used. In one embodiment, the LS stream 110 is recovered by flashing off from the low-solids diluted bitumen 107. The recovered LS stream 110 can be recycled in both the method of the invention and the solvent extraction process. In one embodiment, a greater portion of the recovered LS stream 110 is reused in the mixer 14, while a lesser portion 111 of the recovered LS stream 110 is reused in the solvent extraction process.

Removal of the LS stream 110 from the low-solids diluted bitumen 107 produces a low-solids, water-free stream 109 comprising predominantly bitumen and HS. In one embodiment, the stream 109 (also referred to herein as the marketable bitumen product) contains less than about 500 mg/kg solids on dry bitumen basis. In one embodiment, the HS is a light gas oil. The stream 109 may be pipelined either to a distillation unit for HS recovery prior to sale, or to market directly as synthetic bitumen or "synbit" including the HS as a diluent. In one embodiment, the synbit has a filterable solids content of less than about 300 mg/kg which is considered fungible in refineries.

At this stage, the method of the invention is integrated with the existing solvent process. The high-solids asphaltene-rich tails stream 108 enters the solvent extraction process downstream of the repulper 11 to avoid liberating the captured fines through agitation. The tails stream 108 is fed to the second solid-liquid separator 12 only after passage of filtrate stream from the repulped slurry 102 through the second solid-liquid separator 12 and formation of a filter cake 103, which is a precursor of first filter cake 103a. The liquids of the tails stream 108 drain through the filter cake 103, while highly viscous asphaltene fine-solids tails are retained by the top layer of the filter cake 103 to form first filter cake 103a. The filter cake 103a is washed at least once with LS, for example light paraffinic solvent 111. After washing and draining, the solids in tails stream 108, now mixed with first filter cake 103a to form second filter cake 103b, are relatively dry. Second filter cake 103b is further dried in the solids dryer 13 to recover LS as part of the solvent extraction process. The subsequent dry tailings 104 thus include the asphaltene-fine solids tails and spent oil sand solids. The heat duty to recover the LS from tails stream 108 is minimized following this integration.

In one embodiment, the total hydrocarbon loss including maltene, asphaltene and HS after the treatment of the tails stream 108 is less than about 5 wt% on oil sand bitumen basis. Taking into account a typical hydrocarbon loss of about 4 wt% on oil sand bitumen basis for the existing solvent extraction process, the combined bitumen recovery is greater than about 90%.

FIG. 2 shows one embodiment of the method of the present invention integrated with an existing solvent extraction process wherein bitumen is extracted from oil sand using only LS. However, the method of the invention is generally the same as that shown in FIG. 1.

The solvent extraction process is shown separated with a dashed line in FIG. 2. The oil sand is delivered in a dry form from a mine to a slurry preparation and conditioning unit (e.g., a tumbler/crusher circuit) which is located in an extraction plant.

The oil sand is prepared, conditioned, crushed, and mixed with a LS-rich stream to form an oil sand/solvent slurry 300. The oil sand/solvent slurry 300 is passed through a solid-liquid separator 30, e.g., a top-loaded filter, to separate high-solids diluted bitumen or high solids "dilbit" 303 and a first filter cake 301a. The first filter cake 301a is then washed with a pure LS stream. A second filtrate stream 332 and a second filter cake 301b are separated from the solid-liquid separator 30. Second filtrate stream 332 may be recycled back to the solvent extraction process, e.g., an oil sand/solvent slurry preparation unit, as the LS-rich stream. The second filter cake 301b is dried in a solids dryer 31 to recover the LS and to produce dry tailings 302 for disposal.

The high-solids diluted bitumen 303 is sufficiently mixed with a LS stream 308 in a mixer 32 to produce a diluted bitumen-LS mixture 304. In one embodiment, the LS stream 308 comprises C_5-C_8 paraffins.

The mass ratio of LS to bitumen in stream 304 is controlled to be in the range of about 1.2 to about 2.0 by adjusting the flow rate of the LS stream 308.

The diluted bitumen-LS mixture 304 is fed to a separator, e.g., a gravity settler, 33 in which it is subjected to separation to produce low-solids diluted bitumen 305 and high-solids asphaltene-rich tails stream 306. In one embodiment, the separator 33 is a general solid-liquid separator that includes a bank of centrifuges.

