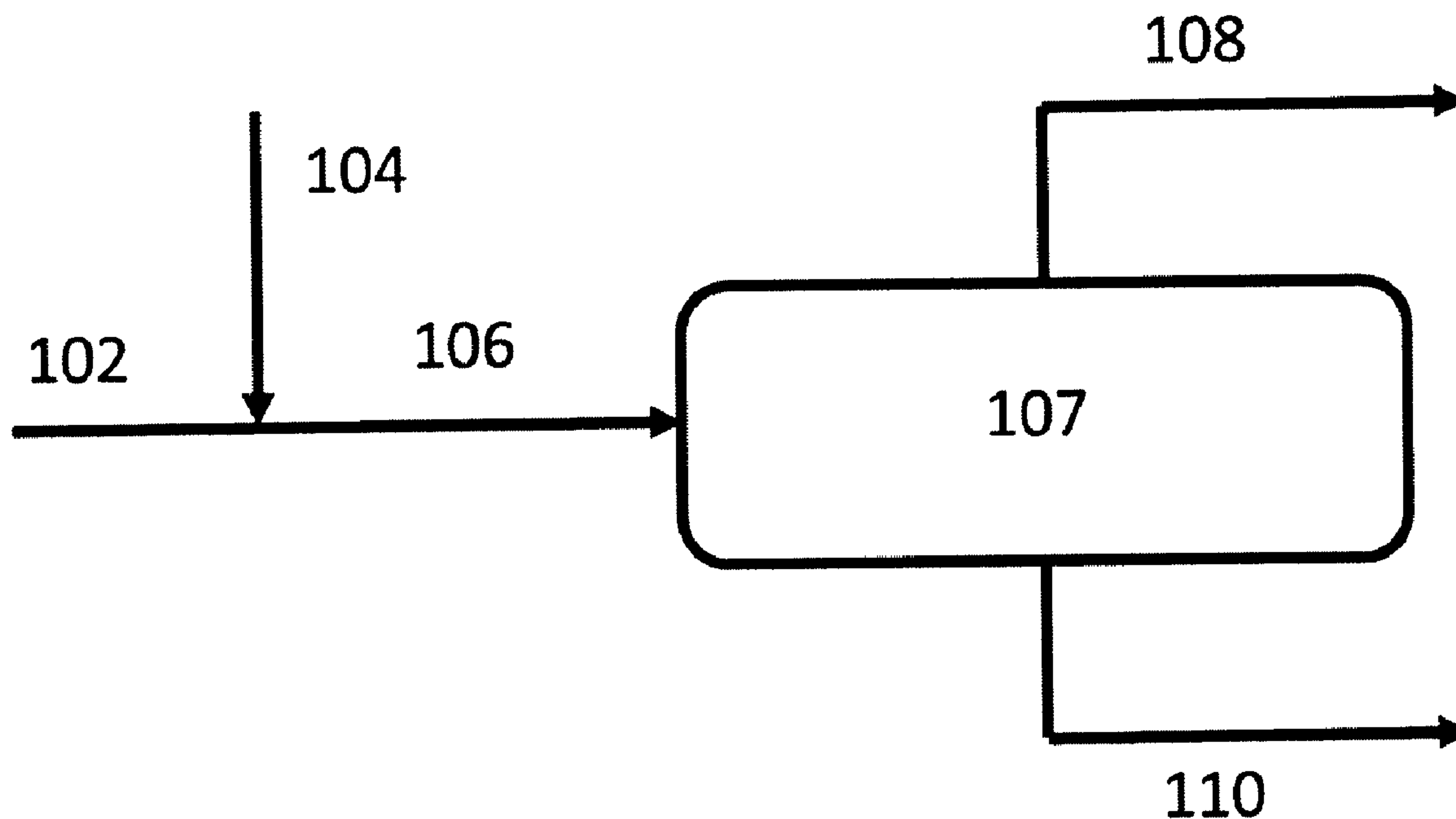




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(54) Titre : NETTOYAGE DE PRODUITS DE BITUME EXTRAIT AU MOYEN DE PROCEDES D'EXTRACTION DE SOLVANTS DE SABLES BITUMINEUX
(54) Title: PRODUCT CLEANING OF BITUMEN EXTRACTED FROM OIL SAND SOLVENT EXTRACTION PROCESSES



(57) Abrégé/Abstract:

A method comprising providing a bitumen extract stemming from solvent-based extraction, the bitumen extract comprising bitumen, water, and solids; adding a diluent to the bitumen extract to produce a diluted bitumen stream; and separating, by

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

enhanced gravity separation, the diluted bitumen stream into a diluted bitumen product and tailings. The diluent is added in an amount sufficient to precipitate asphaltenes such that the diluted bitumen product has a C5 asphaltene precipitation of between 0.1 and 30%.

ABSTRACT

A method comprising providing a bitumen extract stemming from solvent-based extraction, the bitumen extract comprising bitumen, water, and solids; adding a diluent to the bitumen extract to produce a diluted bitumen stream; and separating, by enhanced gravity separation, the diluted bitumen stream into a diluted bitumen product and tailings. The diluent is added in an amount sufficient to precipitate asphaltenes such that the diluted bitumen product has a C5 asphaltene precipitation of between 0.1 and 30%.

PRODUCT CLEANING OF BITUMEN EXTRACTED FROM OIL SAND SOLVENT EXTRACTION PROCESSES

BACKGROUND

Field of Disclosure

[0001] The disclosure relates generally to the field of oil sand processing. More specifically, the disclosure relates to the field of solvent-based bitumen extraction and product cleaning of bitumen extracts stemming from solvent-based extraction.

Description of Related Art

[0002] This section is intended to introduce various aspects of the art, which may be associated with the present disclosure. This discussion is believed to assist in providing a framework to facilitate a better understanding of particular aspects of the present disclosure. Accordingly, it should be understood that this section should be read in this light, and not necessarily as admissions of prior art.

[0003] Modern society is greatly dependent on the use of hydrocarbon resources for fuels and chemical feedstocks. Hydrocarbons are generally found in subsurface formations that can be termed “reservoirs.” Removing hydrocarbons from the reservoirs depends on numerous physical properties of the subsurface formations, such as the permeability of the rock containing the hydrocarbons, the ability of the hydrocarbons to flow through the subsurface formations, and the proportion of hydrocarbons present, among other things. Easily harvested sources of hydrocarbons are dwindling, leaving less accessible sources to satisfy future energy needs. As the costs of hydrocarbons increase, the less accessible sources become more economically attractive.

