



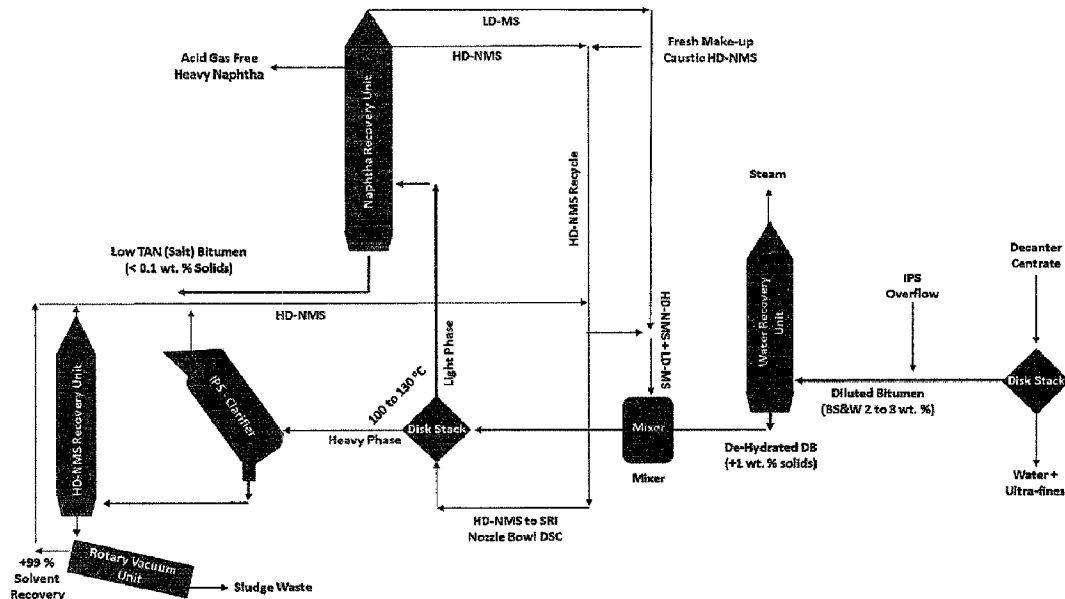
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(71) Demandeur/Applicant:
USO (UTAH) LLC, US
(72) Inventeurs/Inventors:
FOURNIER, JOSEPH, CA;
LAVALLEY, TYLER L., CA...
(74) Agent: BENNETT JONES LLP

(54) Titre : METHODE DE PRODUCTION DU BITUME AUX SPECIFICATIONS DU PIPELINE A PARTIR DES INSTALLATIONS D'EXPLOITATION ET D'EXTRACTION DES SABLES BITUMEUX AU MOYEN DE SOLVANTS NON MISCIBLES ET D'UN TRAITEMENT CENTRIFUG
(54) Title: METHOD FOR PRODUCING PIPELINE SPECIFICATION BITUMEN FROM OIL SANDS MINING AND EXTRACTION FACILITIES USING NON-MISCIBLE SOLVENTS AND CENTRIFUGE PROCESSING



(57) **Abrégé/Abstract:**

A method of producing pipeline quality bitumen, includes the steps of: receiving bitumen diluted with a diluent solvent from a secondary froth treatment process; thermally dehydrating the diluted bitumen at a temperature above about 100 °C and below the

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

boiling point of the diluent solvent; mixing a high-density, non-miscible solvent (HD-NMS) and optionally, a low density, miscible solvent (LD-MS) to the diluted bitumen; and separating any remaining fine solids and precipitates by gravitational separation at a temperature above about 100 °C and below the boiling point of the diluent solvent.

ABSTRACT

A method of producing pipeline quality bitumen, includes the steps of: receiving bitumen diluted with a diluent solvent from a secondary froth treatment process; thermally dehydrating the diluted bitumen at a temperature above about 100 °C and below the boiling point of the diluent solvent; mixing a high-density, non-miscible solvent (HD-NMS) and optionally, a low density, miscible solvent (LD-MS) to the diluted bitumen; and separating any remaining fine solids and precipitates by gravitational separation at a temperature above about 100 °C and below the boiling point of the diluent solvent.

METHOD FOR PRODUCING PIPELINE SPECIFICATION BITUMEN FROM OIL
SANDS MINING AND EXTRACTION FACILITIES USING NON-MISCIBLE SOLVENTS
AND CENTRIFUGE PROCESSING

Field of the Invention

5 [0001] The invention relates to the treatment of solvent-diluted bitumen produced in an oil
sands bitumen extraction facility prior to solvent recovery, and particularly a method which
produces pipeline specification bitumen without resorting to upgrading or carbon rejection at
any time.

Background

10 [0002] Oil sands ore, known as bituminous sands, comprises a naturally occurring mixture of
water, bitumen and a mineral phase comprising sand and clay. Oil sands ore may vary in
quality and character from region to region, or deposit to deposit. Generally, Athabasca oil
sands in Canada comprises water-wet sand grains, while Utah oil sands in the United States
comprises oil-wet sand grains.

15 [0003] Oil sand mining and extraction processes are used to liberate and separate bitumen
from the water and mineral phases such that the bitumen can be further processed to produce
market specification grade crude oil. Numerous oil sands mining and bitumen extraction
processes have been developed and commercialized, all of which involve the use of water as
the processing medium. The role of water is to provide sensible heat to enhance bitumen
20 liberation through viscosity reduction, to produce a fluid that can be pumped and to create an

environment in which gravimetric separation can develop. One such water extraction process is the Clark Hot Water Extraction Process, which was the first commercially successful oil sand extraction process.

