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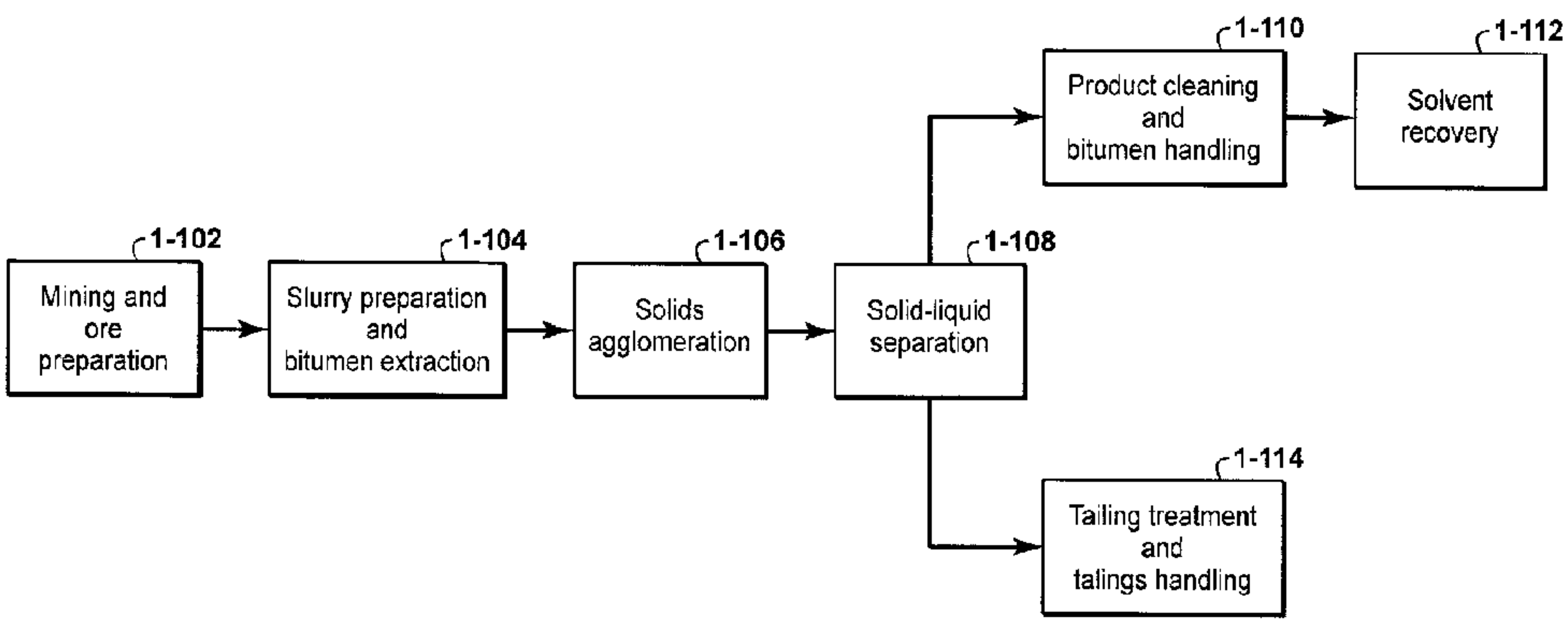

(57) Abrégé/Abstract:
Described is a solvent bitumen extraction with solids agglomeration method, the method comprising:
(a) inerting a bituminous feed to produce an inerted bituminous feed;
(b) adding a first solvent to the inerted bituminous feed and sizing the inerted bituminous feed to produce a sized bituminous feed;
(c) contacting the sized bituminous feed with a first high velocity fluid;
(d) dissolving the sized bituminous feed in the first high velocity fluid to produce a dissolved bituminous slurry;
(e) contacting the dissolved bituminous slurry with a second high velocity fluid to produce an agglomerated slurry; and
(f) filtering, washing with a second solvent and desolventizing the agglomerated slurry.

ABSTRACT

Described is a solvent bitumen extraction with solids agglomeration method, the method comprising:

(a) inerting a bituminous feed to produce an inerted bituminous feed;

(b) adding a first solvent to the inerted bituminous feed and sizing the inerted bituminous feed to produce a sized bituminous feed;

(c) contacting the sized bituminous feed with a first high velocity fluid;

(d) dissolving the sized bituminous feed in the first high velocity fluid to produce a dissolved bituminous slurry;

(e) contacting the dissolved bituminous slurry with a second high velocity fluid to produce an agglomerated slurry; and

(f) filtering, washing with a second solvent and desolventizing the agglomerated slurry.

DEMANDES OU BREVETS VOLUMINEUX

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CECI EST LE TOME __1___ DE __2 __

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JUMBO APPLICATIONS / PATENTS

THIS SECTION OF THE APPLICATION / PATENT CONTAINS MORE THAN ONE VOLUME.

THIS IS VOLUME __1___ OF __2___

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BITUMINOUS FEED PROCESSING

BACKGROUND

Field of Disclosure

[0001] The disclosure relates generally to the field of bituminous feed processing.

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 water, steam or solvents to extract the heavy oil.

[0005] Oil sand extraction processes are used to liberate and separate bitumen from oil sand so that the bitumen can be further processed to produce synthetic crude oil or mixed with diluent to form "dilbit" and be transported to a refinery plant. Numerous oil sand extraction processes have been developed and commercialized, many of which involve the use of water as a processing medium. Where the oil sand is treated with water, the technique may be referred to as water-based extraction (WBE). WBE is a commonly used process to extract bitumen from mined oil sand.

[0006] One WBE process is the Clark hot water extraction process (the "Clark Process"). This process typically requires that mined oil sand be conditioned for extraction by being crushed to a desired lump size and then combined with hot water and perhaps other agents to form a conditioned slurry of water and crushed oil sand. In the Clark Process, an amount of sodium hydroxide (caustic) may be added to the slurry to increase the slurry pH, which enhances the liberation and separation of bitumen from the oil sand. Other WBE processes may use other temperatures and may include other conditioning agents, which are added to the oil sand slurry, or may operate without conditioning agents. This slurry is first processed in a Primary Separation Cell (PSC), also known as a Primary Separation Vessel (PSV), to extract the bitumen from the slurry.