[0004] Recently, the harvesting of oil sand to remove heavy oil has become more economical. Hydrocarbon removal from oil sand may be performed by several techniques. For example, a well can be drilled to an oil sand reservoir and steam, hot air, solvents, or a combination thereof, can be injected to release the hydrocarbons. The released hydrocarbons may be collected by wells and brought to the surface. In another technique, strip or surface mining may be performed to access the oil sand, which can be treated with hot water, steam or

solvents to extract the heavy oil. This other technique may be referred to as a water-based extraction (WBE). The WBE is a commonly used process to extract bitumen from mined oil sand. In another technique, non-water-based extraction can be used to treat the strip or surface mined oil sand. The non-water-based extraction may be referred to as a solvent-based extraction.

[0005] The commercial application of solvent-based extraction has, for various reasons, eluded the oil sand industry. A major challenge associated with the solvent-based extraction is the tendency of fine particles within the oil sand to hamper the separation of solids from the heavy oil (e.g., bitumen) extracted. The fine particles that remain with the bitumen have an adverse impact on the transport of the bitumen within pipelines and have a negative impact on the downstream upgrading and/or refining of the bitumen. For these reasons, it is desirable to reduce the solids content of the bitumen to a value much less than 1 weight (wt.) %, on a dry bitumen basis. "Dry bitumen basis" means ignoring the presence of water and solvent in the bitumen for the purpose of calculating solids wt. %. Similarly, when calculating water content of the bitumen on a "dry bitumen basis", the presence of solids and solvent in the bitumen is ignored for the purpose of calculating water wt.%.

[0006] A solid agglomeration process has been proposed for use in the solvent-based extraction. The solid agglomeration process was coined Solvent Extraction Spherical Agglomeration (SESA). Previously described methodologies for SESA have not been commercially adopted. In general, the SESA process involves mixing oil sand with a hydrocarbon solvent to form an oil sand slurry, adding an aqueous bridging liquid to the oil sand slurry to form a mixture, agitating the mixture in a 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. The aqueous bridging liquid may be water or an aqueous solution since the solids of oil sand are mostly hydrophilic and water is immiscible to hydrocarbon solvents. The aqueous bridging liquid preferentially wets the solids. With the right amount of the aqueous bridging liquid and suitable agitation of the slurry, the aqueous bridging liquid displaces the suspension liquid on the surface of the solids. As a result of interfacial forces among three phases (i.e. the aqueous bridging liquid, the suspension liquid,

and the solids), fine particles within the solids consolidate into larger, compact agglomerates that are more readily separated from the suspension liquid.

[0007] The SESA process described by Meadus *et al.* in U.S. Patent No. 4,057,486 involves combining solvent extraction with solids agglomeration to achieve dry tailings suitable for direct mine refill. Organic material is separated from oil sand by mixing the oil sand material with an organic solvent to form a slurry, after which an aqueous bridging liquid is added in an amount of 8 to 50 weight percent (wt. %) of the feed mixture. By using controlled agitation, solid particles from oil sand come into contact with the aqueous bridging liquid and adhere to each other to form macro-agglomerates with a mean diameter of 2 millimeters (mm) or greater. The macro-agglomerates are more easily separated from the organic solvent compared to un-agglomerated solids. The macro-agglomerates are referred to as macro-agglomerates because they result from the consolidation of both fine particles and coarse particles that make up oil sand.

[0008] U.S. Patent No. 4,719,008 (Sparks *et al.*) describes a process to apply SESA to varying ore grade qualities by a micro-agglomeration procedure in which the fine particles of the oil sand are consolidated to produce micro-agglomerates with a similar particle size distribution to coarser grained particles of the oil sand. Using the micro-agglomeration procedure, the solid-liquid separation behavior of the agglomerated oil sand will be similar regardless of ore grade quality. The micro-agglomeration procedure occurs within a slowly rotating horizontal vessel. The conditions of the slowly rotating horizontal vessel are that which favor the formation of large agglomerates; however, a light milling action is used to continuously break down the large agglomerates. The micro-agglomerates are formed by obtaining an eventual equilibrium between cohesive and destructive forces. Since agglomerates of large size can lead to bitumen recovery losses owing to entrapment of extracted bitumen within the agglomerated solids, the level of bridging liquid is kept to as low as possible commensurate with achieving economically viable solid-liquid separations.

[0009] With the formation of the micro-agglomerates, the process of solid-liquid separation using common separation devices is easier compared to the situation where the fine particles are un-agglomerated. Applicable separation devices include at least one of gravity separators,

centrifuges, hydrocyclones, screens, and filters. Although the separation devices have been shown to be effective in separating micro-agglomerates from bitumen extract, a portion of the fine solids remain un-agglomerated because they are non-wetting with the aqueous bridging liquid and thus remain as residual fine solids in the bitumen extract. The amount of the residual fine solids that remain in the bitumen extract can be greater than 0.5 wt. %, or greater than 1.0 wt. %, on a dry bitumen basis.

[0010] Solvent-based extraction may produce a bitumen extract having approximately 0.5-8 wt. % solids, on a dry bitumen basis, and 0.5-2 wt. % water, based on a total weight of the bitumen extract.

[0011] Solvent deasphalting has previously been proposed as a method to remove the residual fine solids that remain from the bitumen extract. U.S. Patent No. 4,888,108 (Farnand) describes a process where an aliphatic solvent, such as pentane, is added along with a chemical additive to the bitumen extract. The addition of the aliphatic solvent causes asphaltenes to precipitate onto the residual fine solids. The combination of the precipitated asphaltenes and the chemical additive causes the residual fine solids to aggregate so that they can be readily separated from the bitumen extract. Farnand describes that the most effective chemical additives are water-soluble organic compounds with a low miscibility with the bitumen extract. The organic compounds preferably comprise a carboxylic acid and/or hydroxyl groups, and have a weakly acidic and/or polar character. The chemical additives, such as resorcinol, catechol, formic acid, and maleic acid, have a synergistic effect with the addition of the aliphatic solvent. Less additive and aliphatic solvent was needed, when used in combination, to obtain the same level of solids removal as compared to when the additive or aliphatic solvent was used alone. Farnand theorized that the improved residual fine solids aggregation was due to the precipitated asphaltenes increased attraction to the residual fine solids with the polar additives adsorbed onto the residual fine solids surfaces.