The low-solids diluted bitumen 305 is fed to a diluent recovery unit 34 to recover the LS stream 308. Any manner of recovering the LS stream 308 from the low-solids diluted bitumen 305 may be used. In one embodiment, the LS stream 308 is recovered by flashing off from the low-solids diluted bitumen 305. The recovered LS stream 308 is recycled in both the method of the invention and the solvent extraction process. In one embodiment, a greater portion of the recovered LS stream 308 is reused in the mixer 32, while a lesser portion 309 of the recovered LS stream 308 is reused in the solvent extraction process.

Removal of the LS stream 308 from the low-solids diluted bitumen 305 produces a low-solids, essentially water-free stream 307 comprising predominantly bitumen. In one embodiment, the stream 307 contains less than about 400 mg/kg solids on dry bitumen basis.

At this stage, the method of the invention is integrated with the existing solvent process. The high-solids asphaltene-rich tails stream 306 enters the solvent extraction process downstream of any slurry preparation/conditioning unit to avoid liberating the captured fines through agitation. The tails stream 306 is fed to the solid-liquid separator 30 only after passage of the liquid in the oil sand/solvent slurry 300 through the solid-liquid separator 30 and formation of a filter cake 301, which is a precursor of first filter cake 301a. The liquids of the high solids tails stream 306 drain through the filter cake 301, while highly viscous asphaltene fine-solids tails are retained by the top layer of the filter cake 301 to form first filter cake 301a. The first filter cake 301a is washed at least once with fresh LS. After washing and draining, the solids in the high-solids tails stream 306, now mixed in second filter cake 301b, are relatively dry. Second filter cake 301b is further dried in the solids dryer 31 to recover LS as part of the solvent extraction process. The subsequent dry tailings 302 thus include the asphaltene-fine solids tails and spent oil sand solids. The heat duty to recover the LS from high-solids tails stream 306 is minimized following this integration.

In one embodiment, the total hydrocarbon loss including maltene and asphaltene after the treatment of the tails stream 306 is less than about 6 wt% on oil sand bitumen basis. Taking into account a typical hydrocarbon loss of about 6 wt% on oil sand bitumen basis for the existing solvent extraction process, the combined bitumen recovery is greater than about 88 wt%.

In the embodiments shown in FIGS. 1 and 2, the mixer 14 and 32 may comprise a high energy-input impeller. In one embodiment, the impeller comprises a Rushton turbine which is a radial flow impeller having a flat disk upon which flat, concave, or semi-circular blades are vertically mounted. Preferably, the Ruston turbine is run at a speed that causes the mixed liquid to be in a fully turbulent regime in order to enhance collision and aggregation between individual asphaltene particles and asphaltene particles-fine solids. The duration of mixing may range from about 1 minute to about 10 minutes.

In the embodiments shown in FIGS. 1 and 2, the gravity settler 15 and 33 may comprise any suitable apparatus which facilitates gravity settling including, but not limited to, a gravity settling vessel and an inclined plate separator ("IPS"). An IPS refers is an apparatus comprising a plurality of stacked inclined plates onto which a mixture to be separated may be introduced so that the mixture passes along the plates in order to achieve separation of components of the mixture.

Exemplary embodiments of the present invention are described in the following Examples, which are set forth to aid in the understanding of the invention, and should not be construed to limit in any way the scope of the invention as defined in the claims which follow thereafter.

Example 1

A dilbit product of about 620 g containing approximately 33 wt% bitumen, 33 wt% virgin light gas oil and 34 wt% heptane was mixed with additional heptane using various impellers at 50°C. The hydrocarbon mixture of about 1000 g contained approximately 20 wt% bitumen, 20 wt% virgin light gas oil and 60 wt% heptane. The mixed hydrocarbon sample was allowed to settle in a vessel at 50°C.