[0007] In one bitumen extraction process, a water and oil sand slurry is separated into three major streams in the PSC: bitumen froth, middlings, and a PSC underflow.

[0008] Regardless of the type of WBE process employed, the process will typically result in the production of a bitumen froth that requires treatment with a solvent. For example, in the Clark Process, a bitumen froth stream comprises bitumen, solids, and water. Certain processes use naphtha to dilute bitumen froth before separating the product bitumen by centrifugation. These processes are called naphtha froth treatment (NFT) processes. Other processes use a paraffinic solvent, and are called paraffinic froth treatment (PFT) processes, to produce pipelineable bitumen with low levels of solids and water. In the PFT process, a paraffinic solvent (for example, a mixture of iso-pentane and n-pentane) is used to dilute the froth before separating the product, diluted bitumen, by gravity. A portion of the asphaltenes in the bitumen is also rejected by design in the PFT process and this rejection is used to achieve reduced solids and water levels. In both the NFT and the PFT processes, the diluted tailings (comprising water, solids and some hydrocarbon) are separated from the diluted product bitumen.

[0009] Solvent is typically recovered from the diluted product bitumen component before the bitumen is delivered to a refining facility for further processing.

[0010] The PFT process may comprise at least three units: Froth Separation Unit (FSU), Solvent Recovery Unity (SRU) and Tailings SRU (TSRU). Mixing of the solvent with the feed bitumen froth may be carried out counter-currently in two stages in separate froth separation units. The bitumen froth comprises bitumen, water, and solids. A typical composition of bitumen froth is about 60 wt. % bitumen, 30 wt. % water, and 10 wt. % solids. The paraffinic solvent is used to dilute the froth before separating the product bitumen by gravity. The foregoing is only an example of a PFT process and the values are provided by way of example only. An example of a PFT process is described in Canadian Patent No. 2,587,166 to Sury.

[0011] From the PSC, the middlings, comprising bitumen and about 10-30 wt. % solids, or about 20-25 wt. % solids, based on the total wt. % of the middlings, is withdrawn and sent to the flotation cells to further recover bitumen. The middlings are processed by bubbling air through the slurry and creating a bitumen froth, which is recycled back to the PSC. Flotation tailings (FT) from the flotation cells, comprising mostly solids and water, are sent for further treatment or disposed in an external tailings area (ETA).

[0012] In ETA tailings ponds, a liquid suspension of oil sand fines in water with a solids content greater than 2 wt. %, but less than the solids content corresponding to the Liquid Limit are called Fluid Fine Tailings (FFT). FFT settle over time to produce Mature Fine Tailings (MFT), having above about 30 wt. % solids.

[0013] A proposed alternative to WBE, is solvent-based extraction (SBE or solvent-based process). WBE is characterised by the use of water to extract bitumen. On the other hand, SBE is characterized by the use of solvent to extract bitumen. Nevertheless, WBE may also use solvent in the process (for instance as described above in PFT) and SBE may use water in the process (for instance as described below as a bridging liquid). "Bridging liquid" and "bridging fluid" are used interchangeably herein.

[0014] The commercial application of SBE has, for various reasons, eluded the oil sand industry. A challenge associated with SBE is the tendency of fine particles within the oil sand to hamper the separation of solids from the extracted bitumen.

[0015] A solids agglomeration process has been proposed for use in SBE. The solids agglomeration process was coined Solvent Extraction Spherical Agglomeration (SESA). A description of the SESA process can be found in Sparks *et al.*, "The Effect of Asphaltene Content on Solvent Selection for Bitumen Extraction by the SESA Process", *Fuel*, 1992, (71):1349-1353. Previously described methodologies for SESA have not been commercially adopted. In general, the SESA process involves mixing oil sand with a hydrocarbon solvent, adding a bridging liquid to the oil sand slurry, 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 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 bridging liquid preferentially wets the solids. With the right amount of the bridging liquid and suitable agitation of the slurry; the bridging liquid displaces the suspension liquid on the surface of the solids. As a result of interfacial forces among the three phases (i.e. the bridging liquid, the suspension liquid, and the solids), the fines solids consolidate into larger, compact agglomerates that are more readily separated from the suspension liquid.

[0016] 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. In the SESA process, 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 the 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 formed agglomerates are more easily separated from the organic solvent compared to un-agglomerated solids. The formed agglomerates are referred to as macro-agglomerates because they result from the consolidation of both fine particles and coarse particles that make up the oil sand.

[0017] An example of an SBE is described in Canadian Patent Application No. 2,724,806 (Adeyinka *et al*, published June 30, 2011 and entitled "Process and Systems for Solvent Extraction of Bitumen from Oil sand").

[0018] 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 with the oils sands 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 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 extracts is conducted to produce bitumen products of commercial value.

[0019] Adeyinka *et al.* also describes agglomeration of an initial slurry without separation into a fines solids stream and a coarse solids stream. A first solvent is combined with a bituminous feed to form an initial slurry. The solids from the initial slurry are agglomerated to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract. The low solids bitumen extract is separated from the agglomerated slurry. A second solvent is mixed with the low solids bitumen extract 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 extracts is conducted to produce bitumen products of commercial value.

[0020] It is desirable to have an alternative or improved method of processing a bituminous feed.

SUMMARY

[0021] It is an object of the present disclosure to provide an alternative or improved method of processing a bituminous feed. Nothing in the present disclosure is intended as a promise of enhanced utility.

