Office de la Propriété Intellectuelle du Canada
Un organisme d'Industrie Canada

Canadian Intellectual Property Office
An agency of Industry Canada

CA 2867357 C 2017/10/31

(11)(21) **2 867 357**

(12) **BREVET CANADIEN**
CANADIAN PATENT

(13) **C**

(22) **Date de dépôt/Filing Date:** 2014/10/16

(41) **Mise à la disp. pub./Open to Public Insp.:** 2016/04/16

(45) **Date de délivrance/Issue Date:** 2017/10/31

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

(72) **Inventeurs/Inventors:**
ABEL, KEITH A., CA;
ADEYINKA, OLUSOLA B., CA;
OLDENBURG, PAUL D., US;
BOHRA, LALIT K., US

(73) **Propriétaires/Owners:**
IMPERIAL OIL RESOURCES LIMITED, CA;
EXXONMOBIL UPSTREAM RESEARCH COMPANY, US

(74) **Agent:** BORDEN LADNER GERVAIS LLP

(54) **Titre : PROCEDE DE TRAITEMENT DE MATIERE PREMIERE BITUMINEUSE**
(54) **Title: METHODS FOR PROCESSING A BITUMINOUS FEED**

(57) **Abrégé/Abstract:**
A method for processing a bituminous feed includes forming an oil sand slurry, including a bitumen extract and solids, by contacting the bituminous feed with a first extraction liquor; forming a rich bitumen extract stream and separated solids by separating the solids from the bitumen extract; forming a washed solids stream and a lean bitumen extract stream, including precipitated asphaltenes, by washing the separated solids with an aliphatic solvent; forming a deasphalted lean bitumen extract stream by separating the precipitated asphaltenes from the lean bitumen extract stream; and obtaining a bitumen product stream by removing the first solvent from at least one of a first portion of the rich bitumen extract stream and a first portion of the deasphalted lean bitumen extract stream.

ABSTRACT

A method for processing a bituminous feed includes forming an oil sand slurry, including a bitumen extract and solids, by contacting the bituminous feed with a first extraction liquor; forming a rich bitumen extract stream and separated solids by separating the solids from the bitumen extract; forming a washed solids stream and a lean bitumen extract stream, including precipitated asphaltenes, by washing the separated solids with an aliphatic solvent; forming a deasphalted lean bitumen extract stream by separating the precipitated asphaltenes from the lean bitumen extract stream; and obtaining a bitumen product stream by removing the first solvent from at least one of a first portion of the rich bitumen extract stream and a first portion of the deasphalted lean bitumen extract stream.

METHODS FOR PROCESSING A BITUMINOUS FEED

BACKGROUND

Field of Disclosure

[0001] The disclosure relates generally to the field of oil sand processing. More specifically, the disclosure relates to methods for processing a bituminous feed.

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 process (WBE). The WBE is a commonly used process to extract bitumen from mined oil sand. In another technique, a non-water-based extraction process can be used to treat the strip or surface mined oil sand. The non-water-based extraction process may be referred to as a solvent-based recovery process. The commercial application of a solvent-based recovery process has, for various reasons, eluded the oil sand industry. A major challenge associated with the solvent based extraction process 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.) %. Another major challenge to the application of a solvent-based recovery process for oil sand is the recovery of solvent from the bitumen-free solids. This solvent-based recovery process is often energy intensive and limits the economics of the overall solvent-based recovery process.

[0005] A solid agglomeration process has been proposed for use in the solvent-based recovery process. 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 slow and controlled manner to nucleate particles, and continuing such agitation so as to permit these nucleated particles to form larger multi-particle spherical agglomerates for removal. 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.

[0006] 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.

[0007] 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 micro-agglomerates. The micro-agglomerates are formed by obtaining an eventual equilibrium between cohesive and destructive forces. Since micro-agglomerates of large size can lead to bitumen recovery losses owing to entrapment of extracted bitumen within the agglomerated solids, the levels of bridging liquid is kept to as low as possible commensurate with achieving economically viable solid-liquid separations.

[0008] 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 1 wt. % on a dry bitumen basis. "Dry bitumen basis" means ignoring the presence of water in the bitumen extract for the purpose of calculating wt. %.

[0009] 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.

[0010] 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. Patent Publication 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. Blackbourn *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.

[0011] 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. The method involves contacting the oils 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.

[0012] The above-described processes demonstrate that the use of aliphatic solvent in a solvent-based recovery process may reduce the amount of residual solvent in the tailings. However, the use of aliphatic solvent does pose challenges to the solvent-based recovery process. The use of aliphatic solvent may increase the chance that asphaltenes, which have not dissolved (i.e., undissolved asphaltenes), will be present in undesirable locations within the solvent-based recovery process. For example, undissolved asphaltenes may be present in an extraction vessel, thereby trapping bitumen within the asphaltene and inorganic solid pores. Undissolved asphaltenes may be referred to as precipitated asphaltenes. The extraction vessel is a vessel where bitumen is extracted from oil sand. The bitumen trapped may result in additional losses of bitumen with the tailings. The undissolved asphaltenes tend to foul various components, such as piping, valves, and filters, which may result in an increased need for maintenance.

[0013] In view of the aforementioned disadvantages, there is a need for improved methods for processing a bituminous feed. For example, there is a need for a method for using aliphatic solvents in a solvent-based recovery process that takes advantage of the benefits of using aliphatic solvents while mitigating the problems that the presence of undissolved asphaltenes may have on the solvent-based recovery process.

SUMMARY

[0014] It is an object of the present disclosure to provide methods for processing a bituminous feed.

[0015] A method for processing a bituminous feed may comprise: a) forming an oil sand slurry, comprising a bitumen extract and solids, by contacting the bituminous feed with a first extraction liquor, comprising a first solvent; b) forming a rich bitumen extract stream and separated solids by separating the solids from the bitumen extract; c) forming a washed solids stream and a lean bitumen extract stream, comprising precipitated asphaltenes, by washing the separated solids with an aliphatic solvent; d) forming a deasphalted lean bitumen extract stream by separating the precipitated asphaltenes from the lean bitumen extract stream; and e) obtaining a bitumen product stream by removing the first solvent from at least one of a first portion of the rich bitumen extract stream and a first portion of the deasphalted lean bitumen extract stream.

[0016] A method for processing a bituminous feed may comprise: a) forming an oil sand slurry, comprising a bitumen extract and solids, by contacting the bituminous feed with a first extraction liquor comprising a first solvent; b) forming a rich bitumen extract stream, comprising the bitumen extract and residual fine solids, by separating the solids from the bitumen extract; c) providing a hydrocarbon fluid comprising undissolved asphaltenes; d) forming an asphaltene-bitumen extract mixture by mixing the hydrocarbon fluid with the rich bitumen extract stream; e) forming a low solids bitumen extract stream by separating asphaltenes and the residual fine solids from the asphaltene-bitumen extract mixture; and f) obtaining a bitumen product stream by removing the first solvent from the low solids bitumen extract stream.

[0017] A method for processing a bituminous feed may comprise: a) providing a first extraction liquor comprising deasphalted bitumen and a first solvent; b) forming an oil sand slurry, comprising a bitumen extract and solids, by contacting the bituminous feed with the first extraction liquor; c) forming a rich bitumen extract stream by separating the solids from the bitumen extract; and d) obtaining a bitumen product stream by removing the first solvent from a first portion of the rich bitumen extract stream.

[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 chart of a method for processing a bituminous feed.

[0021] Figure 2 is a flow chart of a method for processing a bituminous feed.

[0022] Figure 3 is a flow chart of a method for processing a bituminous feed.

[0023] Figure 4 is a flow chart of a method for processing a bituminous feed.

[0024] Figure 5 is a flow chart of a method for processing a bituminous feed.

[0025] Figure 6 is a flow chart of a method for processing a bituminous feed.

[0026] Figure 7 is a flow chart of a method for processing a bituminous feed.

[0027] Figure 8 is a flow chart of a method for processing a bituminous feed.

[0028] Figure 9 is a flow chart of a method for processing a bituminous feed.

[0029] 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

[0030] 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.

[0031] 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.

[0032] Throughout this disclosure, where a range is used, any number between or inclusive of the range is implied.

[0033] 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.

[0034] "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. %).

In addition, bitumen can contain some water and nitrogen compounds ranging from less than 0.4 wt. % to in excess of 0.7 wt. %. 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.

[0035] "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/m^3) or 0.920 grams per centimeter cubed (g/cm^3)) and 10.0° API (density of 1,000 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 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.

[0036] 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.

[0037] "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).

[0038] "Coarse particles" are generally defined as those solids having a size of greater than 44 microns (μm).

[0039] A "solvent-based recovery process" or "solvent extraction process" or "oil sand solvent extraction process" includes any type of hydrocarbon recovery process that uses a solvent, at least in part, to enhance the recovery, for example, by diluting or lowering a viscosity of the hydrocarbon. Solvent-based recovery processes may be used in combination with other recovery processes, such as, for example, thermal recovery processes. In solvent-based recovery processes, a solvent is injected into a subterranean reservoir. The solvent may be heated or unheated prior to injection, may be a vapor or liquid and may be injected with or without steam. Solvent-based recovery processes may include, but are not limited to, solvent assisted cyclic steam stimulation (SA-CSS), solvent assisted steam assisted gravity drainage (SA-SAGD), solvent assisted steam flood (SA-SF), vapor extraction process (VAPEX), heated vapor extraction process (H-VAPEX), cyclic solvent process (CSP), heated cyclic solvent process (H-CSP), solvent flooding, heated solvent flooding, liquid extraction process, heated liquid extraction process, solvent-based extraction recovery process (SEP), thermal solvent-based extraction recovery processes (TSEP), and any other such recovery process employing solvents either alone or in combination with steam. A solvent-based recovery process may be a TSEP if the solvent is heated prior to injection into the subterranean reservoir. The solvent-based recovery process may employ gravity drainage.

[0040] "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.

[0041] "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).

[0042] A "rich bitumen extract stream" is generally defined as a bitumen extract stream from which at least some solids have been removed.

[0043] A "lean bitumen extract stream" is generally defined as a bitumen extract stream from which a rich bitumen stream and at least some solids have been removed.

[0044] A "washed solids stream" is generally defined as a solids stream that has been washed using a solvent, such as but not limited to an aliphatic solvent.

[0045] A "deasphalted lean bitumen extract stream" is generally defined as a lean bitumen extract stream that has been deasphalted to remove some or all asphaltenes.

[0046] A "bitumen extract" is generally defined as bitumen that has been extracted from oil sand.

[0047] "Residual solid fines" are generally defined as fines remaining in a stream following a solids separation process.

[0048] A "bitumen product stream" is generally defined as a high grade bitumen product that may be suitable for transport within pipelines and processing within downstream refineries. A high grade bitumen product stream may have a solids content of less than 1 wt.%, or less than 0.1 wt. %, on a dry bitumen basis.

[0049] A “low grade bitumen product stream” is generally defined as the result of removing solvent from a stream containing precipitated asphaltenes, such as precipitated asphaltenes which have been removed from a lean bitumen extract stream, or an asphaltene-bitumen extract mixture comprising precipitated asphaltenes, or a precipitated asphaltenes separated from a diluted bitumen extract stream.

[0050] The term “solvent” as used in the present disclosure should be understood to mean either a single solvent, or a combination of solvents.

[0051] “Solvent deasphalting” is generally defined as a method to remove the solids that remain in a bitumen extract from the bitumen extract.

[0052] 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.

[0053] 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.

[0054] “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.

[0055] Solvent deasphalting of a lean bitumen extract stream has the advantage of controlling a location within a solvent extraction process where asphaltenes are precipitated. It may be desirable to limit or eliminate asphaltene precipitation within transfer lines carrying asphaltene containing streams between equipment used in a solvent extraction process to mitigate fouling. It may desirable to limit the amount of undissolved asphaltenes within an extraction vessel of a solvent extraction process to limit the effect undissolved asphaltenes have on reducing the rate by which bitumen dissolves into an extraction liquor. There are locations within the solvent extraction process where asphaltene precipitation may be desirable. For example, asphaltene precipitation may be desirable in locations within the solvent extraction process where the lean bitumen extract stream is mixed with a rich bitumen extract stream to form a combined stream. The combined stream may be deasphalted to produce a deasphalted bitumen extract stream and a deasphalted extraction liquor. The deasphalted bitumen extract stream has the advantage that residual solid fines are removed during deasphalting to produce reduced ash and increased API bitumen product, as compared to a bitumen extract stream that has not been deasphalted, when solvent is removed from the deasphalted bitumen extract. The deasphalted extraction liquor may have the advantage of producing an extraction liquor that more readily extracts bitumen from the bituminous feed than an extraction liquor that is not deasphalted. The deasphalted extraction liquor may have this advantage because of the absence of asphaltene molecules within the extraction liquor. The asphaltene molecules may reduce the rate of bitumen dissolution.