5 [0004] A water-based extraction processes, such as the Clark Process, typically requires that mined oil sand first be conditioned for extraction by being crushed to a desired lump size and then combined with hot water and caustic to form a conditioned slurry of bitumen, water, sand, fine particles and entrained air bubbles. In water-based extraction processes, the water is commonly heated to about 65° to 80° C, and an amount of sodium hydroxide is added to the slurry to adjust or maintain the slurry pH upwards, which enhances the separation of bitumen
10 from the oil sand. The addition of sodium hydroxide (caustic) is intended to elevate the concentration of natural surfactants through an acid–base reaction with organic acids present in the bitumen, and to increase the softness of the water phase by increasing the concentration of sodium ions. Other water-based extraction processes may have other temperature requirements and may include other conditioning agents which are added to the oil sand
15 slurry.

[0005] Air entrainment and dispersion in ore processing and hydrotransport is considered an essential component of effective primary bitumen separation and recovery in conventional water based extraction processes. The mechanism of air bubble attachment onto bitumen surfaces aid in gravimetric separation of oil within primary separation columns. Extensive
20 aeration of the oil sands slurry requires subsequent de-aeration in dedicated vessels after the coarse mineral is rejected in the first stage of primary extraction. As steam is often used in de-

aeration, this additional process step adds to the energy intensity required, which translates to higher capital and operating costs. Likewise, the reliance on hydrotransport retention time to achieve optimal conditioning further adds to capital and operating costs due to extensive pipeline wear. Also, it is commonly believed that the substantial mechanical energy added during standard ore processing and hydrotransport may be partly responsible for the limited ability to achieve rapid fines consolidation within mineral retention times in primary and secondary extraction stages.

[0006] Water-based primary bitumen extraction processes typically result in the production of a number of product streams, some of which are disposed of as waste. For example, these streams include a bitumen froth stream comprising of aerated bitumen, residual fine particulate mineral solids and water, a middlings stream comprising bitumen with entrained fine particulate mineral solids and water, and a coarse tailings stream consisting primarily of coarse particulate mineral solids and water. The coarse tailings stream is not typically processed further, since the coarse particulate solids are relatively easy to dispose of and do not typically present a significant environmental risk. The bitumen froth stream and the middlings stream are typically processed further, both to recover or purify bitumen and to render the fine solids more readily disposable and less of an environmental hazard. Froth treatment typically involves introduction of either heavy naphthenic (naphthenic froth treatment or NFT) or light paraffinic (paraffinic froth treatment or PFT) solvents to produce a high oil content bitumen stream which is low in fines and water content. Subsequent stages of extraction are those associated with solvent recovery from separate fine mineral solids slurry

and solvent diluted bitumen streams. The fine mineral solids and water recovered from the bitumen froth stream are typically ultimately disposed of in tailings ponds, where subsequent consolidation of the fine solids occurs and the water recovered and reused.

5 [0007] Pipeline specification oil must have a basic sediment and water (BS&W) content of less than 0.5 vol%. NFT bitumen fed upgraders and PFT extraction facilities achieve final product quality, in terms of residual BS&W, by means of deep carbon rejection. Additionally, diluted bitumen (DB) from NFT extraction expose overhead systems in upgraders to acid gas corrosion caused by hydrochloric acids generated by dissolved chlorides that hydrolyze residual process water and by reacting with native organic acids in the DB feed. The risk of
10 fires in upgraders, caused by overhead corrosion, is increasing as water usage has been decreasing and with improvements in fine tails dewatering that collectively cause chloride salts in process water, released from ore connate water, to increase in concentration at an accelerated rate.

15 [0008] Traditional models of the tight water-in-oil (W/O) emulsions that exist in naphtha diluted bitumen entering upgrading facilities from both overflow of inclined plate separators (IPS) and disk stack centrifuges (DSC), commonly illustrate the presence of adsorbed semi-solid organics (asphaltenes) and ultrafine minerals at the water/oil (W/O) interface, which act to inhibit coalescence and separation by increasing the interfacial tension of the W/O interface. The limit to which NFT extraction can separate process water and sediment is not
20 sufficient to produce diluted bitumen with BS&W below 0.5 vol. %. Furthermore, it is widely believed that these residual solids and interfacially adsorbed asphaltenes in NFT DB cause

upset conditions in downstream desalter units when attempts have been made to by-pass the midstream and directly feed into a refinery.

[0009] PFT extraction facilities achieve a final product quality that exceeds minimum pipeline quality requirements by using paraffin injection in froth treatment, which causes co-precipitation of ultrafine minerals and residual W/O emulsions, together with asphaltenes that are insoluble in bitumen when exposed to higher ratios of C5/6 paraffin solvent loading. In this sense, both NFT + upgrading and PFT extraction reject large quantities (8 to 20 wt. %) of bitumen in achieving minimum pipeline specification for BS&W.

[0010] It is known to add (e.g., CA Patent No. 2,647,964) low carbon number alcohols such as methanol, ethanol, or isopropanol to naphthenic froth or NFT DB upgrader feed, to destabilize the surface tension of the W/O interface and enhance the ability of W/O emulsions to coalesce, thereby giving rise to lower BS&W in the final product. Due to the immiscibility of alcohols in DB and its higher miscibility in process water, alcohols act to destabilize the W/O interfacial tension by reducing the dielectric constant of the residual water in froth or NFT DB. However, this methodology results in the formation of azeotropic mixtures of the process water and the alcohol.

[0011] This prior art use of solvents with dielectric constants lower than water ($\epsilon = 80$) to improve crude quality was motivated by the physical chemistry fundamentals used in the ASTM methods D664 and D974 to quantify native organic acids in heavy crudes (i.e., Total Acid Number or TAN). In these ASTM methods, caustic isopropyl alcohol, with an intermediate dielectric constant ($\epsilon = 20$), is used to selectively extract and neutralize native

organic acids in heavy crudes ($\epsilon = 2.2$), while remaining immiscible with the bulk of the heavy crude sample. The general principle at work is that compounds that form miscible solutions, commonly have similar dielectric properties and thus miscibility is predictable.

Summary of the Invention

5 [0012] The present invention comprises a two-stage process of producing pipeline quality solvent-diluted bitumen. The objective of the first stage is to dehydrate and collapse residual tight water/oil emulsions present within the diluted bitumen (DB) which may be produced using conventional separation processes such as inclined plate separators (IPS's), cyclones and decanter or DSC units. The objective of the second stage is to remove residual BS&W
10 using a non-miscible solvent and optionally a miscible solvent to lower the specific gravity (SG) of the diluted bitumen.