[0022] Disclosed is a solvent bitumen extraction with solids agglomeration method, the method comprising:

(a) inerting a bituminous feed to produce an inerted bituminous feed;

(b) adding a first solvent to the inerted bituminous feed and sizing the inerted bituminous feed to produce a sized bituminous feed;

(c) contacting the sized bituminous feed with a first high velocity fluid;

(d) dissolving the sized bituminous feed in the first high velocity fluid to produce a dissolved bituminous slurry;

(e) contacting the dissolved bituminous slurry with a second high velocity fluid to produce an agglomerated slurry; and

(f) filtering, washing with a second solvent and desolventizing the agglomerated slurry.

[0023] Also disclosed is a solvent bitumen extraction with solids agglomeration method, the method comprising:

(a) inerting a bituminous feed within an inerting system comprising a hopper to produce an inerted bituminous feed;

(b) adding a first solvent to the inerted bituminous feed and sizing the inerted bituminous feed to produce a sized bituminous feed;

(c) contacting the sized bituminous feed with a first fluid;

(d) dissolving the sized bituminous feed in the first fluid to produce a dissolved bituminous slurry;

(e) contacting the dissolved bituminous slurry with a second fluid to produce an agglomerated slurry; and

(f) filtering, washing with a second solvent and desolventizing the agglomerated slurry.

[0024] Also disclosed is a solvent bitumen extraction with solids agglomeration method, the method comprising:

(a) inerting a bituminous feed to produce an inerted bituminous feed;

(b) adding a first solvent to the inerted bituminous feed and sizing the inerted bituminous feed to produce a sized bituminous feed;

(c) contacting the sized bituminous feed with a first high velocity fluid within a jet pump, wherein the first high velocity fluid is a motive fluid of the jet pump and wherein the jet pump is made to operate at a condition of cavitation;

(d) dissolving the sized bituminous feed in the first high velocity fluid to produce a dissolved bituminous slurry;

(e) contacting the dissolved bituminous slurry with a second fluid to produce an agglomerated slurry; and

(f) filtering, washing with a second solvent and desolventizing the agglomerated slurry.

[0025] Also disclosed is a solvent bitumen extraction with solids agglomeration method, the method comprising:

(a) inerting a bituminous feed to produce an inerted bituminous feed;

(b) adding a first solvent to the inerted bituminous feed and sizing the inerted bituminous feed to produce a sized bituminous feed;

(c) contacting the sized bituminous feed with a first fluid;

(d) dissolving the sized bituminous feed in the first fluid to produce a dissolved bituminous slurry;

(e) contacting the dissolved bituminous slurry with a second fluid to produce an agglomerated slurry;

(f) filtering, washing with a second solvent and desolventizing the agglomerated slurry to produce a rich extract stream and a lean extract stream; and

(g) separating an aqueous liquid from the rich extract stream or the lean extract stream.

[0026] Also disclosed is a solvent bitumen extraction with solids agglomeration method, the method comprising:

(a) inerting a bituminous feed to produce an inerted bituminous feed;

(b) adding a first solvent to the inerted bituminous feed and sizing the inerted bituminous feed to produce a sized bituminous feed;

(c) contacting the sized bituminous feed with a first fluid;

(d) dissolving the sized bituminous feed in the first fluid to produce a dissolved bituminous slurry;

(e) contacting the dissolved bituminous slurry with a high velocity fluid to produce an agglomerated slurry within a jet pump, wherein the high velocity fluid is a motive fluid of the jet pump and wherein the jet pump is made to operate at a condition of cavitation; and

(f) filtering, washing with a second solvent and desolventizing the agglomerated slurry.

[0027] Also disclosed is a solvent bitumen extraction with solids agglomeration method, the method comprising:

(a) inerting a bituminous feed to produce an inerted bituminous feed;

(b) adding a first solvent to the inerted bituminous feed and sizing the inerted bituminous feed to produce a sized bituminous feed;

(c) contacting the sized bituminous feed with a first fluid;

(d) dissolving the sized bituminous feed in the first fluid to produce a dissolved bituminous slurry;

(e) contacting the dissolved bituminous slurry with a second fluid to produce an agglomerated slurry;

(f) filtering, washing with a second solvent and desolventizing the agglomerated slurry to produce a rich extract stream and a lean extract stream;

(g) recovering solvent from at least a portion of the rich extract stream to produce at least one bitumen stream;

(h) removing residual solids from the rich extract stream, the lean extract stream, or the bitumen stream by precipitating asphaltenes using an aliphatic solvent to produce a residual solids stream; and

(i) adding water to the residual solids steam to produce a water containing slurry and recovering solvent from the water containing slurry in a tailings solvent recovery unit.

[0028] Also disclosed is a solvent bitumen extraction with solids agglomeration method, the method comprising:

(a) inerting a bituminous feed to produce an inerted bituminous feed;

(b) adding a first solvent to the inerted bituminous feed and sizing the inerted bituminous feed to produce a sized bituminous feed;

(c) settling the sized bituminous feed;

(d) contacting the sized bituminous feed with a first fluid;

(e) dissolving the sized bituminous feed in the first fluid in a dissolution pipeline to produce a dissolved bituminous slurry;

(f) separating an oversized reject stream from the dissolved bituminous slurry;

(g) washing the oversized reject stream with a second solvent to produce a washed reject stream and an undersized reject stream comprising solids and solvent-rich liquid;

(h) drying the washed reject stream to produce a dry reject stream;

(i) separating an overhead stream from the dissolved bituminous slurry;

(j) contacting the dissolved bituminous slurry with a second fluid to produce an agglomerated slurry;

(k) further agglomerating the agglomerated slurry in an agglomeration pipeline to produce a further agglomerated slurry;

(l) filtering, washing with a third solvent and desolventizing with a condensable gas stream the further agglomerated slurry to produce a rich extract stream, a lean extract stream, and a desolventized dry solids stream;

(m) recovering solvent from at least a portion of the rich extract stream to produce at least one bitumen stream; and

(n) conditioning the desolventized dry solids stream to produce stackable solids.

[0029] 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

[0030] 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.

[0031] Figure 1 is a high level overview of a method of processing a bituminous feed.