[0056] The solvent deasphalting described in the present disclosure may be referred to as controlled deasphalting. The controlled deasphalting may be combined with aspects of other solvent extraction processes, including but not limited to solvent extraction with a solids agglomeration process. Non-limiting examples of solvent extraction processes 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.*").

[0057] 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 steam 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.

[0058] The solvent extraction with solid agglomeration processes described by Adeyinka *et al.* is one suitable solvent extraction process for the processes described in the present disclosure. The aqueous bridging liquid of Adeyinka *et al.* may be added to the slurry (without separating the slurry into a coarse stream and a fine stream), followed by agglomeration. The extraction liquor that contacts the bituminous feed may allow for complete or near complete dissolution of the bitumen to increase overall bitumen recovery. Complete dissolution of the bitumen will result in fine solids dispersing into the bitumen extract which, if left dispersed, will hamper solid-liquid separation downstream of the extraction process. In contrast to the method described in U.S. Patent Publication 2011/0127197 (Blackbourn *et al.*), the initial dispersing of the fine solids of Adeyinka *et al.* is acceptable because the solid agglomeration process will allow for the majority of the fine solids to be recaptured as agglomerates with the aqueous bridging liquid. The lean bitumen extract stream described in the present disclosure may be used as the second solvent in the process described by Adeyinka *et al.* The lean bitumen extract stream, which may be comprised of an aliphatic solvent such as but not limited to pentane, when mixed with the low solids bitumen extract, may result in asphaltene precipitation. The asphaltene precipitation may be referred to as precipitated asphaltenes. The precipitated asphaltenes aggregate with the residual solids, forming aggregated precipitated asphaltenes, and settle by gravity to form a high grade bitumen extract above a low grade bitumen extract. Solvent within the high grade bitumen extract can be recovered from the high grade bitumen extract overflow to form a bitumen product with a solid content of less than 0.1 wt. %. The low grade bitumen extract may be recycled to other units of the solvent extraction process to separate bitumen from the aggregated precipitated asphaltenes. Solvent may be recovered from the low grade bitumen extract to produce a low grade bitumen product with commercial value.

[0059] Figure 1 is a flow chart of a method for processing a bituminous feed. The method may de-asphalt a lean bitumen extract stream. Figure 5 is another flow chart for processing a bituminous feed.

[0060] The method may comprise forming an oil sand slurry (108) by contacting a bituminous feed (102) with a first extraction liquor (104), in a bitumen extraction step (106), (502). The oil sand slurry (108) may comprise a bitumen extract and solids.

[0061] The first extraction liquor may comprise a first solvent. The first solvent may be used to extract bitumen from the bituminous feed. The first extraction liquor may comprise a hydrocarbon solvent capable of dissolving the bitumen. The first extraction liquor may be a solution of a hydrocarbon solvent(s) and bitumen, where the bitumen content of the first extraction liquor may range between 0 and 70 wt.%, or between 0 and 50 wt.%, or between 30 and 70 wt. %. The first extraction liquor may contain dissolved bitumen. When the first extraction liquor contains dissolved bitumen, the volume of the first extraction liquor may be increased without an increase in the required inventory of hydrocarbon solvent(s).

[0062] A second solvent (142) may be added in the bitumen extraction step (106). The second solvent (142) may contact the bituminous feed (102) to help form the oil sand slurry (108).

[0063] The solvent extraction process may be adjusted to provide a ratio of solvent (the first solvent and/or the second solvent) to bitumen in the oil sands slurry that minimizes asphaltenes precipitation during the bitumen extraction step (106). The presence of some amount of precipitated asphaltenes is unavoidable. By adjusting the amount of first and/or second solvent flowing into a bitumen extraction vessel of the bitumen extraction step (106), a ratio of the first and/or second solvent to the bitumen in the bitumen extraction vessel can be controlled. Bitumen in the bitumen extraction vessel comes from the bituminous feed and any bitumen entrained in the first extraction liquor. Selecting the ratio of the first and/or second solvent to the bitumen may decrease the costs for processing the bituminous feed if the ratio is one with less solvent than bitumen. Having less first and/or second solvent than bitumen may lower the costs for processing the bituminous feed because of the lower first and/or second solvent requirements.

[0064] The ratio of the first and/or second solvent to the bitumen may be selected as a target ratio. The target ratio may be less than 2:1. For example but not limited to, the target ratio may be 1.5:1 or less, 1:1 or less, or 0.75:1. For clarity, ratios may be expressed in the present disclosure using a colon between two values, such as "2:1", or may equally be expressed as a single number, such as "2", which carries the assumption that the denominator of the ratio is 1 and is expressed on a weight to weight basis.

[0065] The first extraction liquor may be recycled to the bitumen extraction step (106) from a downstream step, such as but not limited to from liquid splitter (140), as detailed below. Residual bitumen within the first extraction liquor may increase the volume of the first extraction liquor. The residual bitumen within the first extraction liquor may increase the solubility of the first extraction liquor for additional bitumen dissolution.

[0066] Throughout this application including with reference to all Figures, the terms "solvent", "first solvent", "second solvent", and "third solvent" are each considered to be a "solvent" as defined in the present disclosure. The "solvent", "first solvent", "second solvent", and/or "third solvent" may be the same or different from one another. As is evident from the description of the Figures, the "solvent", "first solvent", "second solvent", and/or "third solvent" may be added in different locations in the process and/or may be added alone or as part of a composition such as but not limited to as part of an extraction liquor (e.g., a first extraction liquor, a second extraction liquor). The "first solvent", "second solvent", and/or "third solvent" may interchangeably be referred to as a solvent. This paragraph applies to all of the Figures in the present disclosure.

[0067] Several types of solvents are suitable for use in the solvent extraction process. The solvent may comprise an organic solvent or a mixture of organic solvents. The solvent may comprise light aromatic compounds. The light aromatic compounds may be a light aromatic solvent with zero to 100% aromatic compounds. A light aromatic solvent may have less than 16 carbon atoms per molecule. Exemplary solvents include, but are not limited to, benzene, toluene, naphtha and kerosene. In cases where the aromatic content of the solvent is less than what is needed to fully dissolve the bitumen in the bituminous feed, pre-dissolved bitumen within the extraction liquor can increase the solubility of the extraction liquor towards dissolving additional bitumen. This paragraph applies to all of the Figures in the present disclosure.

[0068] The solvent may comprise at least one of an open chain aliphatic hydrocarbon, and a cyclic aliphatic hydrocarbon. Low boiling point cycloalkanes, or mixture of such cycloalkanes, can substantially dissolve asphaltenes. This paragraph applies to all of the Figures in the present disclosure.

[0069] The solvent may comprise a paraffinic solvent. The paraffinic solvent may be one in which the solvent to bitumen ratio of the bitumen extract and/or the first extraction liquor is maintained at a level to avoid or limit precipitation of asphaltenes. The paraffinic solvent may comprise at least one of an alkane, a natural gas condensate, and a distillate from a fractionation unit (or diluent cut) containing more than 40% small chain paraffins of 3 to 10 carbon atoms, referred to in the present disclosure as a small chain (or short chain) paraffin mixture. This paragraph applies to all of the Figures in the present disclosure.

[0070] Should an alkane be selected as the solvent, the alkane may comprise at least one of a normal alkane and an iso-alkane. The alkane may comprise at least one of heptane, iso-heptane, hexane, iso-hexane, pentane, and iso-pentane. This paragraph applies to all of the Figures in the present disclosure.

[0071] A cyclic aliphatic hydrocarbon may be selected as the solvent, it may comprise a cycloalkane of 4 to 9 carbon atoms. A mixture of C_3-C_9 cyclic and/or open chain aliphatic solvents may be appropriate. Exemplary cycloalkanes include at least one of cyclohexane and cyclopentane. If the solvent is selected as the distillate from a fractionation unit, it may for example be one having a final boiling point of less than 180 °C. An exemplary upper limit of the final boiling point of the distillate may be less than 100°C. A mixture of C_3-C_{10} cyclic and/or open chain aliphatic solvents would also be appropriate. For example, it can be a mixture of C_3-C_9 cyclic aliphatic hydrocarbons and paraffinic solvents where the percentage of the cyclic aliphatic hydrocarbons in the mixture is greater than 50%. This paragraph applies to all of the Figures in the present disclosure.

[0072] The solvent may have a final boiling point of less than 200°C (degrees Celsius). The solvent may have a final boiling point of less than 100°C. While it is not necessary to use a solvent having a boiling point of less than 200°C or less than 100°C, there may be an extra advantage that solvent recovery proceeds at lower temperatures, and requires a lower energy consumption than solvent recovery at higher temperatures.

[0073] The oil sand slurry may have a solid content in the range of 5 to 70 wt.%, 20 to 70 wt.%, or 40 to 70 wt.%. In the case of a solvent extraction process with solids agglomeration process, a higher solids content oil sand slurry may be desired. The higher solids content may increase the compaction forces that may help in the solids agglomeration process. In other cases, a lower solids content may be desired. The lower solids content may reduce the mixing energy needed in the solvent based extraction process. The oil sand slurry may have a higher solids content for the extraction and agglomeration processes and then be diluted to a lower solids content prior to solid-liquid separation. This paragraph applies to all of the Figures in the present disclosure.

[0074] The temperature of the oil sand slurry may be at a value that is configured to minimize a presence of undissolved asphaltenes in the oil sand slurry. The value may include any number within or bounded by the range of 20-100°C. When the temperature of the oil sand slurry is kept at a value that minimizes the presence of undissolved asphaltenes in the oil sand slurry, the bitumen dissolution rate may be decreased; the viscosity of the oil sand slurry may be decreased. Decreasing the bitumen dissolution rate and/or the viscosity of the oil sand slurry may promote more effective sand digestion and agglomerate formation than increasing the bitumen dissolution rate and/or decreasing the viscosity of the oil sand slurry. When the temperature of the oil sand slurry is kept at the value that minimizes the presence of undissolved asphaltenes in the oil sand slurry, the solid-liquid separation may be improved because higher temperatures may result in a reduced slurry viscosity, which in turn, may improve the solid-liquid separation process. Temperatures above 100°C are generally avoided due to the complications resulting from high vapor pressures. This paragraph applies to all Figures in the present disclosure.

[0075] The method may comprise diluting the oil sand slurry (108) prior to separating the solids in the oil sand slurry (108) from the bitumen extract in the oil sand slurry (108). The oil sand slurry (108) may be diluted in a dilution step (110) to form a diluted oil sand slurry (147). The oil sand slurry (108) may be diluted by a second extraction liquor (112). The oil sand slurry (108) may be diluted by a third solvent (144). The first extraction liquor (104) may have a bitumen content that is the same or more than that of the second extraction liquor (112). The bitumen content of the second extraction liquor (112) may be between 0 and 70 wt. %.

[0076] The method may comprise forming a rich bitumen extract stream (118) and separated solids (116) by separating the solids from the bitumen extract, (504). The method may comprise forming the rich bitumen extract stream (118) and the separated solids (116) in a solid-liquid separator (114). Any suitable solid-liquid separator (114) may be used. For example and without limitation, the solid-liquid separator (114) may comprise a gravity settler or an enhanced gravity settler.

[0077] The method may comprise forming a washed solids stream (124) and a lean bitumen extract stream (126) by washing the separated solids (116) with an aliphatic solvent (122), (506). The separated solids (116) may be washed with the aliphatic solvent (122) in a washer unit (120). The aliphatic solvent (122) may be used to precipitate asphaltenes, which are removed from the washer unit (120) as part of the lean bitumen extract stream (126). The lean bitumen extract stream (122) may comprise precipitated asphaltenes.