[0013] In one aspect, the invention comprises a bitumen extraction system and method, which comprises steps to achieve a bitumen stream with BS&W less than 0.5 vol. % from a diluted bitumen stream resulting from secondary froth treatment. The bitumen has been diluted with
15 a diluent solvent, such as a biosolvent or naphtha. After secondary froth treatment, an oil dehydrator vessel is used to recover residual water by collapsing any residual water-in-oil emulsions. The dehydrator operates above the boiling point of water, but below the boiling point of the solvent. The DB is then mixed with a high-density, non-miscible solvent (HD-NMS) and optionally, a low density, miscible solvent (LDMS). Subsequent steps takes the
20 dehydrated diluted bitumen stream and, at or near the same temperature, passes it through a

gravimetric separator, such as a centrifuge, to extract fine mineral and precipitated salts. The diluted bitumen thus treated may then pass to a solvent recovery stage.

[0014] Therefore, in one aspect, the invention may comprise a method of producing pipeline quality bitumen, comprising the steps of:

- 5 (a) receiving bitumen diluted with a diluent solvent from a secondary froth treatment process;
- (b) thermally dehydrating the diluted bitumen at a temperature above about 100° C and below the boiling point of the diluent solvent;
- (c) mixing a high-density, non-miscible solvent (HD-NMS) and optionally, a low
10 density, miscible solvent (LD-MS) to the diluted bitumen; and
- (d) separating any remaining fine solids and precipitates by gravitational separation at a temperature above about 100 C and below the boiling point of the diluent solvent.

The solvents may subsequently be recovered, by distillation for example.

15 **Brief Description of the Drawings**

[0015] The following drawings form part of the specification and are included to further demonstrate certain embodiments or various aspects of the invention. In some instances, embodiments of the invention can be best understood by referring to the accompanying drawings in combination with the detailed description presented herein. The description and

accompanying drawings may highlight a certain specific example, or a certain aspect of the invention. However, one skilled in the art will understand that portions of the example or aspect may be used in combination with other examples or aspects of the invention.

5 [0016] Figure 1 shows a process flow diagram of one embodiment of a method of the present invention.

[0017] Figure 2 shows a process flow diagram of an alternative embodiment of a method of the present invention.

[0018] Figure 3 shows a cross-sectional schematic of a disc stack centrifuge.

10 [0019] Figure 4 shows a cross-sectional schematic of an alternative embodiment of a disc stack centrifuge.

Detailed Description

[0020] As used herein, certain terms have the meanings defined below. All other terms and phrases used in this specification have their ordinary meanings as one of skilled in the art would understand.

15 [0021] The present invention relates to an improvement to a process of extracting bitumen from oil sands ore.

[0022] Oil sands ore is typically mined and crushed to break down large chunks. The creation of a water-based oil sands ore slurry is known as wet ore processing. Elements of oil sands extraction methods are described in co-owned U.S. Patent No. 8,758,601, co-pending U.S.

Patent Application 14/959,910 - Oilsands Processing Using Inline Agitation and an Inclined Plate Separator, filed December 4, 2015, or U.S. Patent Application No. 15/453,318 entitled Process Water Chemistry in Bitumen Extraction from Oil Sands filed March 8, 2017, or U.S. Patent Application No. 15/467,583, entitled Solvent Addition in Water Based Oil Sands Ore Digestion and Primary Extraction, filed March 23, 2017, or U.S. Patent Application No. 15/494,367, entitled Method for Producing Pipeline Specification Bitumen from Oil Sands Mining and Extraction Facilities, filed April 21, 2017, the entire contents of each which are incorporated herein by reference for all purposes, where permitted.

[0023] In one embodiment, the methods described herein contemplate the use of any suitable solvent or solvent mixture as the primary diluent solvent. For example, the solvent may comprise a "biosolvent" which is a liquid substance which is substantially soluble in bitumen, and which has a biological origin. Exemplary biosolvents may include terpenes such as, without limitation, pinene or limonene. Terpenes may be acidic, which may necessitate the use of a basic sodium salt to neutralize organic acids and to limit solubility of components of the mineral phase which may hinder bitumen extraction. Ultimately, the invention may apply to any solvent formulation applied in the early stages of primary extraction and in particular in ore digestion and hydrotransport.

[0024] In other embodiments, the diluent solvent may comprise naphtha or a paraffinic solvent as may be used in a conventional NFT or PFT process.

[0025] At least in the case of biosolvents, it may be preferable to add the solvent to the slurry during the early stages of ore conditioning, whether in rotating drums or by hydrotransport,

which may increase bitumen recovery in the subsequent water-based separation steps, allowing for lower temperature separation efficiency, for example at temperatures less than about 60° C or less than about 45° C, and the co-production of a stackable fine mineral solid stream. Without restriction to a theory, application of solvent in the ore conditioning step is believed to be part of the reason why fine minerals dispersed into the slurry are able to be dewatered or consolidated above their liquid limit (Atterberg Limit) in subsequent separation stages further downstream using conventional centrifugal processing. The action of solvents during ore conditioning is believed to be at least one causal factor in reducing interfacial repulsion between fine mineral particles, such that relatively low mechanical centrifuge treatment in extraction is able to produce a soil-like dewatered mineral stream.

[0026] In one embodiment, diluent solvent is added at a rate relative to the known bitumen saturation and ore feed rate into ore conditioning and is reported as a ratio of weight of solvent to weight of bitumen. This ratio may vary from about 0.25:1 to about 2:1. The ratio depends at least in part on the grade and type of ore. Higher grades of oil sands ore may comprise up to about 12 wt % bitumen while lower grade may be around 7 wt% bitumen. Lower ore grades may benefit from a greater solvent proportion and oil-wet ore types commonly require higher ratios than water-wet oil sands ore to achieve comparable bitumen separation efficiencies. The amount of solvent added is not intended to "extract" the bitumen into a solvent phase. Rather, the amount of solvent is selected so as to be entirely dissolved into the bitumen phase. In one embodiment, there is substantially no free solvent in the slurry after the conditioning phase.