[0032] Figure 2 illustrates an inerting system.

[0033] Figure 3 is a schematic representation of an embodiment of the process described herein.

[0034] Figure 4 illustrates an integrated process in which streams from a water-based process are directed to a SBE process.

[0035] Figure 5 is a schematic representation of processes for preparation of an aqueous stream for downstream bitumen extraction, within the scope of the present disclosure.

[0036] Figure 6 depicts an embodiment of processes according to Figure 5, which employ primary and secondary water separation.

[0037] Figure 7 is a schematic illustration of processes incorporating the preparation of an aqueous stream according to Figure 5 together with downstream steps for recovery of bitumen using a SBE process.

[0038] Figure 8 is a schematic representation of an exemplary process in which froth tailings are directed to a SBE process to recover bitumen.

[0039] Figure 9 is a schematic representation of an embodiment of the process depicted in Figure 8, in which hydrocarbon from paraffinic froth treatment tailings is extracted in a water-based process involving agglomeration.

[0040] Figure 10 is a schematic representation of a process for utilizing bitumen entrained in froth from a water-based process in a solvent-based process.

[0041] Figure 11 illustrates an exemplary process for utilizing an extraction liquor spiked with bitumen froth from WBE.

[0042] Figure 12 is a schematic representation of a process in which fine solids are removed from a solvent extracted bitumen product by water-assisted partial deasphalting.

[0043] Figure 13 illustrates a process according to Figure 12 in which water-assisted deasphalting is used to create a fungible product from solvent extracted oil sands.

[0044] Figure 14 is a schematic representation of a process in which paraffinic froth treatment is used to remove residual solids within a product stream derived from solvent extraction.

[0045] Figure 15 illustrates a process according to Figure 14 in which the bitumen product produced by PFT is below the threshold of fungible standards to permit the product of a SBE process that does not meet the fungible standards, to be combined directly, resulting in a net fungible product.

[0046] Figure 16 is a schematic diagram of a process in which a SBE product is further processed as an input feed into a WBE process.

[0047] Figure 17 illustrates a process in which a stream derived from SBE is processed in a WBE process.

[0048] Figure 18 is a schematic diagram of a process in which dry tailings from a SBE process are integrated in a WBE process.

[0049] Figure 19 illustrates a process in which integration of dry agglomerated tailings with tailings derived from a WBE process, results in strengthened tailings for use in reclaimed land.

[0050] Figure 20 is a graph illustrating the relationship between bitumen recovery from a solvent extraction with solids agglomeration process and water content in an oil sand slurry.

[0051] Figure 21 is a flow chart illustrating pretreatment of a bituminous feed by combining the feed with one or more additional bituminous feeds.

[0052] Figure 22A is a schematic of a natural gas combined cycle (NGCC) system.

[0053] Figure 22B is schematic of an NGCC system combined with a compressed recycle stream.

[0054] Figure 23 is a schematic of a pretreatment of a bituminous feed in order to decrease the bituminous feed's water content.

[0055] Figure 24 is a schematic of a pretreatment of a bituminous feed in order to increase the bituminous feed's water content.

[0056] Figure 25 is a flow chart of a process for pretreating a bituminous feed.

[0057] Figure 26 is a flow chart of a process for pretreating a bituminous feed.

[0058] Figure 27 is a flow chart illustrating a method of processing a bituminous feed.

[0059] Figure 28 is a flow diagram illustrating a method of processing a bituminous feed.

[0060] Figure 29 is a flow diagram illustrating a method of processing a bituminous feed.

[0061] Figure 30 is a flow diagram illustrating a method of processing a bituminous feed.

[0062] Figure 31 is a flow diagram illustrating a method of processing a bituminous feed.

[0063] Figure 32 is a flow chart illustrating a disclosed embodiment.

[0064] Figure 33 is a schematic illustrating a disclosed embodiment.

[0065] Figure 34 is a schematic illustrating a disclosed embodiment.

[0066] Figure 35 is a schematic illustrating a disclosed embodiment.

[0067] Figure 36 is a flow chart illustrating a disclosed embodiment.

[0068] Figure 37 is a schematic illustrating a disclosed embodiment.

[0069] Figure 38 is a schematic illustrating a disclosed embodiment.

[0070] Figure 39 is a schematic illustrating a disclosed embodiment.

[0071] Figure 40 is a schematic illustrating a disclosed embodiment.

[0072] Figure 41 is a schematic illustrating a disclosed embodiment.

[0073] Figure 42 is a flow chart illustrating a disclosed embodiment.

[0074] Figure 43 is a schematic illustrating a disclosed embodiment.

[0075] Figure 44 is a schematic illustrating a disclosed embodiment.

[0076] Figure 45 is a schematic illustrating a disclosed embodiment.

[0077] Figure 46 is a graph of bitumen recovery and initial filtration rate as a function of extraction time with the agglomeration time kept constant at 2 minutes.

[0078] Figure 47 is a graph is a graph of bitumen recovery and initial filtration rate as a function of agglomeration time with the extraction time kept constant at 5 minutes.

[0079] Figure 48A is a schematic illustrating a disclosed embodiment.

[0080] Figure 48B is a schematic illustrating a disclosed embodiment.

[0081] Figure 48C is a schematic illustrating a disclosed embodiment.

[0082] Figure 48D is a schematic illustrating a disclosed embodiment.

[0083] Figure 49 is a schematic illustrating a disclosed embodiment.

[0084] Figure 50 is a flow chart illustrating a disclosed embodiment.

[0085] Figure 51 is a schematic illustrating a disclosed embodiment.

[0086] Figure 52 is a schematic illustrating a disclosed embodiment.

[0087] Figure 53 is a schematic illustrating a disclosed embodiment.

[0088] Figure 54 is a schematic illustrating a disclosed embodiment.

[0089] Figure 55 is a calibration curve relating bitumen content of a bitumen extract comprised of bitumen and solvent to the measured density of the bitumen extract.