[0078] The method may comprise forming a deasphalted lean bitumen extract stream (132) by separating the precipitated asphaltenes (130) from the lean bitumen extract stream (126), (508). The precipitated asphaltenes (130) may be separated from the lean bitumen extract stream (126) in a separator (128). The separator (128) may be any suitable separator. For example, the separator (128) may include but is not limited to a gravity settler or an enhanced gravity settler. At least a portion of the deasphalted lean bitumen extract stream (132) may be recycled as recycled deasphalted lean bitumen extract stream. The recycled deasphalted lean bitumen extract stream may be the second extraction liquor (112). The recycled deasphalted lean bitumen extract stream may be the first extraction liquor (104). Solvent may be recovered from the precipitated asphaltenes (130) to form a low grade bitumen stream (not shown).

[0079] The method may comprise recycling at least a portion of the rich bitumen extract stream (118) as recycled rich bitumen extract stream. The recycled rich bitumen extract stream may be the first extraction liquor (104). The rich bitumen extraction extract stream (118) may be fed to a liquid splitter (140) to split the rich bitumen extract stream (118) into a first portion of the rich bitumen extract stream (148) and a second portion of the rich bitumen extract stream (104). The second portion of the rich bitumen extract stream (104) may be the at least the portion of the rich bitumen extract stream recycled as the recycled rich bitumen extract stream. The first portion of the rich bitumen extract stream (148) may be referred to as a portion of the rich bitumen extract stream. The second portion of the rich bitumen extract stream 104 may be referred to as a portion of the rich bitumen extract stream. Using at least a portion of the rich bitumen extract stream as the first extraction liquor may ensure that the solvent-to-bitumen ratio (S:B) of the initial bitumen extract obtained from dissolution of bitumen from the bituminous feed is less than the S:B of the lean bitumen extract. The lower S:B ratio has the advantage of increasing the amount of bitumen dissolution from the bituminous feed, which may increase overall bitumen recovery. Additional solvent may be added to the recycled rich bitumen extract stream to achieve a desired S:B ratio.

[0080] The method may comprise obtaining a bitumen product stream (138) by removing the first solvent (136) from at least one of a portion (148) of the rich bitumen extract stream (118) (i.e., the first portion of the rich bitumen extract stream (148)) and a portion (149) of the deasphalted lean bitumen extract stream (132), (510). The bitumen product stream (138) may be obtained by removing solvent in a solvent recovery step (134) from at least one of the portion (148) of the rich bitumen extract stream (118) and a portion of the deasphalted lean bitumen extract stream (132). The portion (148) of the rich bitumen extract stream (118) may be referred to as the first portion of the rich bitumen extract stream; the portion (149) of the deasphalted lean bitumen extract stream may be referred to as the first portion of the deasphalted lean bitumen extract stream, or the second portion of the deasphalted lean bitumen extract stream.

[0081] The method may comprise mixing an additional solvent with the recycled deasphalted lean bitumen extract stream. The method may comprise mixing the additional solvent prior to the recycled deasphalted lean bitumen extract stream's use as the first extraction liquor (104) and/or the second extraction liquor (112). The first extraction liquor and/or the second extraction liquor (112) may comprise, in addition to the deasphalted lean bitumen extract stream (132), the additional solvent.

[0082] The deasphalting of the lean bitumen extract stream, of the process depicted in Figure 1, has the advantage of controlling the location within the solvent extraction process where asphaltenes are precipitated. The precipitated asphaltenes and fine solids may be separated from the lean bitumen extract stream in the separator (128). The deasphalted lean bitumen extract stream (132) may reduce the chance that asphaltene precipitation will foul process equipment, including but not limited to the pipelines used to recycle the lean bitumen extract stream (126) to upstream processes. Reducing the risk of fouling process equipment by asphaltene precipitation may substantially decrease the need for maintenance of the process equipment. The lower solid content of the deasphalted lean bitumen extract stream (132) may reduce the chance of plugging of process equipment by solids. For this reason, the hydrodynamic requirements for fluid flow in pipelines and other process equipment may be dictated by factors other than the risk of solid settling.

[0083] The method may comprise forming an asphaltene-bitumen extract mixture by mixing the precipitated asphaltenes (130) with at least some of the portion of the rich bitumen extract stream (148) (not shown). The asphaltene-bitumen extract mixture may be separated from the first portion of the rich bitumen extract stream (148) to remove the residual solids that are within the first portion of the rich bitumen extract stream (148). Removing the residual solids may allow for the precipitated asphaltenes (130) from the lean bitumen extract stream (126) to assist with the aggregation and separation of the residual fine solids from the first portion of the rich bitumen extract stream (148).

[0084] The temperature and pressure of the asphaltene-bitumen extract mixture can be adjusted to improve the ability of the precipitated asphaltenes (130) to aggregate the fine solids. For example, the asphaltene-bitumen extract mixture temperature may be lowered (i.e., the asphaltene-bitumen extract mixture temperature may be cooled) to increase the viscosity and capture ability of the precipitated asphaltenes (130) and/or to reduce the tendency of the precipitated asphaltenes to dissolve; the asphaltene-bitumen extract mixture temperature may be increased (i.e., the asphaltene-bitumen extract mixture may be heated) to reduce the tendency of the precipitated asphaltenes to dissolve based on their thermodynamic equilibrium. Additional aliphatic solvent, such as but not limited to pentane, may be added to the asphaltene-bitumen extract mixture to precipitate additional asphaltenes that may further help aggregate the fine solids. Solvent may be removed from the asphaltene-bitumen extract mixture to obtain a low grade bitumen product stream.

[0085] Prior to entering the dilution step (110), the oil sand slurry may be mixed with an aqueous bridging liquid to form an agglomerated slurry. Mixing the oil sand slurry with the aqueous bridging liquid may help to agglomerate the solids within the oil sand slurry and form an agglomerated slurry. The agglomerates within the agglomerated slurry may be sized on the order of 0.1-1.0 mm, on the order of 0.1-0.5 mm or on the order of 0.1-0.3 mm. At least 80 wt. % of the agglomerates within the agglomerated slurry may be 0.1-1.0 mm, on the order of 0.1-0.5 mm or 0.1 to 0.3 mm in size. The rate of agglomeration may be controlled by a balance between intensity of agitation within an agglomeration vessel, shear within the vessel which can be adjusted, for example, by changing the shape or size of the vessel, fines content of the slurry, bridging liquid addition, and residence time of the agglomeration process. The agglomerated slurry may have a solids content of 20 to 70 wt. %.

[0086] The aqueous bridging liquid may be a liquid with affinity for the solids particles in the bituminous feed. The aqueous bridging liquid may be a liquid that is immiscible in the first extraction liquor and/or the second extraction liquor. Exemplary aqueous bridging liquids may be water that accompany the bituminous feed and/or recycled water from other aspects or steps of oil sand processing. The aqueous bridging liquid need not be pure water, and may indeed be water containing one or more salts, a waste product from conventional aqueous oil sand extraction processes which may include additives, aqueous solution with a range of pH, or any other acceptable aqueous solution capable of adhering to solid particles in such a way that permits fines to adhere to each other. An exemplary aqueous bridging liquid is water. The aqueous bridging liquid may be added to the slurry in a concentration of less than 20 wt. % of the slurry, less than 10 wt. % of the slurry, between 1 wt. % and 20 wt. %, or between 1 wt. % and 10 wt. %. The aqueous bridging liquid may comprise fine particles (for instance less than 44 micrometer (μm)) suspended within the aqueous bridging liquid. The fine particles suspended may serve as seed particles for the agglomeration process. The aqueous bridging liquid may comprise less than 40 wt.% solid fines, or have a solids content of 20 to 70 wt. %.

[0087] The agglomeration process may be assisted by some form of agitation. The form of agitation may be mixing, shaking, rolling, or another known suitable method. The agitation of the bituminous feed (102) need only be severe enough and of sufficient duration to intimately contact the aqueous bridging liquid with the solids in the bituminous feed. Exemplary rolling type vessels include rod mills and tumblers. Exemplary mixing type vessels include mixing tanks, blenders, and attrition scrubbers. In the case of mixing type vessels, a sufficient amount of agitation is needed to keep the formed agglomerates in suspension. In rolling type vessels, the solids content of the bituminous feed may be greater than 40 wt. % so that compaction forces assist agglomerate formation. The agitation of the oil sand slurry has an impact on the growth of the agglomerates. In the case of mixing type vessels, the mixing power can be increased in order to limit the growth of agglomerates by attrition of said agglomerates. In the case of rolling type vessels the fill volume and rotation rate of the vessel can be adjusted in order to increase the compaction forces used in the communition of agglomerates.

[0088] Figure 2 is a flow chart of a method for processing a bituminous feed. The method shown in Figure 2 may de-asphalt a diluted bitumen product stream.

[0089] The method may comprise forming an oil sand slurry (208) by contacting a bituminous feed (202) with a first extraction liquor (204) in a bitumen extraction step (206), (502). The oil sand slurry (208) may comprise a bitumen extract and solids. The first extraction liquor (204) may be comprised of the same components as the first extraction liquor (104) previously described. A second solvent (242) may be added in the bitumen extraction step (206). The second solvent (242) may contact the bituminous feed (202) to help form the oil sand slurry (208).

[0090] The method may comprise diluting the oil sand slurry (208) prior to separating the solids in the oil sand slurry (208) from the bitumen extract in the oil sand slurry (208). The oil sand slurry (208) may be diluted in a dilution step (210) to form a diluted oil sand slurry (247). The oil sand slurry (208) may be diluted by a second extraction liquor (207). The oil sand slurry (208) may be diluted by a third solvent (244). The first extraction liquor (204) may have a bitumen content that is the same or more than that of the second extraction liquor (207) as described above with reference to Figure 1.

[0091] The method may comprise forming a rich bitumen extract stream (218) and separated solids (216) by separating the solids from the bitumen extract (504) in a separation step (214) as described above with reference to Figure 1.

[0092] The method may comprise forming a washed solids stream (224) and a lean bitumen extract stream (226) by washing the separated solids (216) with an aliphatic solvent (222), (508). The separated solids (216) may be washed with the aliphatic solvent (222) in a washer unit (220). The aliphatic solvent (222) may be used to precipitate asphaltenes which are removed from the washer unit (220) as part of the lean bitumen extract stream (226) as described above with reference to Figure 1. The lean bitumen extract stream (226) may comprise precipitated asphaltenes.

[0093] The method may comprise forming a diluted bitumen extract stream (not shown) by combining a portion of the rich bitumen extract stream (219) with a portion of the lean bitumen extract stream (226) in a deasphalting unit (228). The method may comprise forming the portion of the rich bitumen extract stream (219) that contacts the portion of the lean bitumen extract stream (226) to form the deasphalted bitumen extract stream in a liquid splitter (240). The rich bitumen extract stream (218) may be fed to the liquid splitter (240). Once in the liquid splitter (240), the rich bitumen extract stream (218) may be split into the portion of the rich bitumen extract stream (219), which contacts the portion of the lean bitumen extract stream (226) to form the deasphalted bitumen extract stream, and a second portion of the rich bitumen extract stream (204). The second portion of the rich bitumen extract stream (204) may be used as the first extraction liquor (204). The portion of the lean bitumen extract stream (226) may be mixed with the portion of the rich bitumen extract stream (219) to help remove residual fine solids from the portion of the rich bitumen extract stream (219). The portion of the rich bitumen extract stream (219) may be referred to as a first portion of the rich bitumen extract stream. The second portion of the rich bitumen extract stream (204) may be referred to as a portion of the rich bitumen extract stream.

[0094] The method may comprise forming a deasphalted bitumen extract stream (231) by separating precipitated asphaltenes (230) from the diluted bitumen extract stream in the deasphalting unit (228).

[0095] The method may comprise obtaining a bitumen product stream (238) by removing solvent (236) from the deasphalted bitumen extract stream (231). The solvent (236) may be removed from the deasphalted bitumen extract stream (231) in a solvent recovery unit

(234). The bitumen product stream (238) may have a solids content of less than 1 wt. %, or less than 0.1 wt. %. Solvent (236) can be removed from the deasphalted bitumen extract stream (231) to produce a bitumen product stream (238) with a solids content low enough to be for downstream refining operations.