FIG. 3 shows the filterable solids concentration reduction in the top 1-2 cm of the mixed hydrocarbon sample during settling. "RT" stands for Rushton turbine which is an impeller with high levels of energy dissipation; "PBT" stands for pitched blade turbine which is a medium energy-dissipation impeller; and "A310" is a hydrofoil which is a relatively low energy-dissipation impeller. The mixing time was 5 minutes, except for one RT mixing case of 10 minutes. The average filterable solids concentrations at 20 minutes settling time are shown in Table 1. There is about 35% improvement of the product quality by using a high energy-input impeller (RT) as compared to the low energy-input impeller (A310).

Table 1.

Impeller Type	Solids concentration in dilbit (mg/kg)	Solids concentration on dry bitumen basis (mg/kg)
RT	90	450
PBT	113	565
A310	140	700

Example 2

An oil sand sample containing 8.9 wt% bitumen and 38% fines in its solids was extracted with two solvents: virgin light gas oil and heptane in a batch apparatus. The oil sand/solvent slurry proceeded through four filtration stages with a repulping step between the second and third stages. An asphaltene and solids-rich tails sample from Example 1 was added to the top of the filter cake after the third stage filtration. Alternately, the tails sample was added to the repulper before the third stage filtration. The tails sample mass is about 5% of the oil sand mass.

Table 2 shows the filterable solids concentrations in four filtrates for three cases: the control (i.e., no tails addition); addition of tails after repulping and third stage filtration; and addition of tails during repulping. The first and second stage filtrates varied slightly in their solids contents due to the variation in oil sand feeds. The post-third stage tails addition shows no significant change of the solids concentrations in the third and fourth stage filtrates as compared to the control case, indicating that captured fines in the tails sample were retained by the filter cake. The tails addition during repulping shows drastic increase of the solids concentration in the third stage filtrate, indicating that captured fines in the tails sample were released during repulping. Since all filtrates except the first stage filtrate are recycled in the process, the released solids will eventually reach the first stage filtrate (product) which is undesirable.

Table 2.

Filtrate	No Tails Addition (mg/kg)	Post-Third Stage Tails Addition (mg/kg)	Tails Addition During Repulping (mg/kg)
First Stage	2270	3600	3360
Second Stage	1750	2120	2120
Third Stage	390	320	10530
Fourth Stage	100	150	840

Table 3 shows the variations in filter #2 process rate including third and fourth stage filtrations and total hydrocarbon (bitumen, light gas oil and asphaltene) loss as a result of adding a tails stream on post-third stage filter cake. The results indicate about 15% reduction in filter process rate and 3% increase (on oil sand bitumen basis) in hydrocarbon loss compared to the control case (i.e., no tails addition). This sample of oil sand was aged and poorer in quality than typical fresh oil sands, which resulted in higher hydrocarbon loss in the control case.

Table 3.

Parameter	No Tails Addition	Post-Third Stage Tails Addition
Filter #2 Process Rate (t/m^2h)	14.1	11.9
Hydrocarbon Loss on Oil Sand Bitumen Basis (wt%)	8.5	11.3

The scope of the claims should not be limited by the preferred embodiments set forth in the examples, but should be given the broadest interpretation consistent with the description as a whole.

WHAT IS CLAIMED:

1. A method of producing a marketable bitumen product having low solids and essentially no water from an oil sand/solvent slurry produced in a solvent extraction process of mined oil sand, comprising:

(a) subjecting the oil sand/solvent slurry to a first solid-liquid separation step to produce a high-solids diluted bitumen stream and a first solids stream;

(b) mixing the high-solids diluted bitumen with a light solvent (LS) stream in at least a first mixer to produce a diluted bitumen-LS mixture;

(c) subjecting the diluted bitumen-LS mixture to separation in at least a first separator to produce low-solids diluted bitumen and high-solids asphaltene-rich tails;

(d) recovering the LS from the low-solids diluted bitumen in a diluent recovery unit to produce the marketable bitumen product;

(e) washing the high-solids asphaltene-rich tails with LS and combining the washed high-solids asphaltene-rich tails with the first solids stream to produce a second solids stream; and

(f) drying the second solids stream in a dryer to recover the LS and produce dry tailings.

2. The method of claim 1, wherein the solvent extraction process comprises contacting mined oil sand with a high-flash point heavy solvent and a LS-rich stream to produce the oil sand/solvent slurry.