[0012] Another method for removing the residual fine solids that remain in the bitumen extract is to use aliphatic solvents for the extraction of bitumen from oil sand. U.S. Application Publication No. 2011/0127197 (Blackbourn *et al.*) describes the use of a C3 to C9 paraffinic solvent for extracting bitumen from oil sand. The use of paraffinic solvent, such as pentane,

prevents all or a portion of the asphaltenes within the bitumen from dissolving into solution during the solvent-based recovery process. Since the asphaltenes tend to be associated with fine solids, the asphaltenes that do not dissolve prevent the fine solids from dispersing into the bitumen extract. Blackburn *et al.* described that the use of the paraffinic solvent improved the separation of bitumen extract by filtration. The increased filtration rate, compared to when an aromatic solvent was used for bitumen extraction, was most likely due to the fact that some of the fine solids remained attached to the solid asphaltenes and thus were not free to block the filter media or the solid bed on top of the filter media. The use of paraffinic solvent in the solvent-based recovery process resulted in faster settling fine solids that could be readily separated from the majority of the bitumen extract by gravity to produce a bitumen extract with fine solids content of less than 0.1 wt. % on a dry bitumen basis.

[0013] The use of aliphatic solvents in a solvent-based recovery process has been proposed as a method to reduce the amount of residual solvent in tailings. U.S. Patent No. 8,257,580 (Duyvesteyn *et al.*) describes a method for preparing dry, stackable tailings. Dry, stackable tailings may be defined as comprising less than 0.1 wt. % solvent and from about 2 wt. % to about 15 wt. % water, based on a weight of the tailings. The method involves contacting the oil sand with a light aromatic solvent to dissolve bitumen. The bitumen extract is then separated from the solids in order to produce a first solid tailings that has residual bitumen extract entrained within. The residual bitumen extract is removed from the tailings by washing the solids with a light hydrocarbon solvent to produce solvent-wet tailings where the remaining light hydrocarbon solvent can be readily recovered by heating and/or pressure reduction. A light hydrocarbon solvent may be defined as a cyclo- or iso-paraffin having between 3 and 9 carbons. The light hydrocarbon solvent is typically an aliphatic solvent such as at least one of propane, butane, and pentane. Duyvesteyn *et al.* describes that this method has the potential advantage of reducing the required energy to recover the light hydrocarbon solvent from tailings and the potential advantage of requiring that only the washing stage needs to be pressurized in the solvent-based recovery process.

[0014] Another method of product cleaning a bitumen extract stemming from solvent-based extraction involves the use of an aliphatic solvent after the extraction step. An example is

provided in Canadian Patent No. 2,907,155 (Abel et al.). Consequently, the method is a multi-solvent process; for instance, a cyclo-paraffinic solvent (such as cyclopentane (cC5) or cyclohexane (cC6)) may be used as an extraction solvent, followed by a solvent recovery unit (SRU) for solvent removal prior to adding a high purity paraffinic solvent (such as a mixture of n-pentane and i-pentane (n-C5/i-C5)) for product cleaning. After product cleaning, another SRU is required to recover the high purity paraffinic solvent prior to diluting with diluent for pipeline transportation. This multi-solvent system is expected to be both energy and capital intensive.

[0015] It is desirable to provide an alternative process for reducing the solids content of a bitumen extract stemming from solvent-based extraction.

SUMMARY

[0016] It is an object of the present disclosure to provide a process for reducing the solids content of a bitumen extract stemming from solvent-based extraction.

[0017] A method may comprise:

- a) providing a bitumen extract stemming from solvent-based extraction, the bitumen extract comprising bitumen, water, and solids;
- b) adding a diluent to the bitumen extract to produce a diluted bitumen stream, wherein the diluent is added in an amount sufficient to precipitate asphaltenes such that the diluted bitumen product has a C5 asphaltene precipitation of between 0.1 and 30%; and
- c) separating, by enhanced gravity separation, the diluted bitumen stream into a diluted bitumen product and tailings.

[0018] The foregoing has broadly outlined the features of the present disclosure so that the detailed description that follows may be better understood. Additional features will also be described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] These and other features, aspects and advantages of the disclosure will become apparent from the following description, appending claims and the accompanying drawings, which are briefly described below.

[0020] Figure 1 is a flow diagram of a process for reducing the solids content of a bitumen extract from solvent-based extraction.

[0021] Figure 2 is a graph of bitumen solids content versus time using centrifugation with n-heptane.

[0022] It should be noted that the figures are merely examples and no limitations on the scope of the present disclosure are intended thereby. Further, the figures are generally not drawn to scale, but are drafted for purposes of convenience and clarity in illustrating various aspects of the disclosure.

DETAILED DESCRIPTION

[0023] For the purpose of promoting an understanding of the principles of the disclosure, reference will now be made to the features illustrated in the drawings and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the disclosure is thereby intended. Any alterations and further modifications, and any further applications of the principles of the disclosure as described herein are contemplated as would normally occur to one skilled in the art to which the disclosure relates. It will be apparent to those skilled in the relevant art that some features that are not relevant to the present disclosure may not be shown in the drawings for the sake of clarity.

[0024] At the outset, for ease of reference, certain terms used in this application and their meaning as used in this context are set forth below. To the extent a term used herein is not defined below, it should be given the broadest definition persons in the pertinent art have given that term as reflected in at least one printed publication or issued patent. Further, the present processes are not limited by the usage of the terms shown below, as all equivalents, synonyms, new developments and terms or processes that serve the same or a similar purpose are considered to be within the scope of the present disclosure.

[0025] Throughout this disclosure, where a range is used, any number between or inclusive of the range is implied.

[0026] A “hydrocarbon” is an organic compound that primarily includes the elements of hydrogen and carbon, although nitrogen, sulfur, oxygen, metals, or any number of other elements may be present in small amounts. Hydrocarbons generally refer to components found in heavy oil or in oil sand. However, the techniques described are not limited to heavy oils but may also be used with any number of other reservoirs to improve gravity drainage of liquids. Hydrocarbon compounds may be aliphatic or aromatic, and may be straight chained, branched, or partially or fully cyclic.