[0027] In one embodiment, sufficient water and solvent is added such that the density of the slurry ranges between about 25 to about 60 wt % solids, preferably about 35 to 45% wt % solids.

[0028] The solvent-assisted ore conditioning step of the present invention may be used in conjunction with any water-based bitumen separation or extraction process, including commercially practiced Karl Clark extraction methods.

[0029] In one embodiment, once the ore has been suitably conditioned with the addition of the solvent, the slurry passes to a primary separation stage, using the primary separation vessels (PSV1 and PSV2) shown in Figure 1. In the PSVs, counter current lift water is added to produce a state of hindered settlement in each of the two separation vessels arranged in series. The bottom stream from the first separation vessel acts as feed to the second separation vessel. The bottom stream from the second separation vessel then is fed to a screen shaker unit for dewatering of the coarse tails stream. Separation in the PSVs is the core of the process, where the bitumen is stripped from the host sandstone, which comprises quartz, feldspar, plagioclase and minor percentages of clay minerals, using heat and water. The biosolvent has absorbed into the bitumen phase during conditioning and facilitates this separation. During the separation phase, the solvent-diluted bitumen bond with the sand and clays is more easily broken. The lower specific gravity of the diluted bitumen allows for more effective gravity separation from the water phase to occur.

[0030] The diluted bitumen follows the overflow from the primary separation vessels but is still mixed with a significant amount of water and fine solids. A secondary separation stage

which utilizes a bulk separator produces a water phase, and a diluted bitumen stream which includes fine solids. In one embodiment, the secondary separation stage may comprise an agitator and an inclined plate separator.

5 [0031] Inclined plate separators (IPS) function to reduce the water volumes reporting to downstream centrifuge units. This may be achieved by agitating the mixture from the PSVs in an inline mixer, such that both diluted bitumen and fines exit via the underflow stream of the IPS, while the overflow being predominately process water. The overflow stream from a first IPS unit may then be treated in a second IPS unit. The overflow from the second IPS unit is relatively clean process water and may be used as recycle water. The underflow from both
10 IPS units may then be combined and treated in a decanter (decanting centrifuge) which separates fine solids and outputs diluted bitumen with entrained water and residual fine solids.

[0032] In alternative embodiments, the diluted bitumen may be used as produced by a NFT process.

15 [0033] In any case, the diluted bitumen from the secondary froth treatment (or from a NFT process) will contain about 1.0 to about 2.0% BS&W at this stage. The first step in further processing is to use a dehydration unit (or water recovery unit) to remove substantially all remaining water, which likely remains only in microemulsions within the diluted bitumen. The dehydrator operates at an elevated temperature, preferably above the boiling point of water, but below the boiling point of the diluent solvent. Where a mix of solvents is used, it is
20 preferred to limit the temperature below the lowest boiling point of any substantial component of the solvent mixture. Without restriction to a theory, it is believed that such thermal

treatment of wet diluted bitumen prior to solvent recovery, water micelles are collapsed through evaporation, and dissolved solids are precipitated, including chloride anions.

[0034] The intermediate temperature regime of the water recovery unit acts to further reduce the viscosity of the crude oil, eliminates sterically hindered tight W/O emulsions, which
5 allows for the use of organic acid extracting solvents that would otherwise form azeotropic solutions with residual process water. If the diluted bitumen came from an NFT extraction facility, the water recovery unit will largely evaporate residual process water at lower temperatures where chloride hydrolysis does not develop, for example in the range of about 100 °C to about 130 °C).

10 [0035] The boiling point of terpenes is typically in the range of about 150 °C to about 185 °C. Therefore, a preferred range of thermal treatment may be in the range of about 100 °C to about 150 °C, more preferably about 120 °C to about 140 °C. In some cases, it may be preferable to maintain the temperature below about 130 °C, above which chloride hydrolysis is more likely to occur.

15 [0036] In one embodiment, the dehydrated diluted bitumen then moves into a second stage of treatment that is comprised of a solvent mixer, a disc stack centrifuge and two parallel solvent recovery systems. The purpose of the second stage is to extract residual ultrafine solids and precipitated salts from the evaporated process water. Also, the total acid number (TAN) may be reduced or eliminated within the bitumen final product.

[0037] In the mixer, the HD-NMS is added. The HD-NMS is selected based on numerous important physical properties, particularly its dielectric constant (ϵ), density, boiling point and cost per tonne. This solvent preferably has a SG that is greater than, preferably at least 0.1 greater, than the diluted bitumen (DB) and a ϵ value ranging from, for example, 20 to 40, in order to limit its miscibility in the DB ($\epsilon = 2$). It will still function as an effective solvent for organic acids within the DB. As with isopropyl alcohol used in ASTM methods D664 and D974, the ϵ of this high density non-miscible solvent (HD-NMS) will solubilize caustic salts (e.g., NaOH), which will in turn facilitate caustic-organic acid (TAN) neutralization reactions when organic acids are extracted from the DB. Likewise, the HD-NMS will solubilize the organic ions that are the by-products of TAN neutralization.

[0038] Suitable HD-NMS may include acetylacetone, dimethyl-formamide, or propylene glycol, or mixtures thereof. Desirable properties of these solvents are shown in Table 1 below:

Candidate HD-NMS	STP Dielectric Constant (ϵ)	STP Specific Gravity	STP Boiling Point ($^{\circ}\text{C}$)	ΔH_{vap} (kJ/mole)
Acetylacetone	25	0.975	140	40
Dimethyl-formamide	38	0.9445	153	48
Propylene Glycol	32	1.036	188	56

[0039] The HD-NMS may be added to the diluted bitumen in between about 1 wt. % to about 50 wt. % and preferably between about 20 wt. % to about 30 wt. %.