3. The method of claim 2, wherein the first solids stream is fed to a repulper for mixing with a LS-dominant stream and subjected to a second solid-liquid separation step prior to being combined with the washed high-solids asphaltene-rich tails.

4. The method of claim 3, wherein the second solid-liquid separation step produces a first filtrate stream and a second filtrate stream.

5. The method of claim 4, wherein the first filtrate stream is used in the solvent extraction process as the LS-rich stream and the second filtrate stream is sent to the repulper as the LS-dominant stream.

6. The method of claim 1, wherein in step (b), the LS is a paraffinic C_6-C_7 solvent.

7. The method of claim 1, wherein in step (b), the LS is a paraffinic C_5-C_8 solvent

8. The method of claim 7, wherein in step (b), the LS to diluted bitumen mass ratio in the diluted bitumen-LS mixture ranges from about 2.5 to about 4.0.

9. The method of claim 8, wherein in step (c), the low-solids diluted bitumen comprises less than 500 mg/kg solids and about 1000 mg/kg water on dry bitumen basis.

10. The method of claim 9, wherein in step (d), the LS is recovered in the diluent recovery unit by flashing off the LS from the low-solids diluted bitumen.

11. The method of claim 10, wherein in step (d), a first portion of the recovered LS is recycled to the first mixer, and a second portion of the recovered LS is recycled to the solvent extraction process.

12. The method of claim 11, wherein in step (d), the marketable bitumen product comprises less than 500 mg/kg solids on dry bitumen basis.

13. The method of claim 12, wherein the marketable bitumen product further comprises a heavy solvent.

14. The method of claim 13, wherein the heavy solvent is a light gas oil.

15. The method of claim 14, further comprising recovering the heavy solvent.

16. The method of claim 1, wherein a combined bitumen recovery is greater than 90 wt%.

17. The method of claim 1, wherein the solvent extraction process comprises contacting mined oil sand with a LS-rich stream to produce the oil sand/solvent slurry.

18. The method of claim 17, wherein the first solid-liquid separation step comprises passing the oil sand/solvent slurry through a top-loading filter, whereby the first solids stream is a filter cake.

19. The method of claim 18, wherein, in step (b), the LS is a paraffinic C_5-C_8 solvent.

20. The method of claim 19, wherein, in step (b), the LS to bitumen mass ratio in the diluted bitumen-LS mixture ranges from about 1.2 to about 2.0.

21. The method of claim 20, wherein, in step (d), the LS is recovered in the diluent recovery unit by flashing off the LS from the low-solids diluted bitumen.

22. The method of claim 21, wherein in step (d), a first portion of the recovered LS is recycled to the at least a first mixer, and a second portion of the recovered LS is recycled to the solvent extraction process.

23. The method of claim 17, wherein, in step (d), the marketable bitumen product comprises less than 400 mg/kg solids on dry bitumen basis.