[0027] “Bitumen” is a naturally occurring heavy oil material. Generally, it is the hydrocarbon component found in oil sand. Bitumen can vary in composition depending upon the degree of loss of more volatile components. It can vary from a very viscous, tar-like, semi-solid material to solid forms. The hydrocarbon types found in bitumen can include aliphatics, aromatics, resins, and asphaltenes. A typical bitumen might be composed of:

- 19 weight (wt.) % aliphatics (which can range from 5 wt. % - 30 wt. %, or higher);
- 19 wt. % asphaltenes (which can range from 5 wt. % - 30 wt. %, or higher);
- 30 wt. % aromatics (which can range from 15 wt. % - 50 wt. %, or higher);
- 32 wt. % resins (which can range from 15 wt. % - 50 wt. %, or higher); and
- some amount of sulfur (which can range in excess of 7 wt. %), based on a weight of the bitumen.

In addition, bitumen can contain some water and nitrogen compounds ranging from less than 0.4 wt. % to in excess of 0.7 wt. %, based on a weight of the bitumen. The percentage of the hydrocarbon found in bitumen can vary. The term “heavy oil” includes bitumen as well as lighter materials that may be found in a sand or carbonate reservoir.

[0028] “Heavy oil” includes oils which are classified by the American Petroleum Institute (“API”), as heavy oils, extra heavy oils, or bitumens. The term “heavy oil” includes bitumen. Heavy oil may have a viscosity of about 1,000 centipoise (cP) or more, 10,000 cP or more, 100,000 cP or more, or 1,000,000 cP or more. In general, a heavy oil has an API gravity between 22.3° API (density of 920 kilograms per meter cubed (kg/m³) or 0.920 grams per

centimeter cubed (g/cm^3) and 10.0° API (density of $1,000 \text{ kg/m}^3$ or 1 g/cm^3). An extra heavy oil, in general, has an API gravity of less than 10.0° API (density greater than $1,000 \text{ kg/m}^3$ or 1 g/cm^3). For example, a source of heavy oil includes oil sand or bituminous sand, which is a combination of clay, sand, water and bitumen. The recovery of heavy oils is based on the viscosity decrease of fluids with increasing temperature or solvent concentration. Once the viscosity is reduced, the mobilization of fluid by steam, hot water flooding, or gravity is possible. The reduced viscosity makes the drainage or dissolution quicker and therefore directly contributes to the recovery rate.

[0029] The term “bituminous feed” refers to a stream derived from oil sand that requires downstream processing in order to realize valuable bitumen products or fractions. The bituminous feed is one that comprises bitumen along with undesirable components. Undesirable components may include but are not limited to clay, minerals, coal, debris and water. The bituminous feed may be derived directly from oil sand, and may be, for example, raw oil sand ore. Further, the bituminous feed may be a feed that has already realized some initial processing but nevertheless requires further processing. Also, recycled streams that comprise bitumen in combination with other components for removal as described herein can be included in the bituminous feed. A bituminous feed need not be derived directly from oil sand, 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.

[0030] “Fine particles” are generally defined as those solids having a size of less than 44 microns (μm), that is, material that passes through a 325 mesh (44 micron).

[0031] “Coarse particles” are generally defined as those solids having a size of greater than or equal to 44 microns (μm).

[0032] “Macro-agglomeration” is the consolidation of both fine particles and coarse particles that make up the oil sand. Macro-agglomerates may have a mean diameter of 2 millimeters (mm) or greater.

[0033] “Micro-agglomeration” is the consolidation of fine particles that make up the oil sand. Micro-agglomerates may have a mean diameter of less than 2 millimeters (mm).

[0034] A “bitumen extract” is generally defined as bitumen that has been extracted from oil sand.

[0035] A “diluted bitumen product” is generally defined as a high grade bitumen product that may be suitable for transport within pipelines and processing within downstream refineries. A diluted bitumen product may have a solids content of less than 1 wt. %, or less than 0.1 wt. %, on a dry bitumen basis. A diluted bitumen product may have a solids content of between 0.01 and 1 wt. %, or between 0.01 and 0.1 wt. %, on a dry bitumen basis.

[0036] The term “solvent” as used in the present disclosure should be understood to mean either a single solvent, or a combination of solvents.

[0037] The term “high purity paraffinic solvent” as used herein means solvents containing normal paraffins, isoparaffins and blends thereof in amounts greater than 50 wt%. Presence of other components such as olefins, aromatics or naphthenes counteract the function of the paraffinic solvent and hence should not be present more than 1 to 20 wt% combined and preferably, no more than 3 wt% is present. The high purity paraffinic solvent may be a C₄ to C₂₀ paraffinic hydrocarbon solvent or any combination of iso and normal components thereof. The high purity paraffinic solvent may comprise pentane, iso-pentane, or a combination thereof. The high purity paraffinic solvent may comprise about 60 wt% n-pentane and about 40 wt% iso-pentane, with none or less than 20 wt% of the counteracting components referred above. Because the “high purity paraffinic solvent” enables a high degree of asphaltene precipitation in a product cleaning step, solid-liquid separation is achievable by simple gravity separation.

[0038] The terms “approximately,” “about,” “substantially,” and similar terms are intended to have a broad meaning in harmony with the common and accepted usage by those of ordinary skill in the art to which the subject matter of this disclosure pertains. It should be understood by those of skill in the art who review this disclosure that these terms are intended to allow a description of certain features described and claimed without restricting the scope of these features to the precise numeral ranges provided. Accordingly, these terms should be interpreted

as indicating that insubstantial or inconsequential modifications or alterations of the subject matter described and are considered to be within the scope of the disclosure.

[0039] The articles “the”, “a” and “an” are not necessarily limited to mean only one, but rather are inclusive and open ended so as to include, optionally, multiple such elements.