[0040] The optional LD-MS is fully miscible in the dehydrated dirty crude and acts to reduce its density, viscosity and dielectric constant. Examples of a low density miscible solvent (LD-

MS) include light naphtha and C6/7 paraffins ($\epsilon = 1.8$), which are added in sufficient quantities such that the resulting DB achieves a specific gravity (SG) less than the HD-NMS solvent, preferably at least about 0.05, more preferably at least about 0.10, less than the HD-NMS solvent. Dissolving C6/7 paraffins in the bitumen fraction at a solvent-to-bitumen (S/B) ratio of approximately 1:1 (by weight) will also act to initiate the early stage precipitation of high specific gravity asphaltenes. As with PFT extraction, injection of C6/7 paraffins near a S:B ratio of 1:1 will effectively sequester ultrafine minerals in the asphaltene precipitates that form. However, due to the higher temperatures of gravimetric separation in stage II (100° to 130 °C) and the high centrifugal forces of the disk stack, sedimentation rates will be orders of a magnitude higher than the normal gravity separation conditions used in PFT extraction. Therefore, the use of C6/7 paraffins to create a light DB phase in the disk stack may create a high throughput pathway to decrease sediment content to at least as low as 100 ppm on a bitumen basis.

[0041] After the HD-NMS and the optional LD-MS are mixed into dehydrated DB, the non-miscible mixture is fed into a disc stack centrifuge unit where the HD-NMS solvent will extract the higher density impurities (e.g., ultrafine minerals, precipitated salts and asphaltenes) from the lighter DB phase, and will collectively accelerate towards the heavy phase discharge ports along the outer periphery of the centrifuge (Fig. 3). The heavy and light phases exiting the high G centrifuge will then be pumped to their respective distillation units that will recycle the LD-MS and HD-NMS solvents back to the front end of stage two.

[0042] It is preferable to maintain the DSC under pressure to avoid vaporization of the LD-MS, as the boiling point of the LD-MS may be below the process temperature used in the mixing and gravimetric separation stages.

[0043] In a preferred embodiment, the disk stack centrifuge is configured to allow a HD-NMS fluid to also be injected into the peripheral side region of the disk stack, and that a process control will be used to regulate a constant distance between the DB enriched fluid concentrated along the inside vertical axis and the HD-NMS enriched fluid concentrated along the outside of the disk stack wall. This mode of operability that regulates the distance of the interface between both fluid types at a set distance from the effluent nozzles located along the disk stack wall would be achieved through adjusting separately feed rates of both the DB and HD-NMS phases, and in particular the feed rate of the supplemental HD-NMS fluid through a separate import nozzle located near the side wall of the disk stack. This type of disk stack is often called a self regulating interface nozzle bowl. By using a self-regulating interface (SRI) mode of operation, this configuration will limit the occurrence of DB fluids from unintentional discharging through the heavy phase nozzles or effluent ports and thus hindering its economic performance.

[0044] Figure 2 illustrates one embodiment, where the extraction solvent recovery occurs at the same stage where residual process water is recovered and a self-regulating interface (SRI) DSC is the high G centrifuge. As drawn, the polished light phase DB flows to an independent solvent recovery unit or SRU (50), which fractionates LD-MS and HD-NMS solvents from the final product bitumen. Likewise, the heavy phase impurity enriched HD-NMS stream (25)

is drawn to first pass through an inclined plate separator (IPS) clarifier unit (60), which splits the impurities to the underflow (UF) stream (26) and the clarified HD-NMS returns to the solvent – bitumen Mixer through the overflow (OF) outlet (27). A two-step HD-NMS recovery treatment is outlined that has the IPS UF stream (26) reporting to a dedicated SRU (, 5 followed by a final rotary vacuum SRU to achieve maximum solvent recovery.

[0045] By using HD-NMS fluids with dielectric constants between 20 and 80 and densities higher than the diluted bitumen (DB) being polished, said HD-NMS fluids can be effectively introduced into a disk stack, either homogeneously mixed with the DB feed or into the side wall volume element of a disk stack near the discharge nozzles (ports), and under high 10 separation forces will facilitate the extraction of higher specific gravity residual solids and salts. By using HD-NMS solvents with dielectric constants higher than the DB (2 to 3), but lower than water (80), one will be able to introduce trace amounts of caustic (e.g., NaOH, KOH) into the HD-NMS, which will further facilitate the acid – base neutralization of organic acids in the DB, as well as the subsequent extraction of both reacted & unreacted organic 15 acids from the DB phase and into the HD-NMS phase. The HD-NMS fluid in this invention is functioning as similarly seen in TAN extraction methods as outlined in the ASTM D664 and D974 methods.

[0046] The second stage of the process is intended to recover residual HD-NMS that exits the disk stack in the DB light phase stream, as well as to purify the solids, salts, water, organic 20 acids and their reacted conjugate bases (sodium or potassium naphthenate anions) that exited the disk stack with the HD-NMS heavy phase. Both the light and heavy liquid phases exiting

the disk stack are processed in independent distillation processes, which separate clean HD-NMS fluids from both streams and then recycles the HD-NMS fluid back to the disk stack as a recirculating process. The rate of the HD-NMS recycle is intended to follow the rate of DB being fed into the disk stack, and it is maintained that by using a NMS of higher density than the incoming DB feed in conjunction with a disk stack, the overall volume of HD-NMS required is minimized and its residence time in the process is maximized.

[0047] In this two stage process, the dielectric constant of the HD-NMS fluid should be high enough to maximize the amount of HD-NMS fluid gravimetrically separated from the lighter DB phase and yet not too high such that lower dielectric constant impurities such as minerals, salts and organic acids in the DB are hindered in their separation rates out of the DB and into the HD-NMS fluid. The classical example of a disk stack functioning in this capacity is in the gravimetric separation of cream from whole milk, wherein the lower dielectric constant cream and the higher dielectric constant water based milk form a non-miscible fluid that can be readily separated into a heavy and light phase using a standard disk stack centrifuge. Likewise, the dielectric constant of the LD-MS fluid would be selected to be between 1.5 to 5, such that a close match is made relative to the dielectric constant of diluted bitumen (2 to 3).