24. The method of claim 17, wherein a combined bitumen recovery is greater than 88 wt%.

25. The method of claim 1, wherein the at least a first mixer comprises a high energy-dissipation impeller.

26. The method of claim 25, wherein the impeller is a Rushton turbine.

27. The method of claim 26, wherein the duration of mixing ranges from about 1 minute to about 10 minutes.

28. The method of claim 1, wherein the at least a first separator is a gravity settler.

29. The method of claim 1, wherein the at least a first separator is any conventional solid-liquid separator.

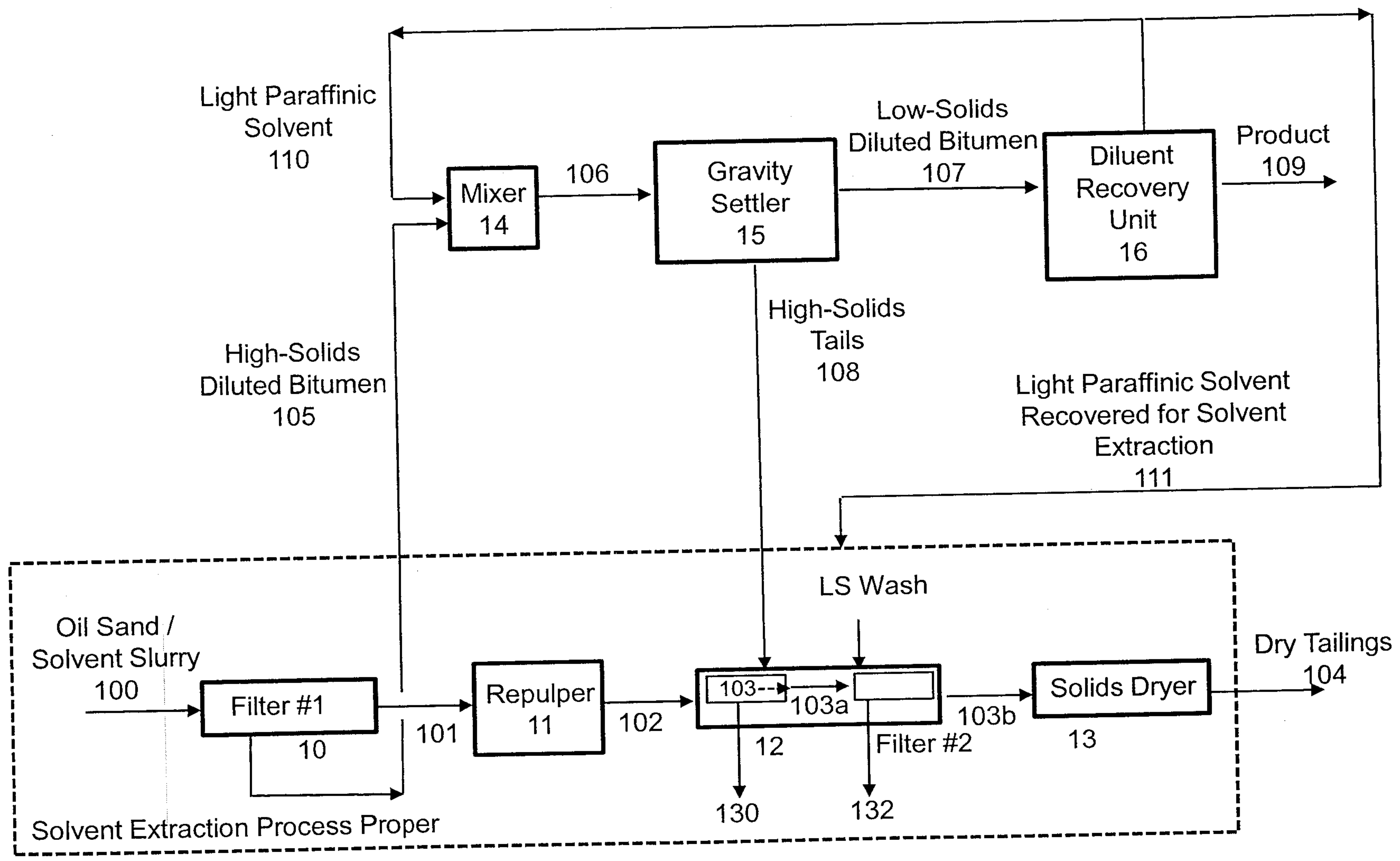
Light Paraffinic Solvent 110
Mixer 14
106
Gravity Settler 15
Low-Solids Diluted Bitumen 107
Diluent Recovery Unit 16
Product 109
High-Solids Diluted Bitumen 105
High-Solids Tails 108
Light Paraffinic Solvent Recovered for Solvent Extraction 111
LS Wash
Oil Sand / Solvent Slurry 100
Filter #1
10
101
Repulper 11
102
103--
103a
12
Filter #2
103b
Solids Dryer
13
Dry Tailings 104
130
132
Solvent Extraction Process Proper