[0090] Figure 56 is a schematic illustrating a disclosed embodiment.

[0091] Figure 57 is a schematic representation of an exemplary system with modular relocatable components within the scope of the present disclosure.

[0092] Figure 58 illustrates a relocatable system that employs solvent extraction near a mine face and directs coarse solids to dry disposal in a pit.

[0093] Figure 59 provides a flow diagram showing an integrated system with relocatable components that employs WBE and solvent extraction for the extraction of bitumen from oil sands.

[0094] Figure 60 illustrates an embodiment of a system described herein.

[0095] Figure 61 illustrates a further embodiment of a system described herein.

[0096] Figure 62 illustrates another embodiment of a system described herein.

[0097] Figure 63 is a flow chart of a method of processing a bituminous feed.

[0098] Figure 64 is a graph of slurry pipeline pressure differential versus solids content of the slurry.

[0099] Figure 65 is a graph of slurry permeability versus slurry water content.

[0100] Figure 66 is a graph of pump pressure and permeability versus residence time.

[0101] Figure 67 is a graph of Fast Fourier Transforms of pressure differential versus slurry water content.

[0102] Figure 68A is a graph of modeled predictions of pressure gradient as a function of particle size in a 4 inch diameter pipe.

[0103] Figure 68B is a graph of modeled predictions of pressure gradient as a function of particle size in a 6 inch diameter pipe.

[0104] Figure 68C is a graph of modeled predictions of pressure gradient as a function of particle size in a 10 inch diameter pipe.

[0105] Figure 69 is a graph of gamma ray scans plotting slurry height in the pipeline against slurry density.

[0106] Figure 70 is a graph of Focused Beam Reflectance Measurement (FBRM) plotting percentage of counts per second against chord length.

[0107] Figure 71 is a flow chart of a system for separating a bitumen extract from solids.

[0108] Figure 72 is a schematic of a single vessel solid-liquid separation system with hydrocyclones as the separator unit.

[0109] Figure 73 is a schematic of a single vessel solid-liquid separation system with a gravity separator as the separator unit.

[0110] Figure 74 is a schematic of a multi-stage solid-liquid separation system with wash stages.

[0111] Figure 75 is a schematic of a process for separating a bitumen extract from solids.

[0112] Figure 76 is a flow chart of a process for separating a bitumen extract from solids.

[0113] Figure 77 is a flow diagram illustrating a horizontal vacuum filter system.

[0114] Figure 78 is a flow diagram illustrating a sealed vacuum filter system.

[0115] Figure 79 is a flow diagram illustrating a sealed vacuum filter system integrated with a solvent based extraction process.

[0116] Figure 80 is a flow chart of a method of filtering an oil sand slurry.

[0117] Figure 81 is a flow chart of a method of processing a bituminous feed.

[0118] Figure 82 is a graph of the resulting permeability of a bed of agglomerates.

[0119] Figure 83 is a flow chart of a method for processing a bitumen extract stream.

[0120] Figure 84 is a flow chart of a method for processing an oil sand slurry.

[0121] Figure 85 is a flow chart of a method for processing an oil sand slurry.

[0122] Figure 86 is a flow chart of a method for processing an oil sand slurry.

[0123] Figure 87 is a flow chart of a method for processing a bituminous feed.

[0124] Figure 88 is a flow chart of a method for processing a bituminous feed.

[0125] Figure 89 is a flow chart of a method for processing a bituminous feed.

[0126] Figure 90 is a flow chart of a method for processing a bituminous feed.

[0127] Figure 91 is a flow chart of a method for processing a bituminous feed.

[0128] Figure 92 is a flow chart of a method for processing a bituminous feed.

[0129] Figure 93 is a flow chart of a method for processing a bituminous feed.

[0130] Figure 94 is a flow chart of a method for processing a bituminous feed.

[0131] Figure 95 is a flow chart of a method for processing a bituminous feed.

[0132] Figure 96 is a flow chart of a process for reducing solids content of a bitumen extract from SBE.

[0133] Figure 97 is a flow diagram of a process for reducing solids content of a bitumen extract from SBE.

[0134] Figure 98 is a flow diagram of a process for reducing solids content of a bitumen extract from SBE, which may be integrated with existing WBE froth cleaning processes.

[0135] Figure 99 is schematic representation of a process within the scope of the present disclosure.

[0136] Figure 100 illustrates an exemplary embodiment of a process consistent with the representation shown in Figure 99.

[0137] Figure 101 is a graph showing Thermo Gravimetric analysis (TGA) results of a sample described herein, in particular change in weight over time.

[0138] Figure 102 is a graph showing Thermo Gravimetric analysis (TGA) results of a sample described herein, in particular change in weight between 10 °C and 600 °C.

[0139] Figure 103 is a graph showing drying rate curve of cyclohexane agglomerates based on Thermo Gravimetric analysis (TGA) results of a sample described herein.

[0140] Figure 104 is a graph showing drying rate over a temperature range based on Thermo Gravimetric analysis (TGA) results of a sample described herein.

[0141] Figure 105 is a graph showing moisture content of water and solvent in agglomerates as a function of time based on Thermo Gravimetric analysis (TGA) results of a sample described herein, over a 10 minute period.

[0142] Figure 106 is a block diagram of a system that may be used to extract bitumen from oil sands using an extraction process.

[0143] Figure 107 is a schematic of a power generation system that utilizes liquid recycle solvent as the working fluid.

[0144] Figure 108 is a schematic of a power generation system that utilizes vapor recycle solvent as the working fluid.

[0145] Figure 109 is a process flow diagram showing a method for the extraction of bitumen from oil sands using non-aqueous solvent.

[0146] Figure 110 is a schematic of a system that utilizes liquid recycle solvent from a non-aqueous extraction (NAE) process as the working fluid within a power generation process.

[0147] Figure 111 is a schematic of a system that utilizes vapor recycle solvent from a NAE process as the working fluid within a power generation process.

[0148] Figure 112 is a schematic illustrating a disclosed embodiment.