[0096] The deasphalting of the diluted bitumen extract stream, of the process depicted in Figure 2, has the advantage of controlling the location within the solvent extraction process where asphaltenes are precipitated. A majority of the solids that remain suspended in the rich bitumen extract stream are oleophilic solids with organic matter adsorbed on the solids. The solids suspended in the rich bitumen extract stream may remain suspended because of strong interactions with certain components of dissolved bitumen. When an aliphatic solvent, such as but not limited to pentane, is mixed with the rich bitumen extract stream, the solids suspended tend to aggregate into larger particles that can be readily separated from the bitumen extract stream within the rich bitumen extract stream. The solids suspended may aggregate with precipitated asphaltenes to form even larger aggregates. The larger aggregates may be readily separated from the lean bitumen extract stream in a separator (214).

[0097] A portion of the lean bitumen extract stream may not be mixed with the rich bitumen extract stream. This portion of the lean bitumen extract stream may be deasphalted in a fashion similar to what is described in the process of Figure 1 to produce a deasphalted lean bitumen extract stream, which can be used as part of the second extraction liquor (207) and/or as part of the first extraction liquor (204).

[0098] Figure 3 is a flow chart of a method for processing a bituminous feed. The method may de-asphalt an extraction liquor and a diluted bitumen product stream.

[0099] The method may comprise forming an oil sands slurry (308) by contacting a bituminous feed (302) with a first extraction liquor (304) comprising a first solvent in a bitumen extraction step (306), (602). The oil sands slurry (308) may comprise a bitumen extract and solids. The first extraction liquor (304) may be comprised of the same components of the first extraction liquor (104) previously described. A second solvent (342) may be added in the bitumen extraction step (306). The second solvent (342) may contact the bituminous feed (302) to help form the oil sand slurry (308).

[00100] The method may comprise diluting the oil sands slurry (308) prior to separating the solids in the oil sands slurry (308) from the bitumen extract in the oil sands slurry (308). The oil sands slurry (308) may be diluted in a dilution step (310) to form a diluted oil sand slurry (347). The oil sands slurry (308) may be diluted by a second extraction liquor (305). The oil sands slurry (308) may be diluted by a third solvent (344).

[00101] The method may comprise forming a rich bitumen extract stream (318) and separated solids (316) by separating the bitumen extract from the solids in a separation step (314) as described above with reference to Figure 1, (604). The separated solids may be referred to as residual fine solids.

[00102] The method may comprise forming a washed solids stream (324) and a lean bitumen extract stream (326) by washing the separated solids (316) with an aliphatic solvent (322). The separated solids (316) may be washed with the aliphatic solvent (322) in a washer unit (320). The aliphatic solvent (322) may be used to precipitate asphaltenes, which are removed from the washer unit (320) as part of the lean bitumen extract stream (326) as described above with reference to Figure 1.

[00103] The method may comprise combining at least a portion of the rich bitumen extract stream (318) with at least a portion of the lean bitumen extract stream (326) in a deasphalting unit (328) to form a diluted bitumen extract stream (not shown). Additional aliphatic solvent may be added to the diluted bitumen extract stream to precipitate asphaltenes, forming a deasphalted bitumen extract stream (329) and separated asphaltenes (330). The deasphalted bitumen extract (329) may be separated by a splitter (327) into a deasphalted extraction liquor (332) and a diluted bitumen product stream (331). The deasphalted extraction liquor (332) can be used as the first extraction liquor (304) for adding to the bituminous feed (302) and/or as the second extraction liquor (305) for adding to the oil sand slurry (308).

[00104] The deasphalting unit (328) may separate the diluted bitumen extract stream with a separator. The separator (328) may separate the deasphalted bitumen extract stream into a deasphalted extraction liquor (332) and a diluted bitumen product stream (331).

[00105] The method may comprise obtaining a bitumen product stream (338) by removing a first solvent (336) from the diluted bitumen product stream (331). The solvent (336) may be removed from the diluted bitumen product stream (331) in a solvent recovery unit (334). The bitumen product stream (338) may have a solids content of less than 1 wt. %, or less than 0.1 wt. %. Solvent can be removed from the diluted bitumen product stream (331) to produce the bitumen product stream (338) with a substantially low solids content. The substantially low solids content may render the bitumen suitable for downstream refining operations.

[00106] The method may comprise obtaining a low grade bitumen product stream by removing the first solvent from the precipitated asphaltenes to obtain a low grade bitumen product stream. The precipitated asphaltenes may be mixed with the rich bitumen extract stream.

[00107] The deasphalting of the diluted bitumen extract stream, of the process depicted in Figure 3, has the advantage of controlling the location within the solvent extraction process where asphaltenes are precipitated. Precipitated asphaltenes and fine solids may be readily separated from the diluted bitumen extract stream in the separator (327). The deasphalted bitumen extract stream (329) can be separated into the deasphalted extraction liquor and the diluted bitumen product stream with both streams having favorable properties. The diluted bitumen product stream has the advantage that residual solid fines are removed during the deasphalting process and results in a low ash bitumen product. The deasphalted extraction liquor has the advantage of being an extraction liquor that may more readily dissolve bitumen from the bituminous feed due to the absence of asphaltene molecules that reduce the rate of bitumen dissolution. The use of a deasphalted extraction liquor can result in an increase in bitumen recovery from a bituminous feed. The deasphalted extraction liquor has the advantage of limiting fouling by asphaltene precipitation within the process equipment pipelines used to transfer the deasphalted extraction liquor to the bituminous feed. The lower solid content of the deasphalted extraction liquor may also reduce the chance of catastrophic plugging of process equipment, including pipelines, by settling solids. The deasphalted bitumen may have an asphaltene content of less than 15 wt.%, less than 10 wt.%, or less than

5 wt.%. The deasphalted bitumen may have an undissolved (precipitated) asphaltene content of less than 1 wt.%, less than 0.5 wt.%, or less than 0.2 wt.%. To achieve these undissolved (precipitated) asphaltene contents, the deasphalted bitumen may be subjected, for instance, to gravity separation.

[00108] Figure 4 is a flow chart of a method for processing a bituminous feed. The method may de-asphalt and solvent extract with solids agglomeration.

[00109] The method may comprise forming an oil sands slurry (408) by contacting a bituminous feed (402) with a first extraction liquor (404) comprising a first solvent in a bitumen extraction step (406). The oil sands slurry (408) may comprise a bitumen extract and solids. The first extraction liquor (404) may be comprised of the same components of the first extraction liquor (104) previously described. A second solvent (442) may be added in the bitumen extraction step (406). The second solvent (442) may contact the bituminous feed (402) to help form the oil sand slurry (408).

[00110] The method may comprise diluting the oil sands slurry (408) prior to separating the solids in the oil sands slurry (408) from the bitumen extract in the oil sands slurry (408). The oil sands slurry (408) may be diluted in a dilution step (410) to form a diluted oil sand slurry (447). The oil sands slurry (408) may be diluted by a second extraction liquor (407). The oil sands slurry (408) may be diluted by a third solvent (444).

[00111] An aqueous bridging liquid (445) may be added to the oil sand slurry (408) as part of an agglomeration step (446) to agglomerate the solids in the slurry and form an agglomerated slurry (448). As described above, the aqueous bridging liquid may wet the solids and displace the suspension liquid on the surface of the solids. The aqueous bridging liquid may be referred to as a bridging liquid. 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 may consolidate into larger, compact agglomerates that are more readily separated from the suspension liquid.

[00112] The method may comprise forming a rich bitumen extract stream (418) and separated solids (416) by separating the bitumen extract from the solids in a separation step

(414) as described with reference to Figure 1. The separated solids may be referred to as residual solids.

[00113] The method may comprise forming a washed agglomerated solids stream (424) and a lean bitumen extract stream (426) by washing the separated solids (416) with an aliphatic solvent (422) in a washer unit (420). The aliphatic solvent (422) may be used to precipitate asphaltenes removed from the washer unit (420) as part of the lean bitumen extract stream (426) as described above with reference to Figure 1.

[00114] The method may comprise forming a diluted bitumen extract stream by combining a portion (419) of the rich bitumen extract stream (418) with a portion of the lean bitumen extract stream (426) in a deasphalting unit (428). The method may comprise forming the portion of the rich bitumen extract stream (419) that contacts the portion of the lean bitumen extract stream (426) in a liquid splitter (440) such as the liquid splitter (240) previously described with respect to Figure 1. The liquid splitter (440) may function in the same way as the liquid splitter (240) previously described with respect to Figure 1 to split the rich bitumen extract stream (218) into the portion of the rich bitumen extract stream (419), which contacts the portion of the lean bitumen extract stream (426), and a second portion of the rich bitumen extract stream (404). The second portion of the rich bitumen extract stream (404) may be the same as the second portion of the rich bitumen extract stream (204) discussed with respect to Figure 1. The portion of the lean bitumen extract stream (426) may be mixed with the portion of the rich bitumen extract stream (418) to help remove residual fine solids from the portion of the rich bitumen extract stream (418). The portion of the rich bitumen extract stream (419) may be referred to as a first portion of the rich bitumen extract stream. The second portion of the rich bitumen extract stream (404) may be referred to as a portion of the rich bitumen extract stream.

[00115] The second portion of the rich bitumen extract stream (404) may not be mixed with the rich bitumen extract stream. The second portion of the rich bitumen extract stream (404) may be deasphalted, in a fashion similar to what is described with respect to Figure 1, to produce a deasphalted lean bitumen extract stream. The deasphalted lean bitumen extract stream may be used as part of the second extraction liquor (407).

[00116] The method may comprise separating the diluted bitumen extract stream, in a solid-liquid separation step, to form a low solids bitumen extract stream (431), settled solids and undissolved asphaltenes (430).

[00117] The method may comprise obtaining another bitumen product stream (438) by removing the first solvent (436) from the low solids bitumen extract stream (431). The solvent (436) may be removed from the low solids bitumen extract stream (431) in a solvent recovery unit (434). The another bitumen product stream (438) may have a solids content of less than 1 wt. %, or less than 0.1 wt. %. Solvent can be removed from the low solids bitumen extract stream (431) to produce the another bitumen product stream (438) with a substantially low solids content. The substantially low solids content may render the bitumen suitable for downstream refining operations.

[00118] Solvent extraction with solid agglomeration process is one suitable solvent extraction process for use with the processes described in the present disclosure. The portion of the rich bitumen extract stream may be recycled so that it is used as the first extraction liquor. Using a portion of the rich bitumen extract stream as the first extraction liquor ensures that the S:B of the initial bitumen extract obtained from dissolution of bitumen from the bituminous feed is less than the S:B of the bitumen extract. The lower S:B ratio has the advantage of increasing the amount of bitumen dissolution from the bituminous feed, which may increase overall bitumen recovery. However, the complete or near complete dissolution of the bitumen will result in fine solids dispersing into the bitumen extract which, if left dispersed, will hamper solid-liquid separation downstream of the solvent extraction process. Dispersion of the fine solids prior to solid agglomeration is acceptable because the solid agglomeration process will allow for the majority of the fine solids to be recaptured as agglomerates with the bridging liquid. The temperature, pressure, solvent composition, extraction liquor composition(s), and/or S:B of the bitumen extract may be configured to minimize the presence of undissolved asphaltenes. The temperature, pressure, solvent composition, extraction liquor composition(s), and/or S:B of the bitumen extract may be configured to minimize the presence of undissolved asphaltenes by keeping a value of the temperature, pressure, solvent composition, extraction liquor composition(s), and/or S:B of the bitumen extract at a value that minimizes the presence of undissolved asphaltenes.

[00119] The residual solids that remain in the rich bitumen extract stream may be removed by mixing a portion of the rich bitumen extract stream with some or all of the lean bitumen extract stream. The increased S:B ratio of the diluted bitumen extract stream may cause the residual solids to aggregate with or without accompanying asphaltene precipitation. The aggregated fine solids may readily be separated from the diluted bitumen extract stream in a separator (428). The solvent can be removed from the diluted bitumen extract stream to produce a bitumen product stream with a solid content of less than 0.1 wt.%. The underflow stream from the separation process may be recycled upstream of the separation process in order to recover residual bitumen extract from the solid agglomerates. For example, the underflow comprised of undissolved asphaltenes may be recycled and mixed with the rich bitumen extract stream to assist with the aggregation of the fine solids. In cases when precipitated asphaltenes are aggregated with the fine solids, the solvent can be recovered from the underflow extract stream to produce a low grade bitumen product with commercial value.