Figure 1

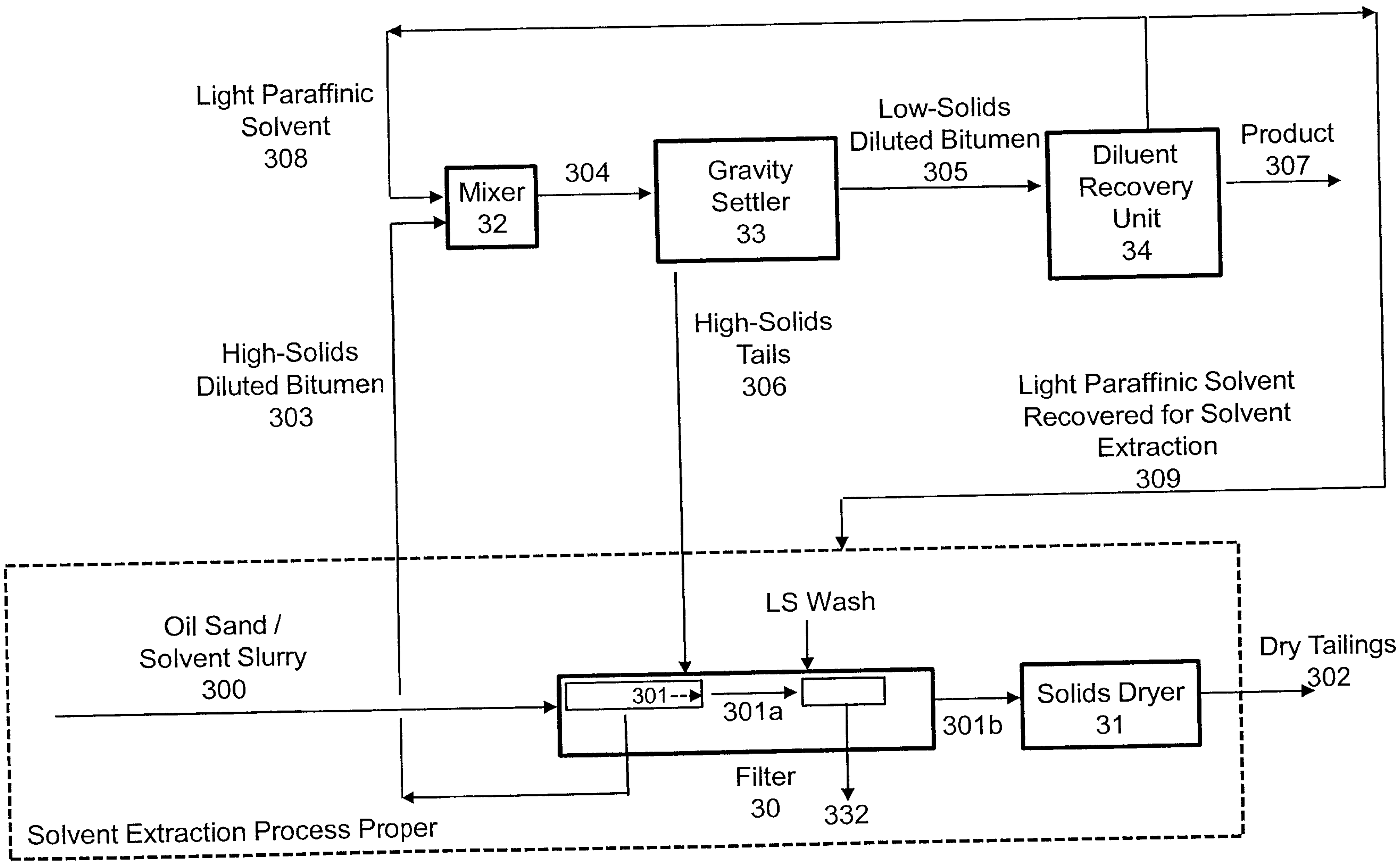
Light Paraffinic Solvent 308
Mixer 32
304
Gravity Settler 33
Low-Solids Diluted Bitumen 305
Diluent Recovery Unit 34
Product 307
High-Solids Diluted Bitumen 303
High-Solids Tails 306
Light Paraffinic Solvent Recovered for Solvent Extraction 309
Oil Sand / Solvent Slurry 300
LS Wash
301-->
301a
301b
Solids Dryer 31
Dry Tailings 302
Filter 30
332
Solvent Extraction Process Proper