[0149] Figure 113 is a schematic illustrating a disclosed embodiment.

[0150] Figure 114 is a schematic illustrating a disclosed embodiment.

[0151] Figure 115 is a schematic illustrating a disclosed embodiment.

[0152] Figure 116 is a schematic illustrating a disclosed embodiment.

[0153] Figure 117 is a schematic illustrating a disclosed embodiment.

[0154] Figure 118 is a schematic illustrating a disclosed embodiment.

[0155] Figure 119 is a schematic illustrating a disclosed embodiment.

[0156] Figure 120 is a schematic illustrating a disclosed embodiment.

[0157] Figure 121 is schematic representation of a process within the scope of the present disclosure.

[0158] Figure 122 illustrates an exemplary embodiment of a system as described herein.

[0159] Figure 123 illustrates an exemplary embodiment of a process described herein.

[0160] Figure 124 is schematic representation of solvent extraction with solids agglomeration using heat from the combustion of product cleaning waste streams.

[0161] Figure 125 illustrates a method of solvent extraction with solids agglomeration using heat from the combustion of product cleaning waste streams.

[0162] Figure 126 illustrates a process by which the residual solvents within the dry tails may be combusted in a fashion consistent with the process described herein, producing dry and sintered tailings.

[0163] Figure 127 is a flow diagram of an embodiment of a solvent bitumen extraction with solids agglomeration method.

[0164] 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

[0165] 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.

[0166] 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.

[0167] Throughout this disclosure, where a range is used, any number between or inclusive of the range is implied.

[0168] 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. Hydrocarbon compounds may be aliphatic or aromatic, and may be straight chained, branched, or partially or fully cyclic.

[0169] "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. %), the weight % based upon total weight of the bitumen.

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

[0170] "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.

[0171] "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. Such a bituminous feed may be also derived directly from oil shale oil, bearing diatomite or oil saturated sandstones.

[0172] "Fine particles" or "fines" are generally defined as those solids having a size of less than 44 microns (μm), as determined by laser diffraction particle size measurement.

[0173] "Coarse particles" are generally defined as those solids having a size of greater than 44 microns (μm).

[0174] 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.

[0175] 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.

[0176] The term "paraffinic solvent" (also known as aliphatic) as used herein means solvents comprising normal paraffins, isoparaffins or blends thereof in amounts greater than 50 wt. %. Presence of other components such as olefins, aromatics or naphthenes may counteract the function of the paraffinic solvent and hence may be present in an amount of only 1 to 20 wt. % combined, for instance no more than 3 wt. %. The paraffinic solvent may be a C_4 to C_{20} or C_4 to C_6 paraffinic hydrocarbon solvent or a combination of iso and normal components thereof. The paraffinic solvent may comprise pentane, iso-pentane, or a combination thereof. The paraffinic solvent may comprise about 60 wt. % pentane and about 40 wt. % iso-pentane, with none or less than 20 wt. % of the counteracting components referred above.

[0177] The term “middlings” or “middling fraction” as used herein refers to the portion of a mixture derived from a separation vessel, for example the primary separation vessel used in WBE. The upper phase of the vessel, the overflow, may comprise froth, while the lowermost phase comprises tailings. This mid-level phase of such a separation vessel may be referred to as “middlings”. In the case of middlings from a primary separation vessel (PSV), the middlings may be directed to floatation for further processing in WBE, and in the integrated process described herein, may alternatively be directed to SBE.

[0178] The term “mature fine tailings” or MFT as used herein refers to the dense mixture of clay, silt and water found in the tailings ponds of WBE facilities. The mixture has a typical solids content of about 30 wt. %. Mature fine tailings are formed when tailings from the WBE are deposited within the tailings ponds. The raw tailings separate and settle into a coarse fraction that forms the beach of the tailings pond, a layer of clarified water, which is recycled back to the extraction process, and below the water layer is the mature fine tailings layer, which remains unconsolidated for decades or more.

[0179] “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.

[0180] “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).

[0181] “Dry tailings” is used to mean a mineral stream left over from a bitumen extraction process which can be stored without the need for dikes or other fluid containment structures.

[0182] A “high velocity fluid” is a fluid which comes into contact with a second fluid, wherein the high velocity fluid has a velocity of at least 5 times the velocity of the second fluid at the point of contact. The high velocity fluid may be a motive fluid in a jet pump and it is oftern referred to as a motive fluid herein.

[0183] “Stackable solids” means a mineral stream left over from a bitumen extraction process which can be stored without the need for dikes or other fluid containment structures.

[0184] The term “exemplary” as used herein does not mean superior but rather is simply used to describe something as an example.

[0185] Abbreviations that are commonly used herein include:

[0186] SBE: Solvent-Based Extraction

[0187] WBE: Water-Based Extraction

[0188] PSV: Primary Separation Vessel (also known as PSC: Primary Separation Cell)

[0189] PFT: Paraffinic Froth Treatment

[0190] FSU: Froth Settling Unit (also known as Froth Separation Vessel)

[0191] TSRU: Tailings Solvent Recovery Unit

[0192] SRU: Solvent Recovery Unit

[0193] MFT: Mature Fine Tailings

[0194] Figure 1 is a high level overview of a method of processing a bituminous feed. The description below includes the following headings, which correspond to boxes (1-102) to (1-114) in Figure 1:

[0195] I: Mining & Ore Preparation (1-102)

[0196] II: Slurry Preparation & Bitumen Extraction (1-104)

[0197] III: Solids Agglomeration (1-106)

[0198] IV: Solid Liquid Separation (1-108)

[0199] V: Product Cleaning and Bitumen Handling (1-110)

[0200] VI: Solvent Recovery (1-112)

[0201] VII: Tailings Treatment and Tailings Handling (1-114)

[0202] After the headings I-VII, additional description is provided under the headings of VIII and IX.