[00120] Figures 6 and 8 are a flow charts of a method for processing a bituminous feed.

[00121] The method may comprise forming an oil sand slurry (808) by contacting a bituminous feed (802) with a first extraction liquor (804), in a bitumen extraction step (806), (602), as described above with reference to Figure 1. The oil sand slurry (808) may comprise a bitumen extract and solids, as described above with reference to Figure 1. The first extraction liquor (804) may comprise a first solvent, as described above with reference to Figure 1.

[00122] The method may comprise forming a rich bitumen extract stream (818) and separated solids (816) by separating the solids from the bitumen extract, (604), as described above with reference to Figure 1. The method may comprise forming the rich bitumen extract stream (818) and the separated solids (816) in a solid-liquid separator (814), as described above with reference to Figure 1.

[00123] The method may comprise providing a hydrocarbon fluid (850) comprising undissolved asphaltenes (606). The hydrocarbon fluid (850) may be any suitable hydrocarbon fluid for increasing the solvent to bitumen ratio and to precipitate asphaltenes as described above with reference to Figure 1.

[00124] The method may comprise forming an asphaltene-bitumen extract mixture (852) by mixing the hydrocarbon fluid (850) with the rich bitumen extract stream (818), (608). The hydrocarbon fluid (850) may be mixed with the rich bitumen extract stream (818) in a mixer (851). The mixer (851) may be any suitable mixer to combine the two streams.

[00125] The method may comprise forming a low solids bitumen extract stream (854) by separating asphaltenes and residual fine solids (856) from the asphaltene-bitumen extract mixture (852), (610). The method may comprise forming the low solids bitumen extract stream (854) and the asphaltenes and residual fine solids (856) in a solid-liquid separator (853), as described above with reference to Figure 1.

[00126] The method may comprise obtaining a bitumen product stream (858) by removing the first solvent (860) from the low solids bitumen extract stream (854), (612), as described above with reference to Figure 1. The bitumen product stream (858) may be obtained by removing the first solvent (860) in a solvent recovery step (862).

[00127] Figures 7 and 9 are flow charts of a method for processing a bituminous feed.

[00128] The method may comprise providing an extraction liquor (904) comprising deasphalted bitumen and a first solvent, in a solvent extraction step (906), (702), as described above with reference to Figure 1.

[00129] The method may comprise forming an oil sand slurry (908) by contacting the bituminous feed (902) with the extraction liquor (904), (704), as described above with reference to Figure 1. The oil sand slurry (908) may comprise a bitumen extract and solids.

[00130] The method may comprise forming a rich bitumen extract stream (918) by separating the solids (916) from the bitumen extract (706), as described above with reference to Figure 1. The rich bitumen extract stream (918) may be separated from the solids (916) in a solid-liquid separator (914), as described above.

[00131] The method may comprise obtaining a bitumen product stream (962) by removing the first solvent (964) from a portion of the rich bitumen extract stream (918) (708), as described above (708) with reference to Figure 1. The bitumen product stream (962) may be obtained by removing the first solvent (964) in a solvent recovery step (968).

[00132] The deasphalted bitumen within the first extraction liquor may have several advantages. The deasphalted bitumen may be more readily able to dissolve bitumen from the bituminous feed. The deasphalted bitumen may be more readily able to dissolve bitumen from the bituminous feed due to a reduced amount of asphaltene content. The reduced amount of asphaltene content can reduce a rate of bitumen dissolution. Therefore, the deasphalted bitumen may increase bitumen dissolution in the first extraction liquor. Therefore, the deasphalted bitumen may result in an increase in bitumen recovery from a bituminous feed. The deasphalted bitumen may have the advantage of limiting fouling by asphaltene precipitation. The deasphalted bitumen may limit fouling by asphaltene precipitiation within the process equipment pipelines used to transfer the deasphalted bitumen to the bituminous feed because of the lower asphaltene content of the deasphalted bitumen. The deasphalted bitumen may reduce the chance of catastrophic plugging of process equipment, including pipelines, by settling solids. The lower solid content of the deasphalted bitumen may allow for this reduction. The deasphalted bitumen may allow for the removal of residual solid fines during deasphalting to produce reduced ash and increased API bitumen product, as compared to a bitumen extract stream that has not been deasphalted, when solvent is removed from the deasphalted bitumen. The deasphalted bitumen may have an asphaltene content of less than 15 wt.%, less than 10 wt.%, or less than 5 wt.%. The deasphalted bitumen may have an undissolved (precipitated) asphaltene content of less than 1 wt.%, less than 0.5 wt.%, or less than 0.2 wt.%. To achieve these undissolved (precipitated) asphaltene contents, the deasphalted bitumen may be subjected, for example but not limited to, to gravity separation.

[00133] Examples

[00134] A bituminous feed of oil sand (10.3 wt.% bitumen, 3.5 wt.% water, 27.8 wt.% fines) was mixed with a pentane-bitumen extraction liquor (first extraction liquor) at 1500

rpm for 15 minutes at room temperature in a mixing vessel (bitumen extraction step) to form an oil sand slurry. The oil sand slurry was 50 wt.% solids and at a solvent-to-bitumen ratio of 0.8. After 15 minutes of mixing, water was added as a bridging liquid and adjusted to achieve a final water-to-solids ratio of 0.08. The oil sand slurry was mixed at 1500 rpm for 2 minutes to achieve microagglomerates via spherical agglomeration. The agglomerated slurry was filtered (solid-liquid separation step), followed by washing of the separated solids with pentane (aliphatic solvent) using a wash ratio of 0.7 mL of solvent/g of solids. Two tests were performed according to the above procedure.

[00135] Test 1: The bitumen of the pentane-bitumen extraction liquor (first extraction liquor) was a non-deasphalted bitumen comprising approximately 18 wt.% asphaltenes.

[00136] Test 2: The bitumen of the pentane-bitumen extraction liquor (first extraction liquor) was a partially deasphalted bitumen comprising approximately 9 wt. % asphaltenes.

[00137] Bitumen recovery was determined by the Dean-Stark method. In the Dean-Stark method, a weighed sample is separated into bitumen, water, and solids by refluxing toluene. Condensed toluene and co-distilled water an continuously separated in a trap designed to recycle the solvent through an extraction thimble, dissolving the bitumen present in the sample, while the water is retained in the trap. Once the three components have been physically separated, they can be determined by various means. Test 1, using a partially deasphalted bitumen (first extraction liquor), had a total bitumen recovery of 85%. Test 2, using a deasphalted bitumen (first extraction liquor), had a total bitumen recovery of 90%. This result strongly suggests that a deasphalted bitumen has the advantage of producing an extraction liquor that more readily extracts bitumen from the bituminous feed.

[00138] 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 for processing a bituminous feed, the method comprising:
   a) forming an oil sand slurry, comprising a bitumen extract and solids, by contacting the bituminous feed with a first extraction liquor, comprising a first solvent;
   b) forming a rich bitumen extract stream and separated solids by separating the solids from the bitumen extract;
   c) forming a washed solids stream and a lean bitumen extract stream, comprising precipitated asphaltenes, by washing the separated solids with an aliphatic solvent;
   d) forming a deasphalted lean bitumen extract stream by separating the precipitated asphaltenes from the lean bitumen extract stream; and
   e) obtaining a bitumen product stream by removing the first solvent from at least one of a first portion of the rich bitumen extract stream and a first portion of the deasphalted lean bitumen extract stream.

2. The method of claim 1, further comprising diluting the oil sand slurry with a second extraction liquor prior to separating the solids from the bitumen extract.

3. The method of claim 2, further comprising recycling a second portion of the deasphalted lean bitumen extract stream as recycled deasphalted lean bitumen extract stream, wherein the recycled deasphalted lean bitumen extract stream is the first extraction liquor or the second extraction liquor.

4. The method of claim 3, further comprising mixing an additional solvent with the recycled deasphalted lean bitumen extract stream.

5. The method of any one of claims 1-4, wherein (a) further comprises contacting the bituminous feed with a second solvent to form the oil sand slurry.

6. The method of any one of claims 1-5, further comprising adding a third solvent to the oil sand slurry.

7. The method of any one of claims 1-6, wherein (e) comprises removing the first solvent from the first portion of the rich bitumen extract stream.

8. The method of any one of claims 1-7, wherein separating the precipitated asphaltenes from the lean bitumen extract stream occurs in a gravity settler or an enhanced gravity settler.

9. The method of any one of claims 1-8, further comprising forming an asphaltene-bitumen extract mixture by mixing the precipitated asphaltenes with the first portion of the rich bitumen extract stream.

10. The method of claim 8, further comprising mixing additional aliphatic solvent with the asphaltene-bitumen extract mixture.

11. The methods of any one of claims 1-10, further comprising cooling or heating the asphaltene-bitumen extract mixture.

12. The method of any one of claims 1-11, further comprising obtaining a low grade bitumen product stream by removing the first solvent from the precipitated asphaltenes separated from the lean bitumen extract stream.

13. The method of any one of claims 1-12, further comprising recycling a second portion of the rich bitumen extract stream as recycled rich bitumen extract stream, wherein the recycled rich bitumen extract stream is the first extraction liquor.

14. The method of claim 13, further comprising mixing additional solvent with the recycled rich bitumen extract stream.

15. The method claim 1, further comprising forming a diluted bitumen extract stream by combining the first portion of the rich bitumen extract stream with the first portion of the deasphalted lean bitumen extract stream.

16. The method of claim 15, further comprising forming a low solids bitumen extract stream by separating settled solids and undissolved asphaltenes from the diluted bitumen extract stream.

17. The method of claim 16, further comprising obtaining another bitumen product stream by removing the first solvent from the low solids bitumen extract stream.

18. The method of claim 17, wherein the another bitumen product stream has a solids content of less than 1 wt. %.

19. The method of claim 17, wherein the another bitumen product stream has a solids content of less than 0.1 wt. %.

20. The method of any one of claims 1-19, further comprising adding additional aliphatic solvent to the diluted bitumen extract stream.

21. The method of any one of claims 1-20, further comprising forming the deasphalted lean bitumen extract stream by separating the precipitated asphaltenes from the diluted bitumen extract stream.

22. The method of any one of claims 15-21, further comprising separating the deasphalted bitumen extract stream into a deasphalted extraction liquor and a diluted bitumen product stream.

23. The method of any one of claims 15-22, further comprising obtaining the bitumen product stream by removing the first solvent from the at least one of the first portion of the rich bitumen extract stream and the first portion of the deasphalted lean bitumen extract stream by removing the first solvent from the diluted bitumen product stream.

24. The method of claim 21, further comprising obtaining a low grade bitumen product stream by removing the first solvent from the precipitated asphaltenes.

25. The method of claim 21, further comprising mixing the precipitated asphaltenes with the rich bitumen extract stream.

26. The method of any one of claims 23-25, wherein the bitumen product stream has a solid content of less than 1 wt. %.

27. The method of any one of claims 23-25, wherein the bitumen product stream has a solid content of less than 0.1 wt. %.

28. The method of any one of claims 22-27, wherein the deasphalted extraction liquor is the first extraction liquor.

29. The method of any one of claims 22-27, further comprising diluting the oil sand slurry with a second extraction liquor prior to separating the solids from the bitumen extract, wherein the deasphalted extraction liquor is the second extraction liquor.

30. The method of any one of claims 1-29, further comprising agglomerating the solids in the oil sand slurry and forming an agglomerated slurry by adding a bridging liquid to the oil sand slurry.

31. The method of any one of claims 1-30, wherein the first extraction liquor has a bitumen content between 0 and 70 wt. %.

32. The method of any one of claims 2-4, wherein the second extraction liquor has a bitumen content between 0 and 70 wt. %.

33. The method of any one of claims 1-32, wherein the first extraction liquor has a bitumen content between 30 and 70 wt. %.

34. The method of any one of claims 1-33, wherein the first solvent comprises an organic solvent or a mixture of organic solvents.

35. The method of any one of claims 1-34, wherein the first solvent comprises light aromatic compounds.

36. The method of any one of claims 1-35, wherein the first solvent comprises at least one of an open chain aliphatic hydrocarbon and a cyclic aliphatic hydrocarbon.