[0048] The resulting bitumen product is now substantially free of water and solids, having a BS&W less than 0.5 wt. %. The diluted bitumen may then be treated in a distillation unit to recover the diluent solvent, leaving saleable bitumen product. Approximately 98 to 99% of the solvent may be recovered with distillation and is recycled to a holding tank for re-use. In tailings dewatering and solvent recovery approximately 90 to 95% of the circulating process

water is recovered from the produced sand and fines tailings to be recycled indefinitely until fractionally lost to tailings discharge. Make up water and make up process chemical aids may be added as necessary.

Definitions and Interpretation

5 [0049] The description of the present invention has been presented for purposes of illustration and description, but it is not intended to be exhaustive or limited to the invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the invention. Embodiments were chosen and described in order to best explain the principles of the invention and the practical
10 application, and to enable others of ordinary skill in the art to understand the invention for various embodiments with various modifications as are suited to the particular use contemplated. To the extent that the following description is of a specific embodiment or a particular use of the invention, it is intended to be illustrative only, and not limiting of the claimed invention.

15 [0050] The corresponding structures, materials, acts, and equivalents of all means or steps plus function elements in the claims appended to this specification are intended to include any structure, material, or act for performing the function in combination with other claimed elements as specifically claimed.

[0051] References in the specification to "one embodiment", "an embodiment", etc., indicate
20 that the embodiment described may include a particular aspect, feature, structure, or

characteristic, but not every embodiment necessarily includes that aspect, feature, structure, or characteristic. Moreover, such phrases may, but do not necessarily, refer to the same embodiment referred to in other portions of the specification. Further, when a particular aspect, feature, structure, or characteristic is described in connection with an embodiment, it is within the knowledge of one skilled in the art to combine, affect or connect such aspect, feature, structure, or characteristic with other embodiments, whether or not such connection or combination is explicitly described. In other words, any element or feature may be combined with any other element or feature in different embodiments, unless there is an obvious or inherent incompatibility between the two, or it is specifically excluded.

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[0052] It is further noted that the claims may be drafted to exclude any optional element. As such, this statement is intended to serve as antecedent basis for the use of exclusive terminology, such as "solely," "only," and the like, in connection with the recitation of claim elements or use of a "negative" limitation. The terms "preferably," "preferred," "prefer," "optionally," "may," and similar terms are used to indicate that an item, condition or step being referred to is an optional (not required) feature of the invention.

[0053] The singular forms "a," "an," and "the" include the plural reference unless the context clearly dictates otherwise. The term "and/or" means any one of the items, any combination of the items, or all of the items with which this term is associated.

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[0054] As will be understood by one skilled in the art, for any and all purposes, particularly in terms of providing a written description, all ranges recited herein also encompass any and all possible sub-ranges and combinations of sub-ranges thereof, as well as the individual values

making up the range, particularly integer values. A recited range (e.g., weight percents or carbon groups) includes each specific value, integer, decimal, or identity within the range. Any listed range can be easily recognized as sufficiently describing and enabling the same range being broken down into at least equal halves, thirds, quarters, fifths, or tenths. As a
5 non-limiting example, each range discussed herein can be readily broken down into a lower third, middle third and upper third, etc.

[0055] As will also be understood by one skilled in the art, all language such as "up to", "at least", "greater than", "less than", "more than", "or more", and the like, include the number
10 recited, and such terms refer to ranges that can be subsequently broken down into sub-ranges as discussed above. In the same manner, all ratios recited herein also include all sub-ratios falling within the broader ratio.

WHAT IS CLAIMED IS:

1. A method of producing pipeline quality bitumen, comprising the steps of:
 - (a) receiving bitumen diluted with a diluent solvent from a secondary froth treatment process;
 - 5 (b) thermally dehydrating the diluted bitumen at a temperature above about 100 °C and below the boiling point of the diluent solvent;
 - (c) mixing a high-density, non-miscible solvent (HD-NMS) and optionally, a low density, miscible solvent (LD-MS) to the diluted bitumen; and
 - (d) separating any remaining fine solids and precipitates by gravitational
10 separation at a temperature above about 100 °C and below the boiling point of the diluent solvent.
2. The method of claim 1 further comprising the step of recovering and reusing the HD-NMS and optionally the LD-MS.
3. The method of claim 1 or 2 wherein the HD-NMS has a specific gravity at least about
15 0.1 larger than the diluted bitumen and a dielectric constant greater than about 20.
4. The method of claim 1, 2 or 3 wherein the HD-NMS comprises acetylacetone, dimethyl-formamide, or propylene glycol, or mixtures thereof.