[0040] “At least one,” in reference to a list of one or more entities should be understood to mean at least one entity selected from any one or more of the entity in the list of entities, but not necessarily including at least one of each and every entity specifically listed within the list of entities and not excluding any combinations of entities in the list of entities. This definition also allows that entities may optionally be present other than the entities specifically identified within the list of entities to which the phrase “at least one” refers, whether related or unrelated to those entities specifically identified. Thus, as a non-limiting example, “at least one of A and B” (or, equivalently, “at least one of A or B,” or, equivalently “at least one of A and/or B”) may refer, to at least one, optionally including more than one, A, with no B present (and optionally including entities other than B); to at least one, optionally including more than one, B, with no A present (and optionally including entities other than A); to at least one, optionally including more than one, A, and at least one, optionally including more than one, B (and optionally including other entities). In other words, the phrases “at least one,” “one or more,” and “and/or” are open-ended expressions that are both conjunctive and disjunctive in operation. For example, each of the expressions “at least one of A, B and C,” “at least one of A, B, or C,” “one or more of A, B, and C,” “one or more of A, B, or C” and “A, B, and/or C” may mean A alone, B alone, C alone, A and B together, A and C together, B and C together, A, B and C together, and optionally any of the above in combination with at least one other entity.

[0041] The present method treats a bitumen extract stemming from solvent-based extraction. The solvent-based extraction may include, but is not limited to, solvent extraction with a solids agglomeration process. Non-limiting examples of solvent-based extraction that are solvent extraction with solids agglomeration processes include those described in the background of the present disclosure and in CA 2,724,806 (Adeyinka *et al.*).

[0042] Adeyinka *et al.* discloses extracting bitumen from oil sand in a manner that employs solvent. A first solvent is combined with a bituminous feed derived from oil sand to form an

initial slurry. The initial slurry is separated into a fines solids stream and a coarse solids stream, where the majority of the fine solids within the oil sand are in the fine solids stream and the majority of the coarse solids within oil sand are in the coarse solids stream. The coarse solids stream can be separated into coarse solids and a first low solids bitumen extract stream. Aqueous bridging liquid is added to the fine solids stream to agglomerate the fine solids in the stream and form an agglomerated slurry. The agglomerated slurry can be separated into agglomerates and a second low solids bitumen extract stream. A second solvent can be mixed with the first and second low solids bitumen extract streams to form a solvent-bitumen low solids mixture, which can then be separated further into low grade and high grade bitumen extracts. Recovery of solvent from the low grade and high grade bitumen extracts is conducted to produce bitumen products of commercial value.

[0043] A method may comprise:

- a) providing a bitumen extract stemming from solvent-based extraction, the bitumen extract comprising bitumen, water, and solids;
- b) adding a diluent to the bitumen extract to produce a diluted bitumen stream, wherein the diluent is added in an amount sufficient to precipitate asphaltenes such that the diluted bitumen product has a C5 asphaltene precipitation of between 0.1 and 30%; and
- c) separating, by enhanced gravity separation, the diluted bitumen stream into a diluted bitumen product and tailings.

[0044] Using a diluent for product cleaning may eliminate the need for an additional paraffinic solvent treatment step, using a high purity paraffinic solvent, and the additional SRU, as well as the additional infrastructure for handling the paraffinic solvent. Additionally, a sufficient amount of the lower cost diluent may be retained to meet pipeline viscosity and density requirements, such that no additional diluent is required for transport.

[0045] High-purity paraffinic solvents are commonly used for deasphalting and subsequent solids and water removal in paraffinic froth treatment following water-based extraction of oil sands because the resulting precipitated asphaltene flocs are large and dense enough to gravity settle quickly. However, diluent is a less aggressive deasphalting solvent compared to a high

purity paraffinic solvent such as pentane and it is therefore anticipated that settling rates would be too slow for the gravity settling high purity paraffinic solvent step currently in the art. By using enhanced gravity separation, the need for a high purity paraffinic solvent may be eliminated or reduced, while still achieving acceptable separation of solids without the further need for the additional paraffinic solvent step currently in the art.

[0046] Without intending to be bound by theory, rather than requiring a high degree of asphaltene precipitation, it is believed that it is sufficient to merely destabilize the mineral solids using a less aggressive deasphalting solvent such as diluent followed by enhanced gravity separation to achieve acceptable solids separation.

[0047] Figure 1 is a flow diagram of a process for reducing the solids content of a bitumen extract (102) from solvent-based extraction. A typical bitumen extract (102) may include bitumen, up to 5 wt. % (more typically up to 1.5 wt. %) solids, on a dry bitumen basis, and up to 5 wt. % (more typically up to 1.5 wt. %) water, based on a weight of the bitumen extract. The bitumen extract may have greater than 0.1, 0.2, 0.5, 1.0, or 3.0 wt. % solids, on a dry bitumen basis. The bitumen extract may have from 0.1 to 5.0, 0.1 to 3.0, 0.1 to 1.0, or 0.1 to 0.5 wt. % solids, on a dry bitumen basis. The bitumen extract may be extracted from oil sand and may comprise greater than 0.5 wt. % solids, on a dry bitumen basis. The bitumen extract may have greater than 0.1, 0.2, 0.5, 1.0, or 3.0 wt. % water, based on a weight of the bitumen extract. The bitumen extract may have from 0.1 to 5.0, 0.1 to 3.0, 0.1 to 1.0, or 0.1 to 0.5 wt. % water, based on a weight of the bitumen extract.

[0048] Because the solids and water content of a bitumen extract from solvent-based extraction is much lower than the solids and water content of bitumen froth from water-based extraction, it is anticipated that less asphaltene precipitation is required to remove the solids and water. Furthermore, as a result of the low solids and water content, the tailings stream (solids, water, and precipitated asphaltenes) is relatively small compared to water-based extraction and enhanced gravity separators are enabled.

[0049] A diluent (104) may be added to the bitumen extract in an amount sufficient to precipitate asphaltenes, or an amount sufficient as to be near the onset of precipitation, to produce a diluted bitumen stream (106).

[0050] The diluent may be added in an amount sufficient to precipitate asphaltenes such that the diluted bitumen product has a C5 asphaltene precipitation of between 0.1 and 30%, or between 0.1 and 10%, or between 0.5 and 5%.