Figure 2

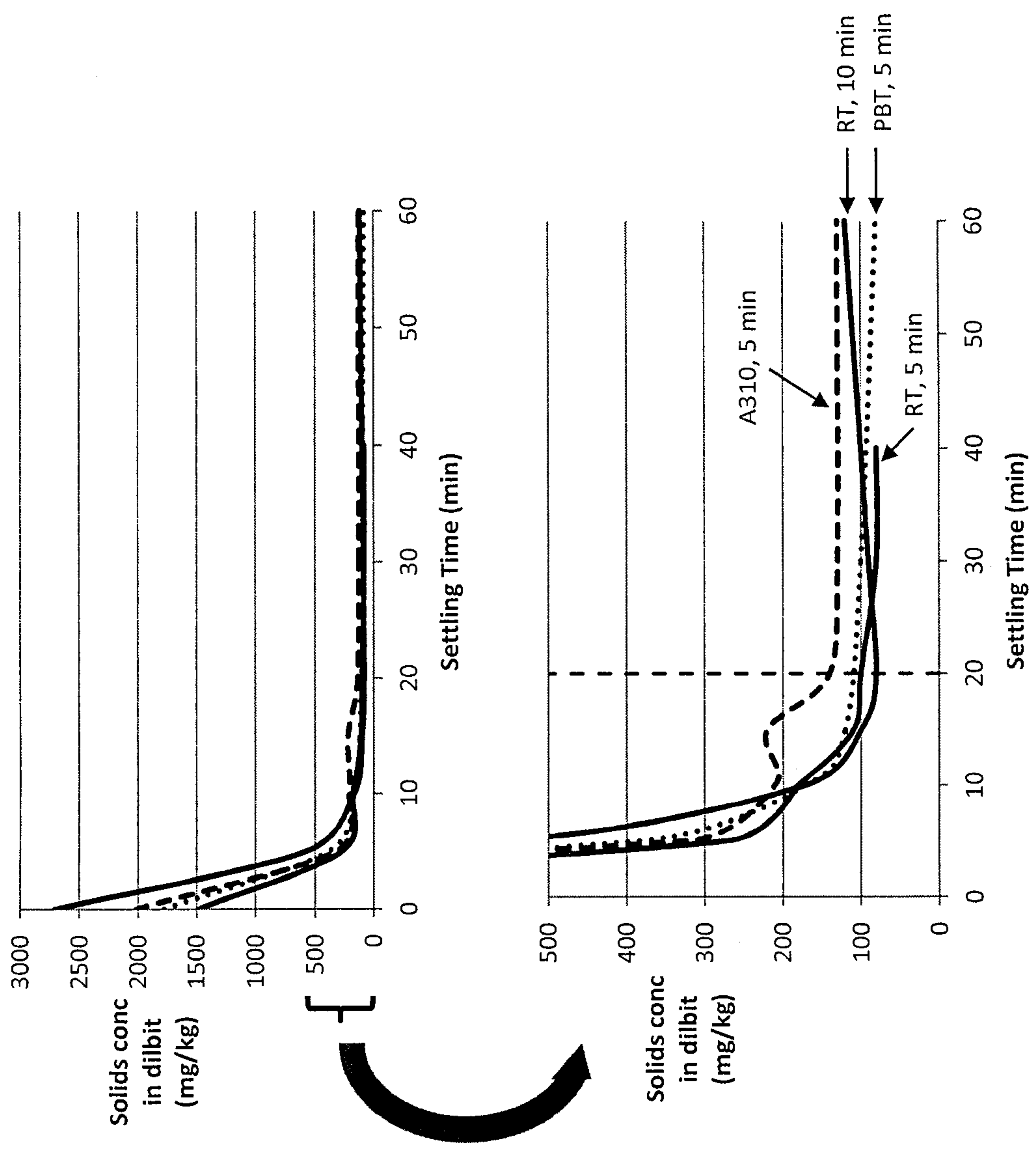
Solids conc in dilbit (mg/kg)
3000
2500
2000
1500
1000
500
0
0
10
20
30
40
50
60
Settling Time (min)
Solids conc in dilbit (mg/kg)
500
400
300
200
100
0
A310, 5 min
RT, 10 min
PBT, 5 min
RT, 5 min

Figure 3