37. The method of any one of claims 1-36, wherein the aliphatic solvent comprises a paraffinic solvent.

38. The method of claim 37, wherein the paraffinic solvent comprises at least one of an alkane, a natural gas condensate, and a distillate from a fractionation unit containing more than 40% small chain paraffins of 3 to 10 carbon atom.

39. The method of claim 38, wherein the alkane comprises at least one of a normal alkane and an iso-alkane.

40. The method of claim 38, wherein the alkane comprises at least one of heptane, iso-heptane, hexane, iso-hexane, pentane, and iso-pentane.

41. The method of claim 36, wherein the cyclic aliphatic hydrocarbon comprises a cycloalkane of 4 to 9 carbon atoms.

42. The method of claim 41, wherein the cycloalkane comprises at least one of cyclohexane and cyclopentane.

43. The method of any one of claims 1-42, wherein a ratio of the first solvent to the bitumen is configured to minimize a presence of undissolved asphaltenes in the oil sand slurry.

44. The method of any one of claims 2-4, wherein a composition of the first extraction liquor or the second extraction liquor is configured to minimize a presence of undissolved asphaltenes in the oil sand slurry.

45. The method of any one of claims 1-44, wherein a temperature of the oil sand slurry is at a value configured to minimize a presence of undissolved asphaltenes in the oil sand slurry.

46. The method of any one of claims 1-45, wherein a pressure of the oil sand slurry is at a value configured to minimize a presence of undissolved asphaltenes in the slurry.

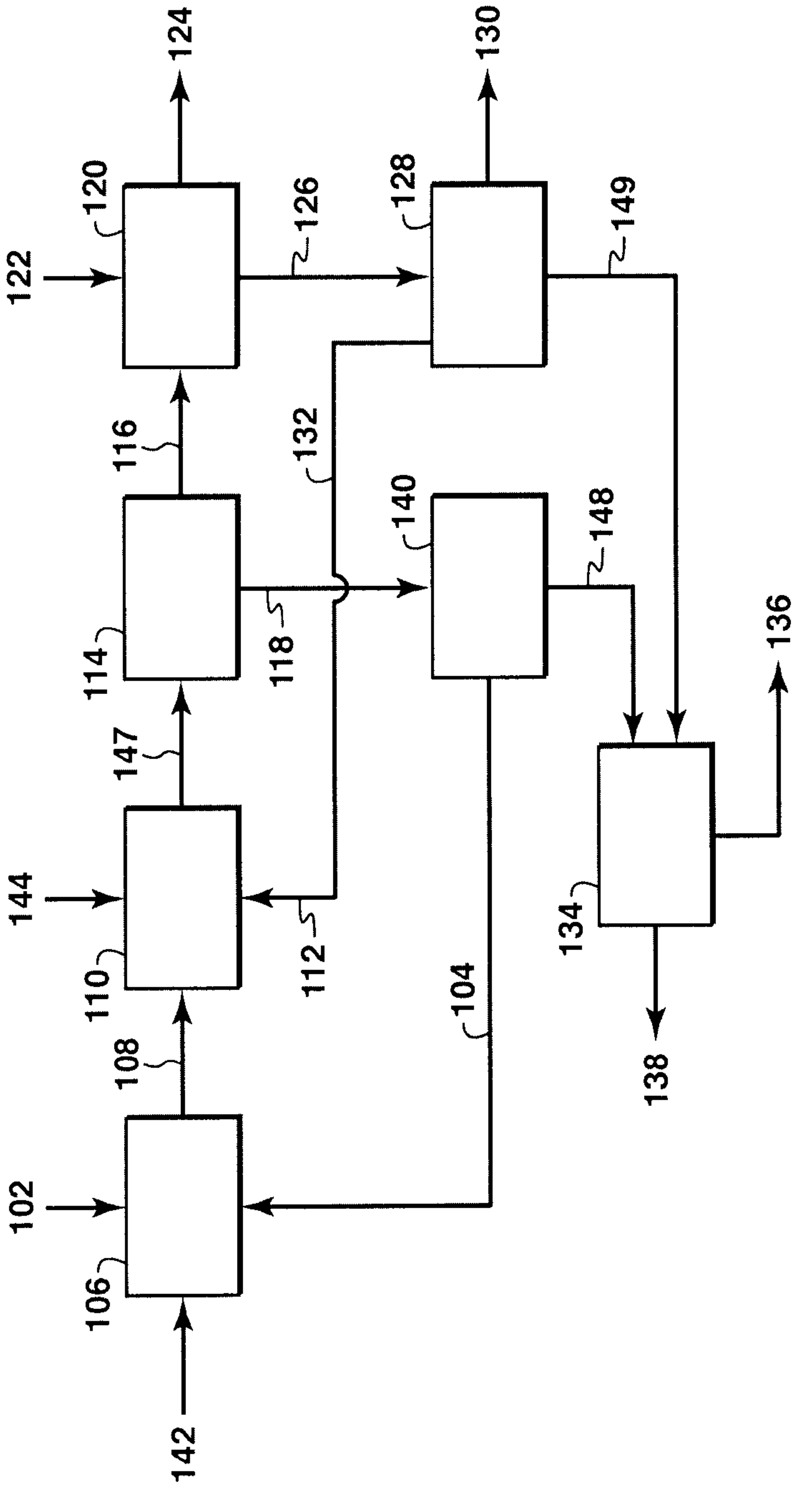
124
130
120
122
126
128
149
116
132
140
148
114
118
136
147
144
110
112
134
104
108
102
106
138
142

FIG. 1

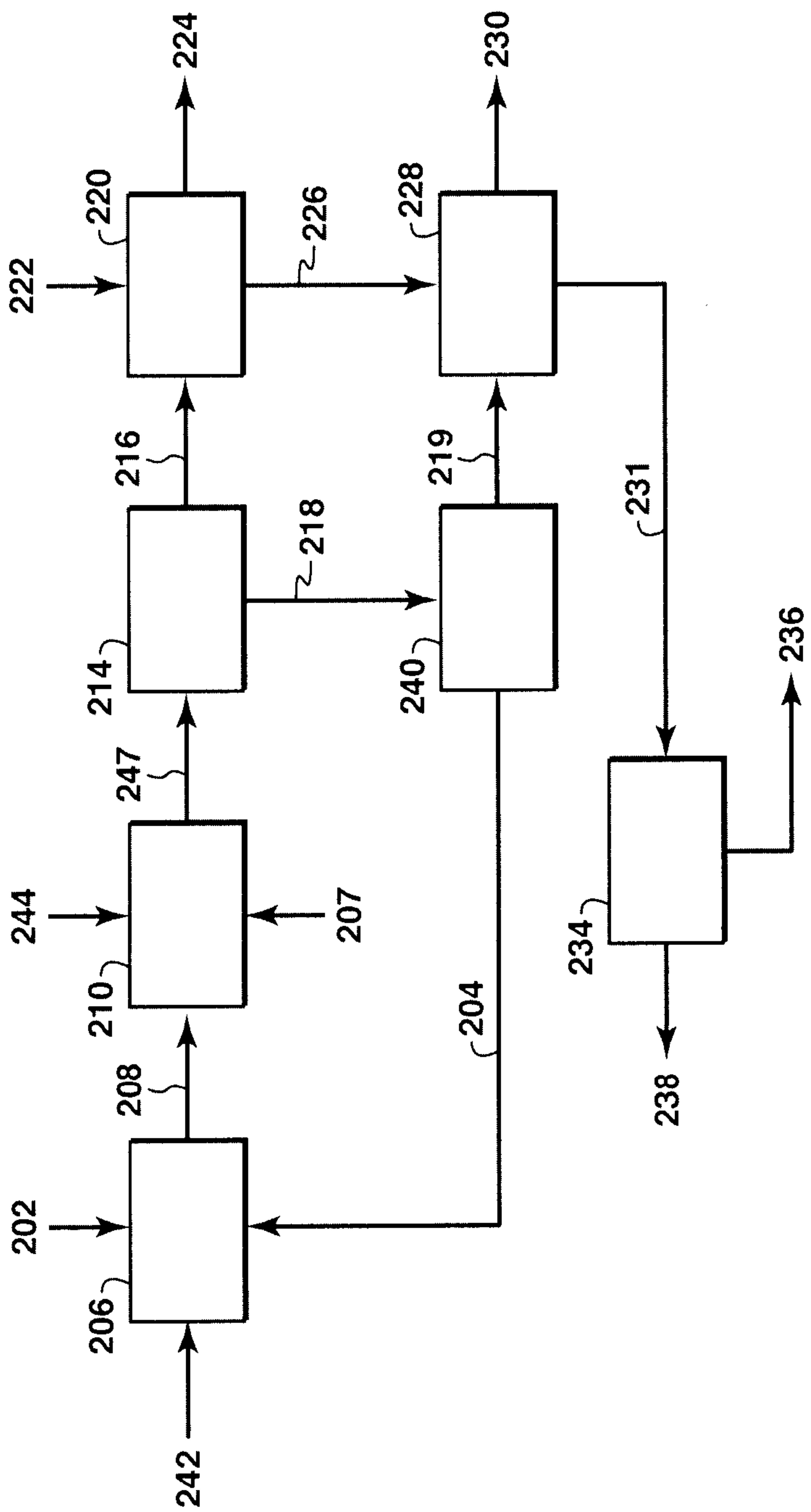
242
206
202
208
210
244
207
247
214
216
218
220
222
224
226
228
230
219
240
204
231
234
236
238

FIG. 2

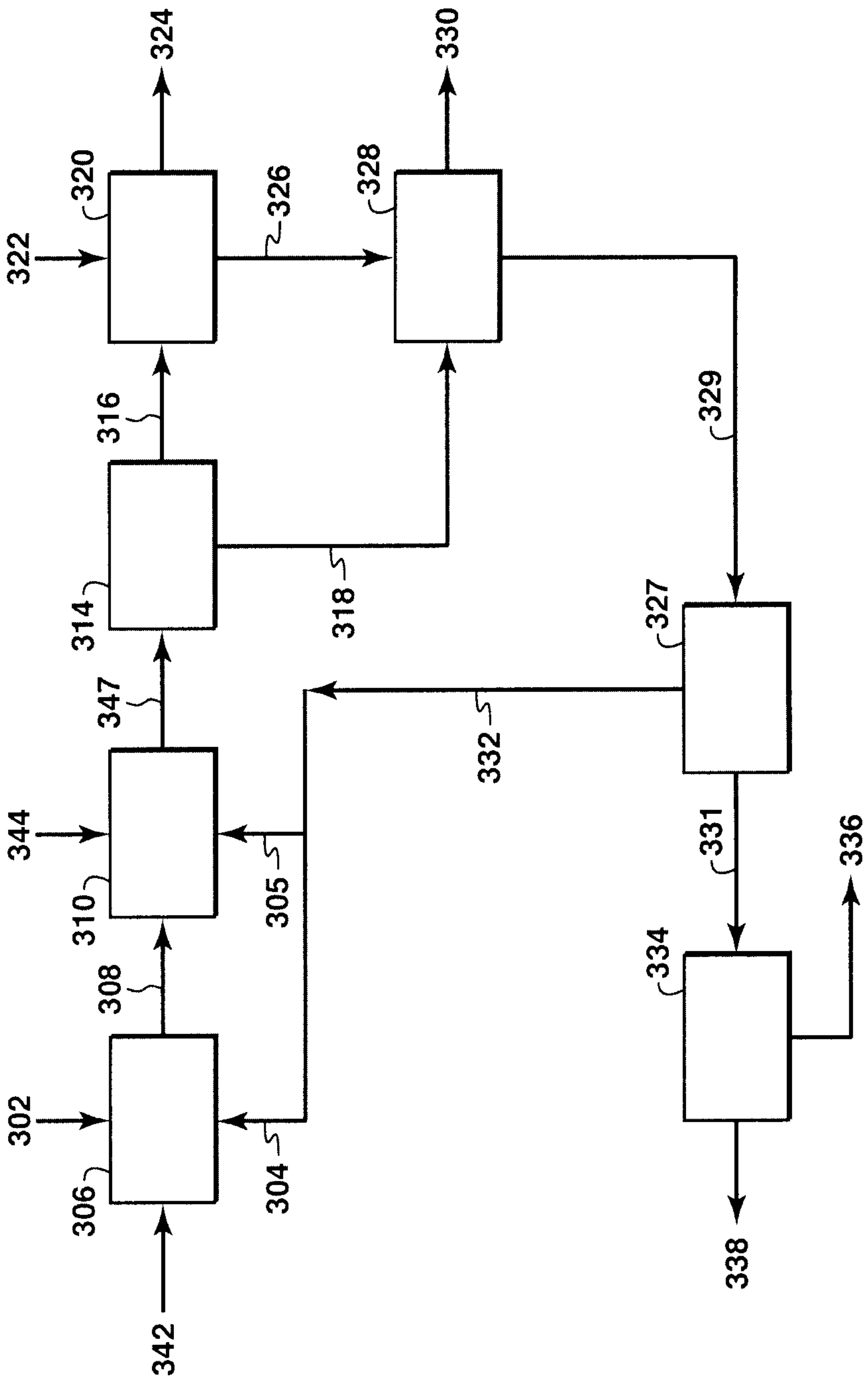
324
330
320
322
326
328
316
329
314
318
327
347
332
344
310
305
331
336
308
334
302
306
304
342
338