[0051] The C5 asphaltene precipitation is calculated as follows:

[0052] *C5 asphaltene precipitation (%) =*

$$\frac{\text{C5 asphaltenes in the diluted bitumen stream} - \text{C5 asphaltenes in the diluted bitumen product}}{\text{C5 asphaltenes in the diluted bitumen stream}}$$

[0053] By way of non-limiting example to illustrate the equation, if the diluted bitumen stream has a C5 asphaltene mass flow rate of 20 Kg/min and the diluted bitumen product has a C5 asphaltene mass flow rate of 8 Kg/min, then the C5 asphaltene precipitation is 60%. The C5 asphaltene component mass flow rate [Kg/min] is calculated from the stream flow rate [Kg/min] and the C5 asphaltene content of that stream [wt.%] as measured by ASTM D4055-04.

[0054] The diluent may comprise natural gas condensate, naphtha, C1-C8 hydrocarbons, or a combination thereof. A “diluent” is a hydrocarbon fluid that is used to dilute heavy oil and reduce its viscosity for easier transportation. Generally, a distillation tower cut such as naphtha is used for heavy oil dilution and transportation. The added diluent may be recovered at the destination using distillation and the diluent may be subsequently pumped back for re-use. The diluent may have a molecular composition that is sufficient to precipitate asphaltenes at a diluent to bitumen weight ratio of between 1 and 10, between 1 and 7, or between 1.5 and 3. The diluent is not a “high purity paraffinic solvent” as defined herein.

[0055] The diluent may be added to the bitumen extract at once or in any suitable number of stages for process control. For instance, two or three stages may be used.

[0056] A sufficient amount of the diluent added in the diluted bitumen product may be retained to meet pipeline transportation viscosity and density requirements. For example, at least 5-30 wt. % of the diluent added in step b) may be retained in the diluted bitumen product to meet pipeline transportation viscosity and density requirements.

[0057] The diluent may be selected such that at less than 40 wt. % or less than 30 wt. % diluent, the diluted product will meet pipeline transportation viscosity and density requirements.

[0058] Figure 1 illustrates an embodiment of the processes herein. Prior to adding the diluent (104), solvent (not shown) may be recovered from an upstream bitumen extract stemming from solvent-based extraction to produce the bitumen extract (102). The step of recovering solvent may be effected in a solvent recovery unit (SRU). The solvent is an extraction solvent used in the solvent-based extraction. By way of example only, following the step of recovering solvent, the bitumen extract may contain less than 1000 ppmw solvent.

[0059] The diluted bitumen stream (106) may be separated, by enhanced gravity separation (107), into a diluted bitumen product (108) and tailings (110). The diluted bitumen product may contain less than 1000 ppmw, less than 500 ppmw, less than 300 ppmw, less than 100 ppmw, or less than 50 ppmw solids, on a dry bitumen basis. The diluted bitumen product may contain between 50 and 500 ppmw, or between 100 and 300 ppmw solids, on a dry bitumen basis.

[0060] The diluted bitumen product may be sent to a refinery for refining. Refinery specifications generally require less than 300 ppmw solids, on a dry bitumen basis. The diluted bitumen product may have a water content of less than 1000 ppmw, less than 500 ppmw, or less than 200 ppmw, based on a weight of the diluted bitumen product. The diluted bitumen product may have less than 1300 ppmw combined water and solids, based on a weight of the diluted bitumen product, which is a typical refinery specification.

[0061] The diluted bitumen product may have an asphaltene content of less than 20 wt. %, less than 12 wt. %, or less than 8 wt. %, based on a weight of the diluted bitumen product.

[0062] The method may further comprise heating or cooling the bitumen extract before or after the diluent addition for process control. That is, parameters such as settling rates, solids separation, asphaltene rejection are temperature dependent.

[0063] Any suitable enhanced gravity separation may be used. The enhanced gravity separation may be effected by a centrifuge or a cyclone. The enhanced gravity separation may be effected by a plurality of enhanced gravity separation devices in parallel or in series.

[0064] Water may be added to one or more of the enhanced gravity separation devices to reduce hydrocarbon loss to the tailings. Water may be added in any suitable amount, for instance up to 50 wt. %, or between 1 and 50 wt.%.

[0065] The method may further comprise separating the diluted bitumen product into a diluent stream and a bitumen-rich diluent product. The separating of the diluted bitumen product may be effected in a diluent recovery unit (DRU). The bitumen-rich diluent product may meet pipeline specifications for viscosity and density. Any diluent beyond those specifications may be recovered and recycled.

[0066] In practice, it is desirable to meet pipeline specifications for viscosity and density, but to not have too much excess diluent, as this excess diluent is an additional cost. Therefore, the diluted bitumen product may be separated into a diluent stream and a bitumen-rich diluent product, and a trim diluent may be added to the bitumen-rich diluent product (for instance just prior to custody transfer) to meet pipeline transportation viscosity and density requirements. In this way, the diluent remaining in the bitumen-rich stream together with the trim diluent ensure that pipeline transportation viscosity and density requirements are met. The trim diluent may be the same or a different composition as the diluent used upstream. The trim diluent is a top-up for cases where the bitumen-rich diluted product does not quite meet the pipeline transportation viscosity and density requirements, for instance due to excess diluent having been removed or due to seasonal conditions.

[0067] The diluent stream may be recycled and used as the diluent in step b). The diluent stream may be cleaned or subjected to fractionation separation prior to being recycled. The cleaning may involve increasing a weight % of C1-C8 hydrocarbons, or a weight % of C5-C7 hydrocarbons, to assist solids separation.

[0068] Diluent may be recovered from the tailings, for instance in a tailings solvent recovery unit (TSRU).

[0069] Examples

[0070] A centrifugation study with n-heptane (n-C7) was completed on bitumen samples.

[0071] Bitumen was extracted from an oil sand sample with a solvent-based extraction process using cyclohexane as the extraction solvent. The cyclohexane was removed by evaporation (to less than 1000 ppmw residual cyclohexane) and the bitumen was re-dissolved in n-heptane with a solvent-to-bitumen ratio of 2 and 1.5 and a solids content of approximately 1.3 wt.% on a bitumen basis. The n-heptane solvent was selected as a surrogate for diluent. The bitumen sample was loaded into a centrifuge for solids separation testing at room temperature and a centrifugal g-force of approximately 439 g was applied for varying times (1 min, 3 min, 5 min). After centrifugation was complete, samples were re-measured for solids content. After 3 min of centrifugation, the solids content was reduced by approximately 98%. The results of this experimentation are shown in Figure 2.