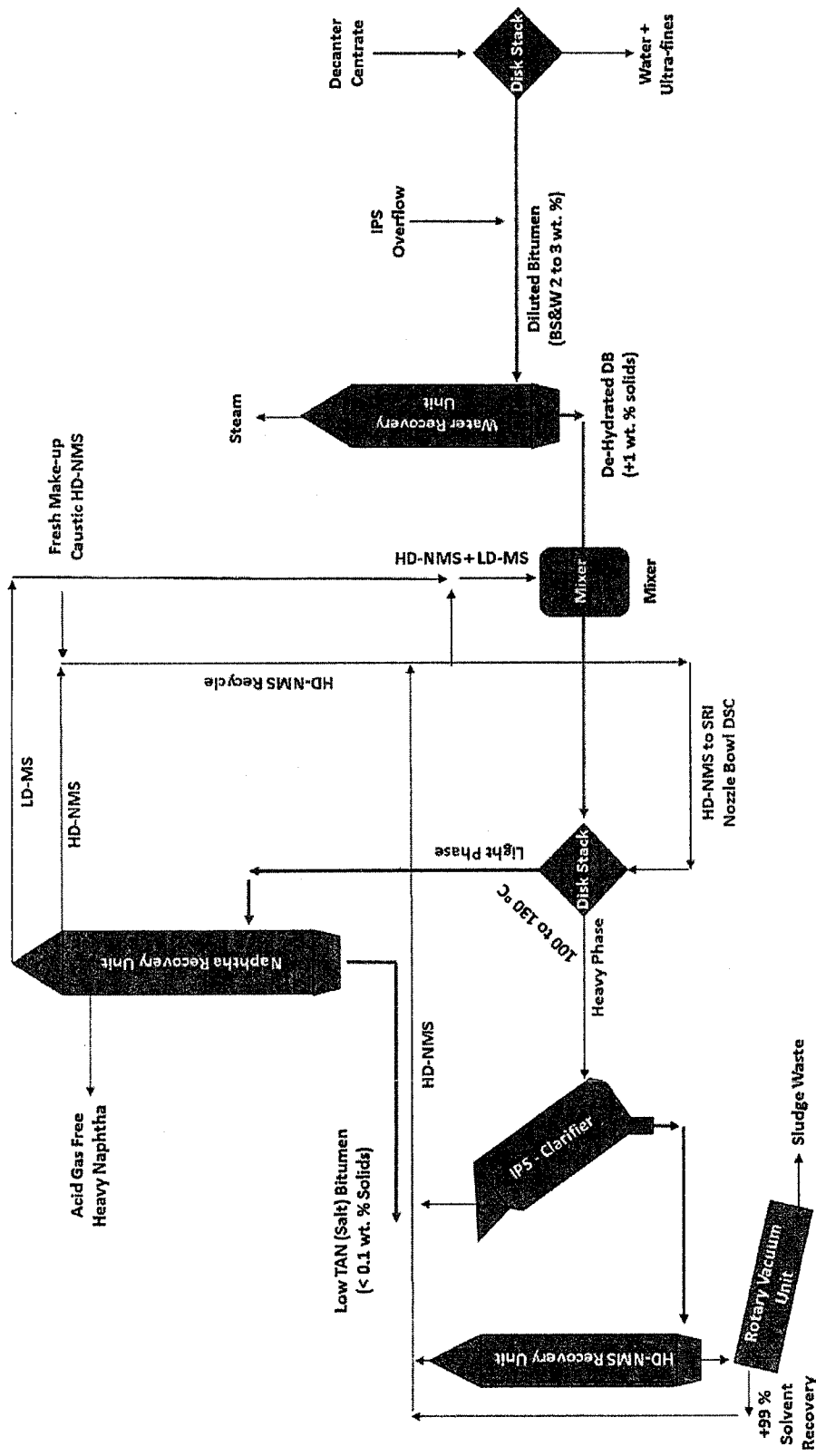


Figure 1

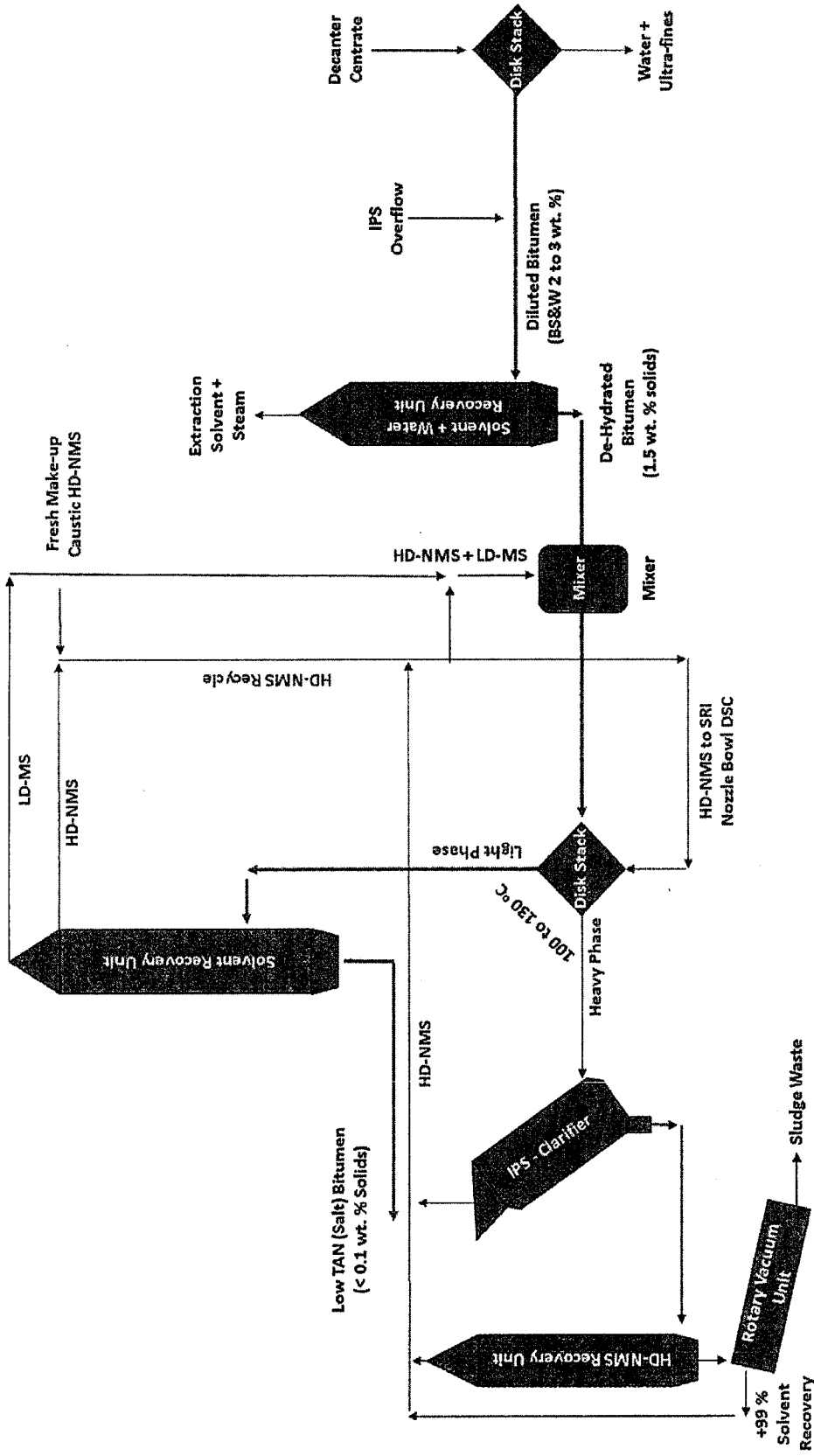


Figure 2

Split Bowl DSC