FIG. 3

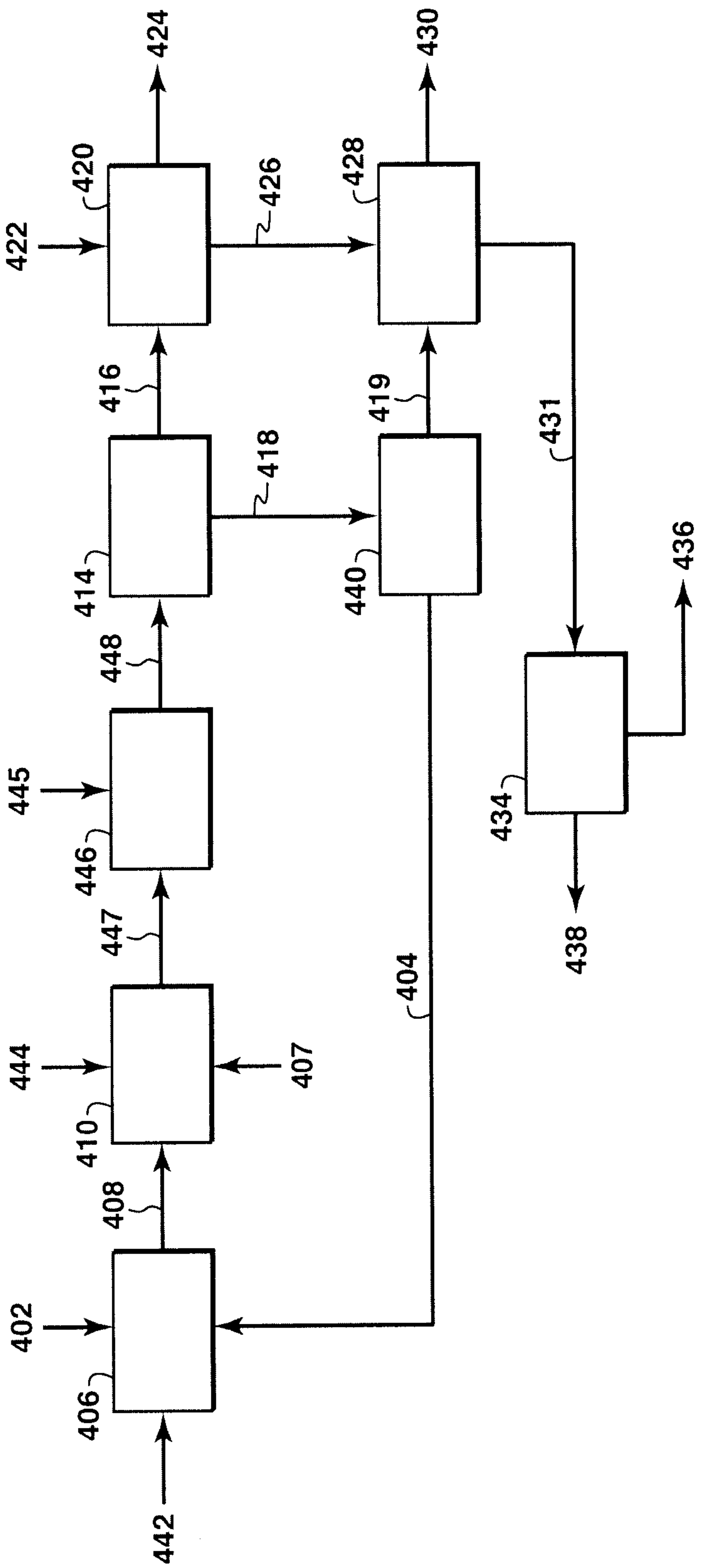
424
430
420
426
428
422
416
418
419
431
414
440
436
448
445
446
434
438
447
404
444
407
410
408
402
406
442

FIG. 4

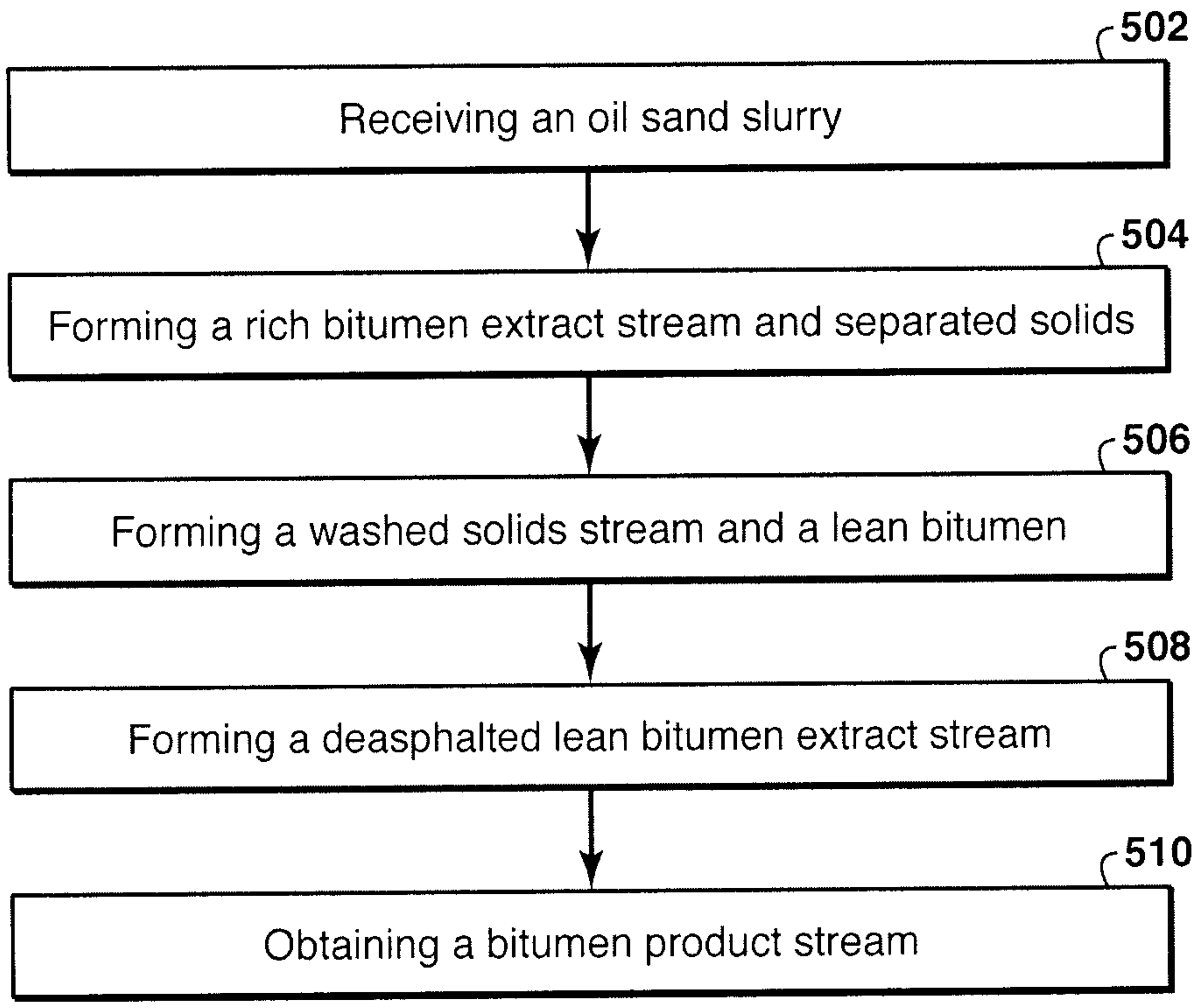
502
Receiving an oil sand slurry
504
Forming a rich bitumen extract stream and separated solids
506
Forming a washed solids stream and a lean bitumen
508
Forming a deasphalted lean bitumen extract stream
510
Obtaining a bitumen product stream

FIG. 5

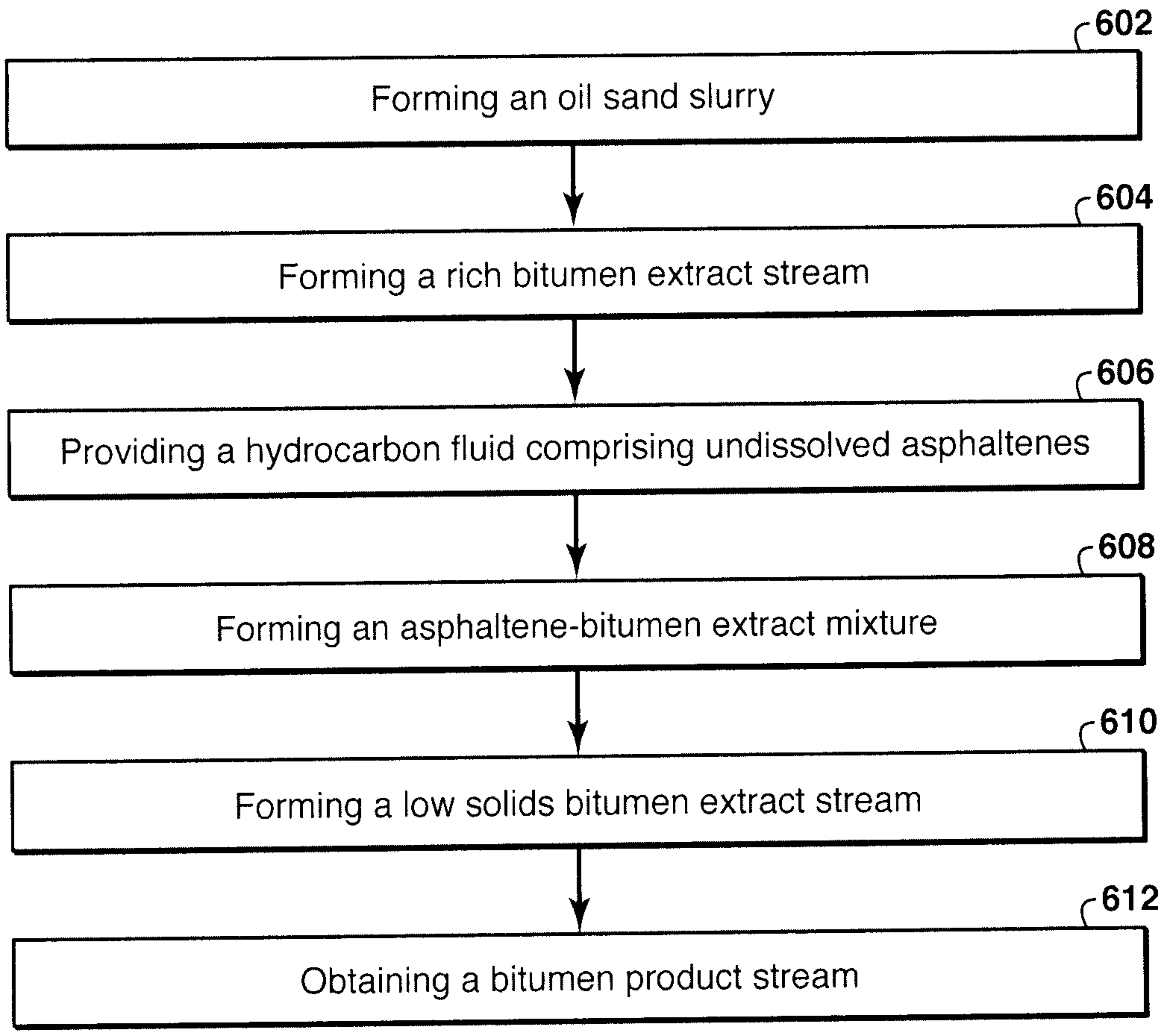
602
Forming an oil sand slurry
604
Forming a rich bitumen extract stream
606
Providing a hydrocarbon fluid comprising undissolved asphaltenes
608
Forming an asphaltene-bitumen extract mixture
610
Forming a low solids bitumen extract stream
612
Obtaining a bitumen product stream