I. Mining & Ore Preparation

[0203] **Ore Preparation Plant (OPP).** An OPP may be used to prepare oil sand ore. Mine haul trucks may deliver oil sand ore to a receiving hopper or dump pocket installed in the OPP area. The raw ore may then be moved through a series of conveyors and crushers to eventually provide material of a maximum particle size to the slurry system. An exemplary crusher is a double roll crusher. Crushed ore may be delivered to the slurry system via a surge bin which may be proximal to the location of the slurry system. The slurry system may comprise or be proximal to an inerting system that is used to purge the bituminous feed of oxygen to a level well below the flammability limit of the solvent. The purge gas of the inerting system may be an inert gas, such as nitrogen, and/or a hydrocarbon gas such as methane or natural gas. The purge gas acts to replace the volume previously occupied by the air and/or oxygen gas.

[0204] It is desirable to develop techniques to increase the availability of an SBE facility. It is also desirable to develop techniques to ensure the continuous operation of an SBE facility even during significant downtime in operations upstream of solvent addition to the bituminous feed, such as in mining equipment and dry crushing. The dry crushed bituminous feeds may be directed to large surge piles prior to being directed to solvent containing portions of the SBE facility. The constructed and maintained large surge piles may assist continued operation of the SBE facility during downtime in operations upstream of the surge piles. The surge piles may be of size to allow for days long continuous operation of the SBE facility.

[0205] A conventional WBE facility may comprise large surge bins which typically provide a residence time on the order of an hour. The bins are primarily used for maintaining smooth operation of the extraction plant since they act to dampen transients that are less than an hour in duration. These surge bins do not allow for continued operation of the WBE facility during periods of significant downtime in equipment upstream of the surge bins such as the crushers. In a conventional WBE facility, large surge piles comprising crushed ore is typically not desired because it has been found that crushed ore within surge piles weather over a certain time period. The weathering of the crushed ore has a tendency to negatively impact the extractability of the bitumen during the WBE process.

[0206] It has been found for the SBE process described herein, the extractability of the bitumen within the bituminous feed is not negatively impacted by the type and degree of weathering the bituminous feed may be subjected to while within a surge pile. For this reason, it may be advantageous to incorporate within a SBE facility large surge piles which receive crushed bituminous feeds from the dry crushers of the SBE facility. The large surge piles may be of sufficient size to allow for days of continued operation of the SBE facility during periods of maintenance and/or repair of the lower availability dry crushers and/or other items upstream of the surge piles.

Inerting Feed System

[0207] The bituminous feed of a SBE process may be directed to an inerting feed system to allow for the transfer of the bituminous feed from the oxygen containing environment to the solvent containing environment of the SBE process. The term "inerting the feed system" or "inerting a bituminous feed" as used herein means to reduce the maximum oxygen concentration within the interstitial spacing and internal pores of the bituminous feed to a value below the limiting oxygen concentration required for combustion of the first solvent to be added to the feed system or the bituminous feed in the processes herein. The maximum allowable oxygen concentration may be less than 11 mol%, or less than 5 mol%, or less than 3 mol%. The reduction in oxygen concentration of the bituminous feed may allow the inerting feed system to act as a barrier separating the non-classified region of the facility from the classified region of the facility.

[0208] The inerting feed system may have the capability to receive and inert bituminous feeds of varying physical properties. The types of bituminous feed may range, for example, from frozen lumps often experienced during the winter to soft and sticky lumps experienced during the summer. The inerting feed system may be capable of mitigating loss of solvent vapor and other hydrocarbon vapor to the environment. The inerting feed system may have a turndown ratio of at least 3:1. Furthermore, a metal detection system may be disposed upstream of the feed inerting system so that detected metals can be removed prior to the bituminous feed entering the classified areas of the SBE facility. Additionally, a metal detection system may be disposed immediately downstream of the inerting system but prior to the bituminous feed coming into contact with solvent.

[0209] The inerting system may comprise at least two hoppers arranged in series with the second hopper receiving solids from the first hopper. Each hopper may comprise a solids plug located from the bottom exit of the hopper to minimize backflow of gas. A sealed feeder such as an apron feeder or other suitable rotary device (e.g. a Posimetric^{TM} Feeder, Pennsylvania Crusher Brand, TerraSource Global, St. Louis, MO) or a vibrating feeder may be located proximate to the bottom exist of each hopper in order to convey solids from the hopper. Nitrogen gas may be used as the inert gas to displace oxygen associated with the bituminous feed. Nitrogen may be introduced near the bottom of each of the hoppers and provide an inert gas which displaces the oxygen counter-currently to the flow of the solids.

[0210] Figure 2 illustrates an embodiment of an inerting system herein. The inerting system (2-100) may provide the transition from an air environment to a solvent environment. The inerting system may comprise a first hopper (2-101) which receives a bituminous feed from the air environment. A first apron feeder (2-102) directs the bituminous feed from the first hopper (2-101) to a second hopper (2-103). The second hopper (2-103) directs the bituminous feed to the solvent environment via a second apron feeder (2-104). The first hopper (2-101) and the second hopper (2-103) may comprise a bituminous feed layer (2-105), (2-106) from the bottom of each hopper in order to provide a solids plug for each hopper. The bituminous feed layer inside each hopper may be monitored continuously in order to maintain a minimum height. Oxygen and hydrocarbon sensors may be provided within the vent lines to monitor the effectiveness of the inerting process and to detect release of hydrocarbon gases.

[0211] The inerting system may be designed for mass flow conditions. The control of minimum solid bed height in the hoppers may be desired in order to reduce the chances of forming rat holes which provide a direct passageway for the backflow of vapor from the top section of the hopper to the bottom section. The inerting system may comprise instrumentation / control systems that are in place to detect the formation of rat holes.