[0072] Operating near the onset of precipitation using n-heptane (n-C7) was sufficient to destabilize the mineral solids in solution and achieve the less than 0.1 wt.% solids target.

[0073] It is anticipated that diluent is sufficiently paraffinic to enable solids removal in an enhanced gravity separator and achieve similar solids separation performance to n-heptane (n-C7). As can be seen by viewing the data set of Figure 2 using n-heptane (common component of a diluent) as a solvent, less than 0.1 wt.% bitumen solids content was able to be achieved with a short duration of centrifuging.

[0074] The scope of the claims should not be limited by particular embodiments set forth herein, but should be construed in a manner consistent with the specification as a whole.

CLAIMS:

1. A method comprising:

- a) providing a bitumen extract stemming from solvent-based extraction, the bitumen extract comprising bitumen, water, and solids;
- b) adding a diluent to the bitumen extract to produce a diluted bitumen stream, wherein the diluent is added in an amount sufficient to precipitate asphaltenes such that the diluted bitumen product has a C5 asphaltene precipitation of between 0.1 and 30%.; and
- c) separating, by enhanced gravity separation, the diluted bitumen stream into a diluted bitumen product and tailings.

2. The method of claim 1, wherein the diluent is added in an amount sufficient to precipitate asphaltenes such that the diluted bitumen product has a C5 asphaltene precipitation of between 0.1 and 10%.

3. The method of claim 1, wherein the diluent is added in an amount sufficient to precipitate asphaltenes such that the diluted bitumen product has a C5 asphaltene precipitation of between 0.5 and 5%.

4. The method of any one of claims 1 to 3, wherein the diluent has a molecular composition sufficient to precipitate asphaltenes at a diluent-to-bitumen weight ratio of between 1 and 10.

5. The method of any one of claims 1 to 3, wherein the diluent has a molecular composition sufficient to precipitate asphaltenes at a diluent-to-bitumen weight ratio of between 1 and 7.

6. The method of any one of claims 1 to 3, wherein the diluent has a molecular composition sufficient to precipitate asphaltenes at a diluent-to-bitumen weight ratio of between 1.5 and 3.

7. The method of any one of claims 1 to 6, further comprising retaining a sufficient amount of the diluent added in step b) in the diluted bitumen product to meet pipeline transportation viscosity and density requirements.
8. The method of any one of claims 1 to 6, further comprising retaining at least 5-30 wt. % of the diluent added in step b) in the diluted bitumen product to meet pipeline transportation viscosity and density requirements.
9. The method of any one of claims 1 to 8, wherein the diluent is added to the bitumen extract in stages.
10. The method of any one of claims 1 to 9, further comprising, prior to step a), recovering solvent from an upstream bitumen extract stemming from solvent-based extraction to produce the bitumen extract.
11. The method of claim 10, wherein the recovering solvent is effected in a solvent recovery unit (SRU).
12. The method of any one of claims 1 to 11, wherein the diluted bitumen product contains less than 500 ppmw solids, on a dry bitumen basis.
13. The method of any one of claims 1 to 12, further comprising heating or cooling the bitumen extract before or after the diluent addition.
14. The method of any one of claims 1 to 13, wherein the enhanced gravity separation is effected by a centrifuge or a cyclone.

15. The method of claim 14, wherein the enhanced gravity separation is effected by a plurality of enhanced gravity separation devices.
16. The method of any one of claims 1 to 15, further comprising adding water in step c) to reduce hydrocarbon loss to the tailings.
17. The method of any one of claims 1 to 16, further comprising separating the diluted bitumen product into a diluent stream and a bitumen-rich diluent product.
18. The method of claim 17, wherein the separating the diluted bitumen product is effected in a diluent recovery unit (DRU).
19. The method of claim 17 or 18, wherein the diluent stream is recycled and used as the diluent in step b).
20. The method of claim 19, wherein the diluent stream is cleaned or subjected to fractionation separation prior to being recycled.
21. The method of claim 20, wherein the cleaning or fractionation separation of the diluent stream involves increasing a weight % of C1-C8 hydrocarbons, or a weight % of C5-C7 hydrocarbons.
22. The method of any one of claims 1 to 21, wherein the diluent comprises natural gas condensate, naphtha, C1-C8 hydrocarbons, or a combination thereof.
23. The method of any one of claims 1 to 22, further comprising recovering diluent from the tailings.

24. The method of claim 23, wherein the recovering diluent from the tailings is effected in a tailings solvent recovery unit (TSRU).

25. The method of any one of claims 1 to 6, further comprising separating the diluted bitumen product into a diluent stream and a bitumen-rich diluent product, and adding a trim diluent to the bitumen-rich diluent product to meet pipeline transportation viscosity and density requirements.