FIG. 6

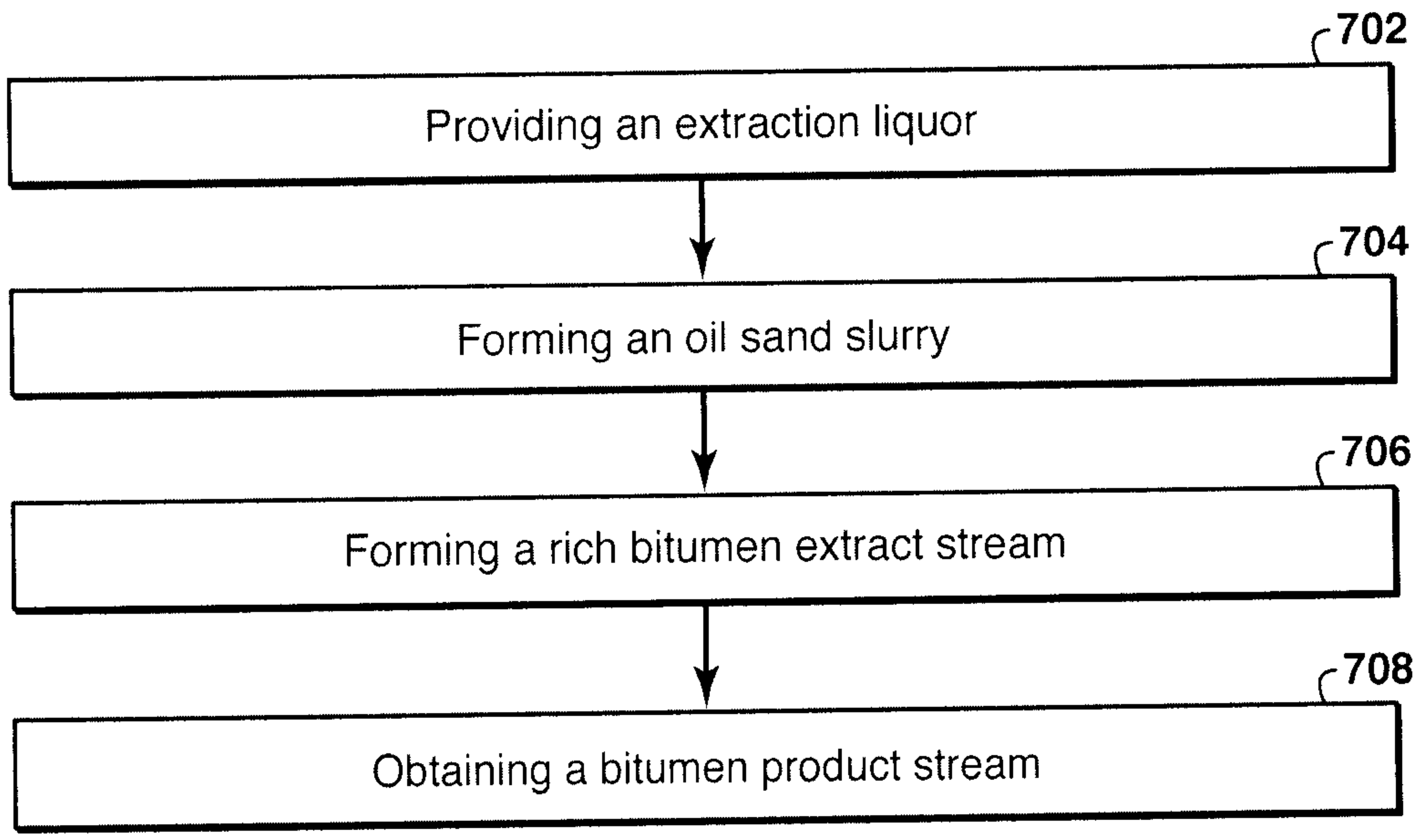
702
Providing an extraction liquor
704
Forming an oil sand slurry
706
Forming a rich bitumen extract stream
708
Obtaining a bitumen product stream

FIG. 7

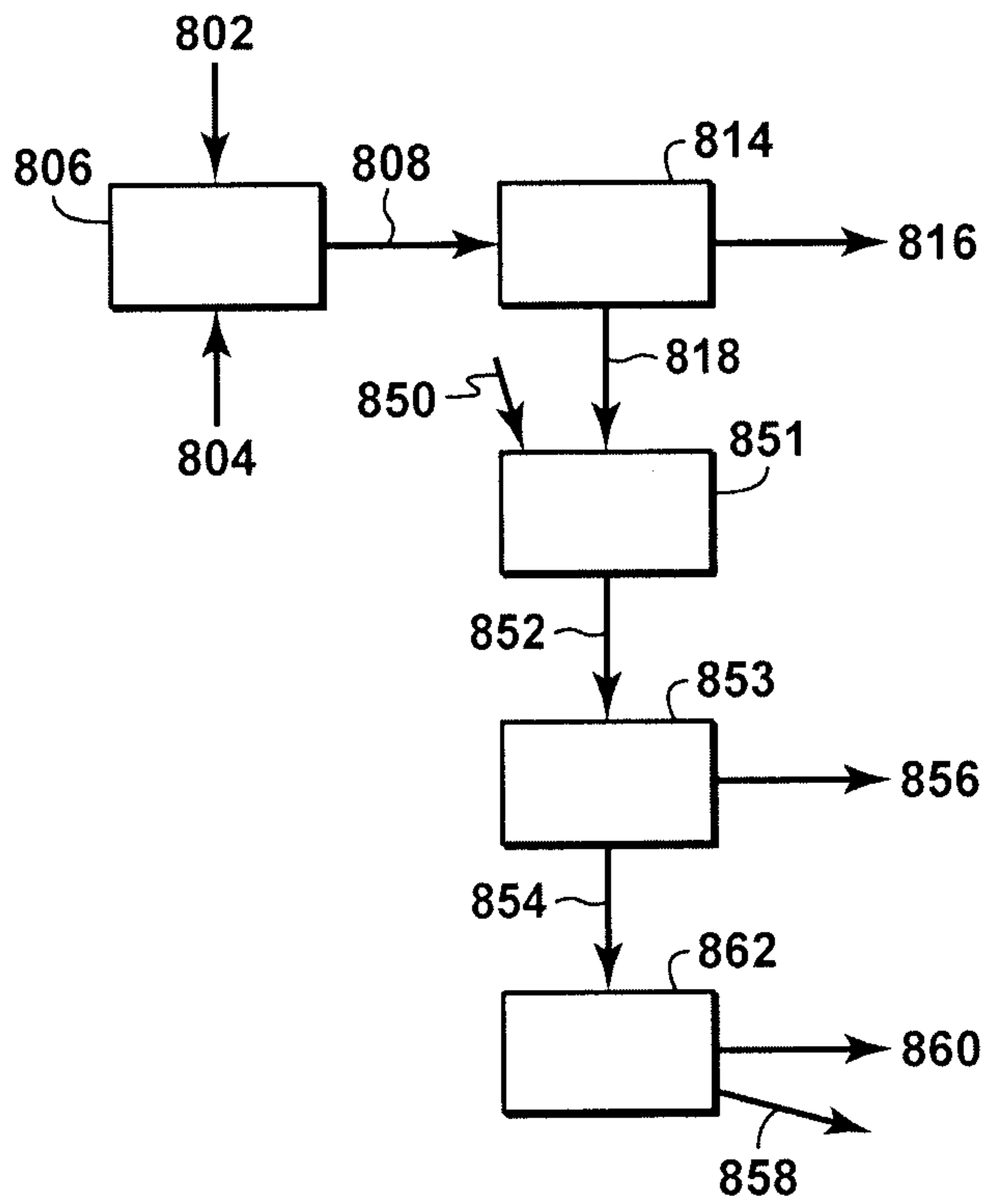
802
806
808
814
816
818
850
851
804
852
853
856
854
862
860
858

FIG. 8

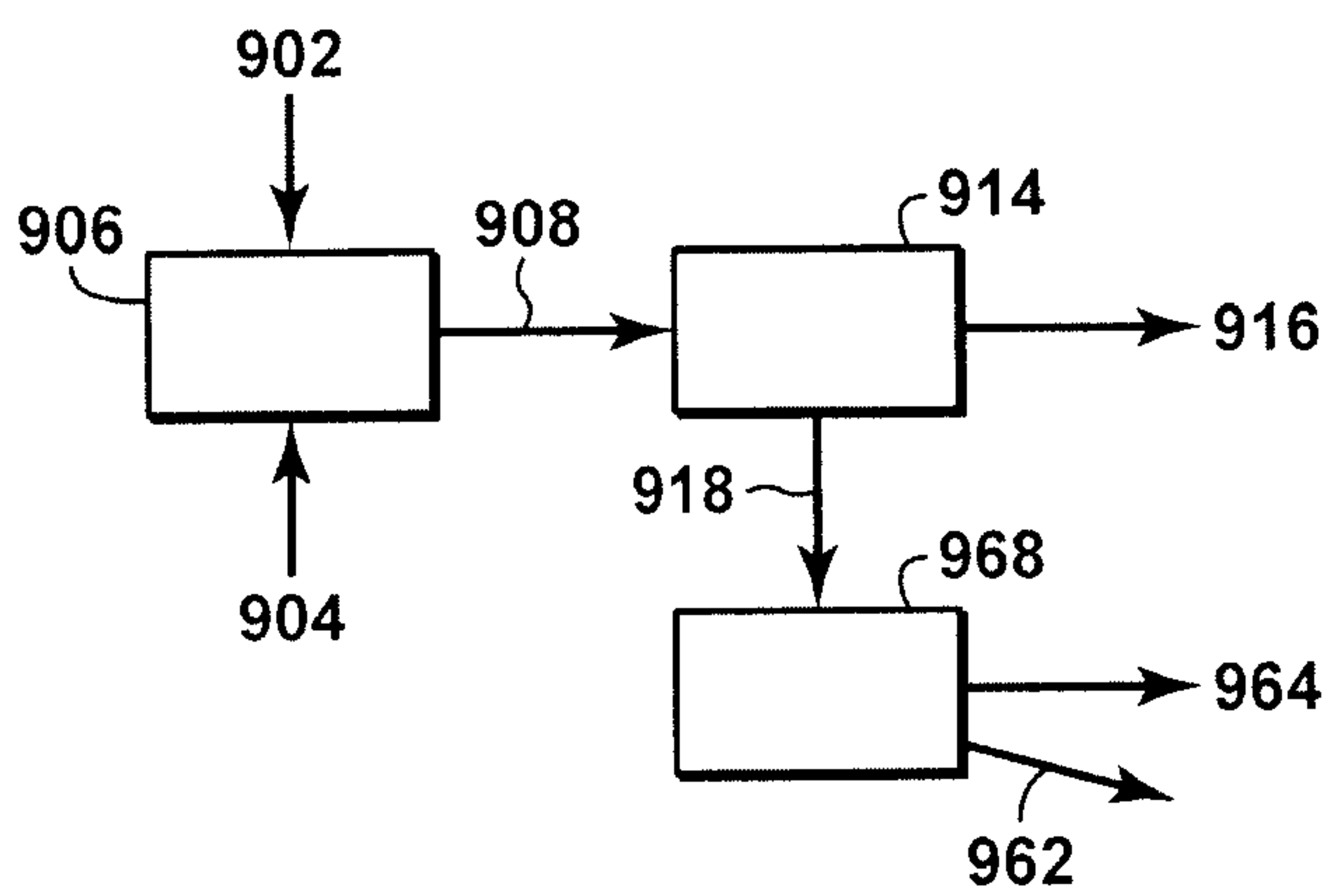
902
906
908
914
916
918
968
904
964
962

FIG. 9