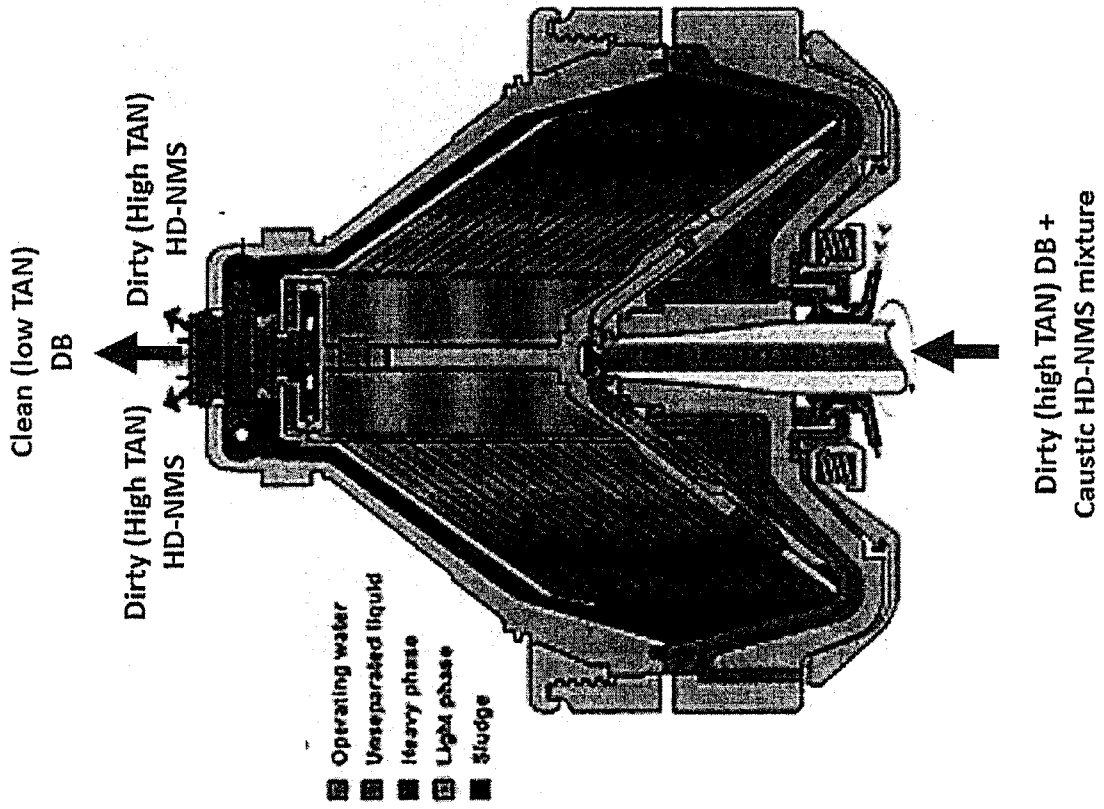


Figure 3

Nozzle Bowl DSC with Self Regulating Interface (SRI)

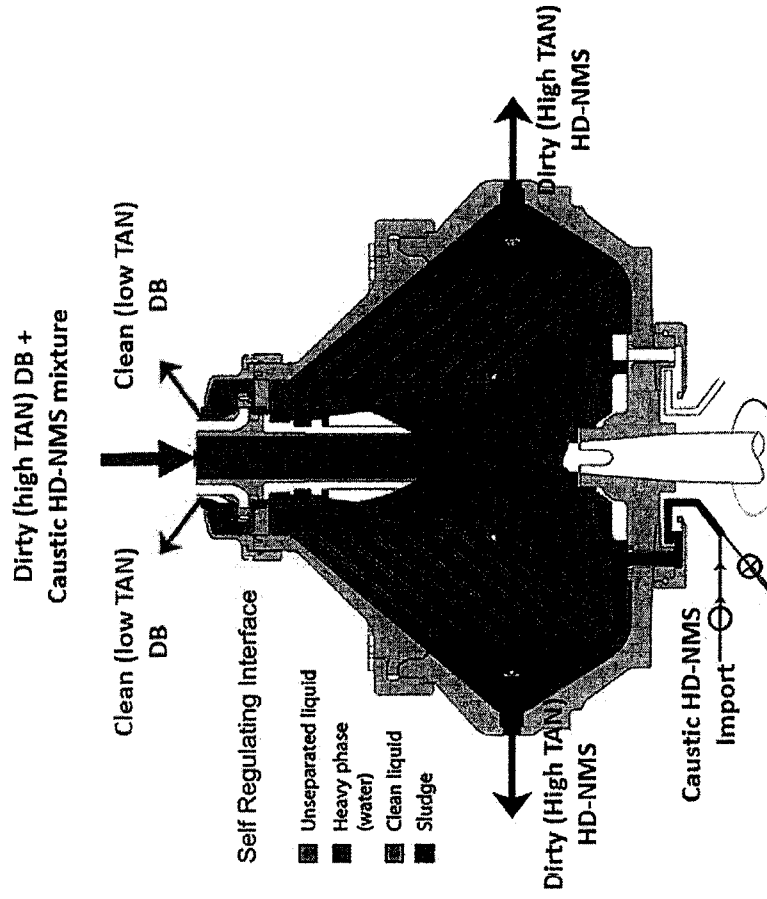


Figure 4