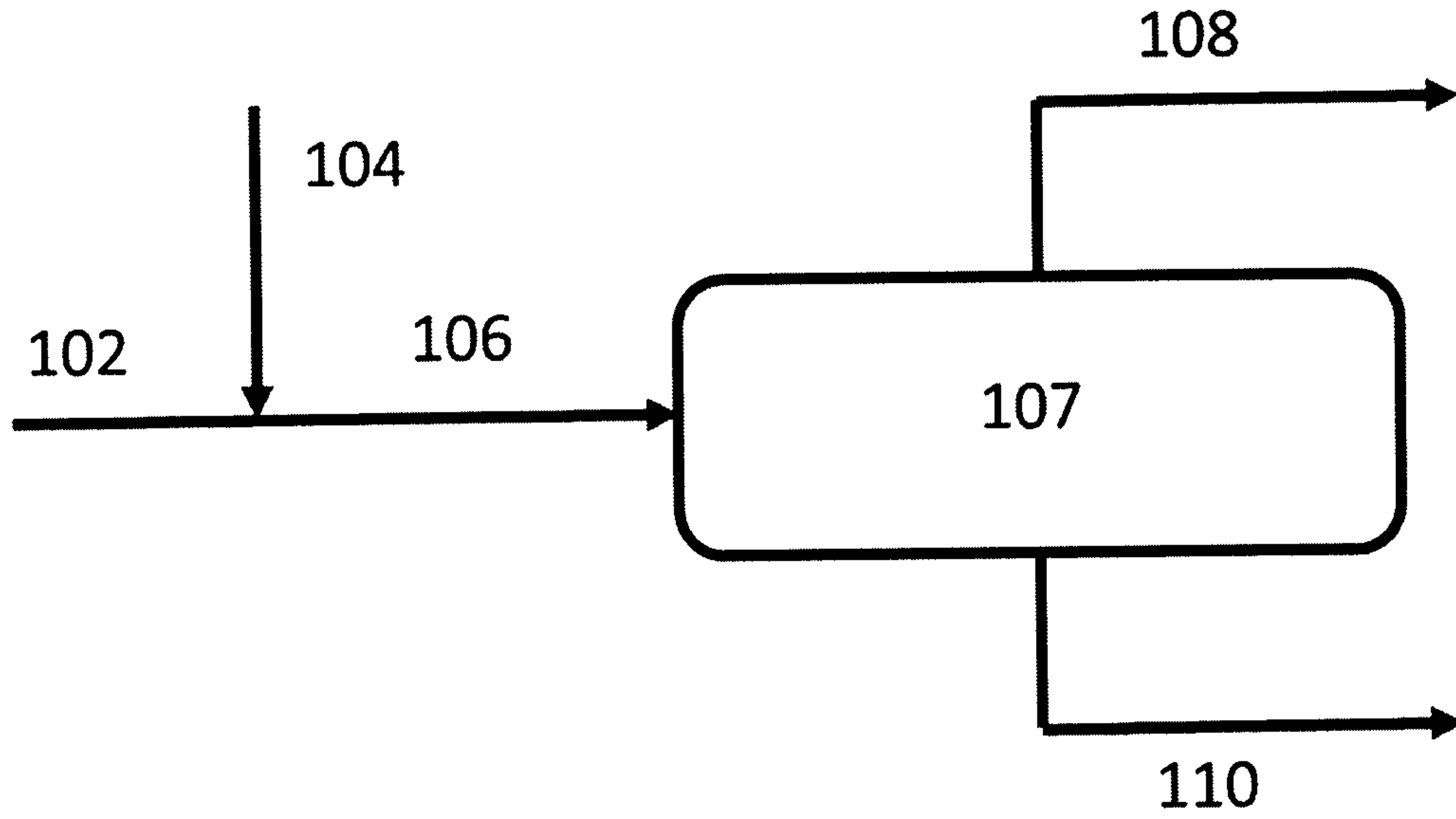


FIGURE 1

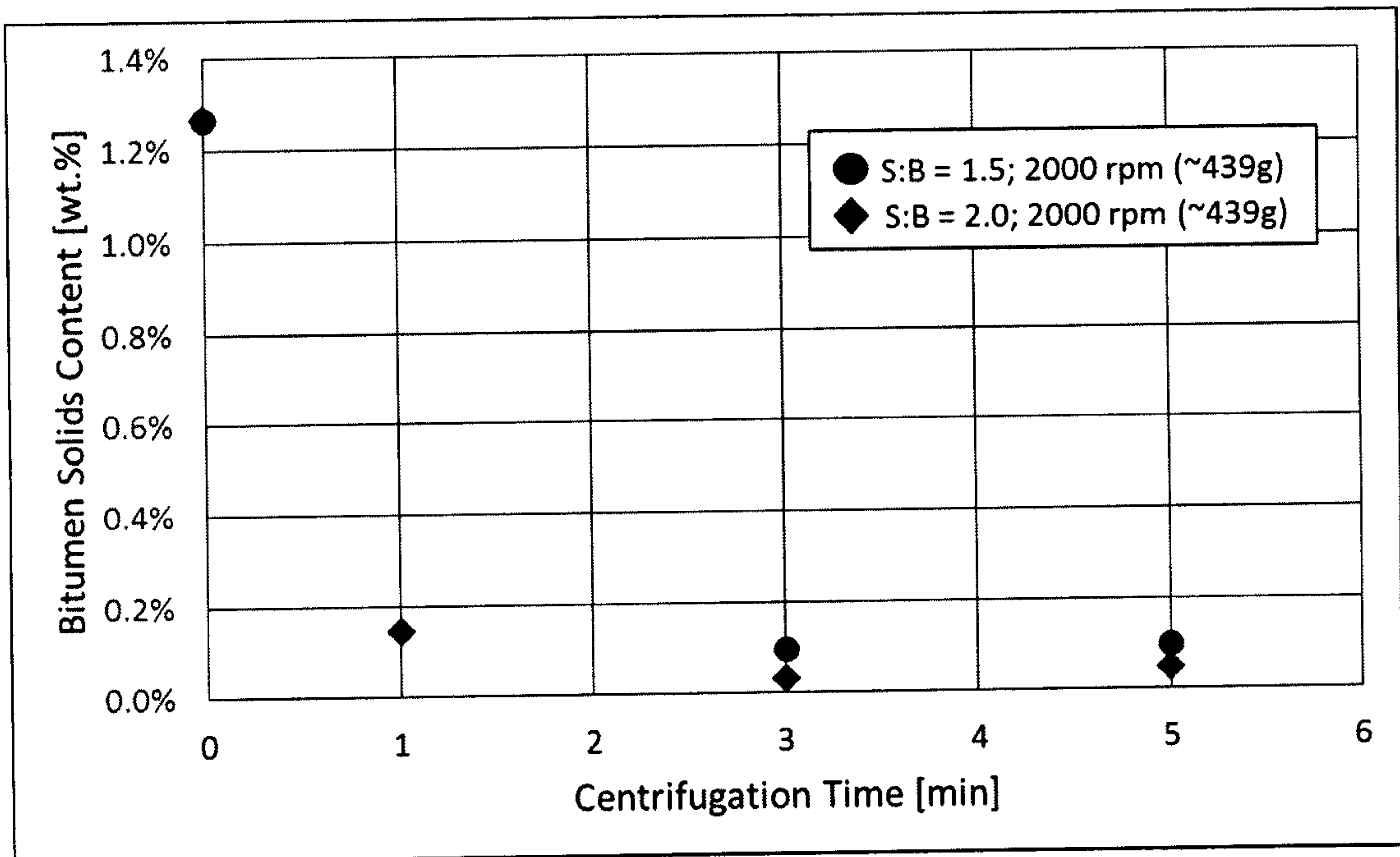


FIGURE 2