[0212] Bituminous feed from a surge bin (not shown) may be elevated to the first hopper (2-101) of the feed inerting system. The first hopper (2-101) and the second hopper (2-103) may be sized to provide a minimum residence time of approximately 3 minutes. A longer retention time may require taller hoppers and/or larger diameter hoppers. Taller hoppers may come with the penalties of higher capital cost and requiring higher nitrogen pressure. Larger diameter hoppers may come with the penalty of reducing the effectiveness of the gas sweep. Nitrogen gas (2-107) may be injected near the bottom section of the first hopper to displace oxygen trapped in the bituminous feed vapor spaces. Nitrogen gas (2-108) may also be supplied in the chute area between the bottom of the first hopper (2-101) and the first apron feeder (2-102). The nitrogen gas may be supplied at a pressure and height to predominantly flow the gas upward. A portion of the nitrogen gas may flow downward to prevent egress of the solvent vapor. The first hopper (2-101) may be shrouded to maximize the collection of the nitrogen gas comprising hydrocarbon vapors. The vapors may be vented (2-111) to a safe location, or sent to flare or for incineration. A sealed first apron feeder (2-102) at the bottom of the first hopper may transfer the bituminous feed to the second hopper. The discharging of the bituminous feed from the first apron feeder may impart a tumbling motion to the feed in order to expose more surfaces to the nitrogen purge. Nitrogen gas (2-110) may also be supplied in the area that connects the first apron feeder to the second hopper to sweep across the falling bituminous feed.

[0213] In the second hopper (2-103), nitrogen gas (2-109) may be injected into the bottom of the second hopper to remove any residual oxygen that may have entered and/or remained within the bituminous feed. The nitrogen gas (2-109) may be introduced into the second hopper (2-103) in much the same fashion as the nitrogen gas (2-107) is introduced into the first hopper. The second hopper may be sealed from the environment. Hydrocarbon vapor released from the second hopper may be vented to the flare, incinerator or to a solvent recovery step. Alternatively, the hydrocarbon vapor released from the second hopper may be directed to combustion equipment such as boilers and/or fired heaters within the facility. The double hopper arrangement described herein mimics the double block and bleed concept typically used for safe isolation of equipment.

[0214] A sealed second apron feeder (2-104) at the bottom of the second hopper (2-103) may transfer the bituminous feed to a solvent containing step of the SBE process such as solvent wet crushing. A spill conveyor may be provided below each apron feeder to catch any spillage from the apron feeders. A sloped spill chute may be provided below the second apron feeder. This chute may be continuously or periodically flushed with solvent to remove spilled bituminous feed, and transport the feed to the wet crushing stage.

[0215] In an alternative design, the feed inerting system may comprise a hopper, a sealed first apron feeder, and a sealed second apron feeder. Within each apron feeder, nitrogen gas may flow counter currently or co-currently to the flow of the bituminous feed. Additionally within each apron feeder, nitrogen gas may flow perpendicular to the flow of the bituminous feed through the porous sections of the apron feeders. The apron feeder may vibrate to minimize trapped gas pockets within the bituminous feed which may contain oxygen.

I.A. Feed Dewatering

[0216] It is desirable to use techniques to recover bitumen from aqueous hydrocarbon-containing streams arising from WBE, that can operate efficiently in the presence of fines, or which are largely unaffected by the presence of fines.

[0217] Certain embodiments described herein may advantageously permit recovery of hydrocarbon from aqueous hydrocarbon-containing streams that were previously considered too dilute for recovery, in part due to a high fines content combined together with a high water content of over 50% by weight. By de-watering such aqueous streams containing bitumen to the point that the effluent contains less than 40% water, the streams can then be used in a process that employs agglomeration of fines.

[0218] Recycling conventionally discarded aqueous hydrocarbon-containing streams may be important from an environmental perspective as well as from an efficiency perspective. By decreasing water content of an aqueous hydrocarbon-containing stream to a desirable level, the stream would become more desirable for use in SBE processes. Recovered water may advantageously be put to use in any suitable aspect of bitumen production that may incorporate recycled water. By de-watering an aqueous hydrocarbon-containing stream prior to attempts to remove all hydrocarbon or bitumen, steps in a conventional WBE process can be omitted, thereby introducing efficiencies at certain steps in the process.

[0219] Described is a process for pre-treating an aqueous hydrocarbon-containing feed for a downstream SBE for bitumen recovery. The feed may include from 50 wt. % to 95 wt. % water, from 0.1 wt. % to 10 wt. % bitumen, and from 5 wt. % to 50 wt. % solids, wherein said solids comprise fines. The process may involve removing water from the feed to produce an effluent comprising 40 wt. % water or less; and subsequently providing the effluent to the downstream SBE for bitumen recovery. The downstream SBE may comprise fines agglomeration. Removing water from the aqueous hydrocarbon-containing feed may entail flowing the feed into a primary water separation system to remove water therefrom, such as a clarifier, a settler, a thickener or a cyclone. A flocculant may be added, for example mixed in with the feed prior to separation within a clarifier. This step of water removal may produce a reduced-water stream of from 30 wt. % to 60 wt. % solids, and recycled water. Further, water may be removed from the reduced-water stream using a secondary water separation system to produce an effluent comprising 40 wt. % water or less.

[0220] The feed may be one that is produced from a WBE wherein a flocculant or coagulant is used to induce aggregation of fines and hydrocarbons within the WBE.

[0221] Where a secondary water separation system is employed, this may comprise a centrifuge with filtering capacity, a shale shaker, a vacuum belt filter, or one or more clarifiers.

[0222] The aqueous hydrocarbon-containing feed may be the effluent of a froth separation unit, for example, or may be derived from tailings from a TSRU. TSRUs are described herein.

[0223] Likewise, described is a system for pre-treating an aqueous hydrocarbon-containing feed for a downstream SBE for bitumen recovery, wherein the feed contains from 50 wt. % to 95 wt. % water, from 0.1 wt. % to 10 wt. % bitumen, and from 5 wt. % to 50 wt. % solids, wherein said solids are fines. The system may comprise a dewatering unit for removing water from the aqueous hydrocarbon-containing feed to produce an effluent comprising 40 wt. % water or less; and a conduit for providing the effluent to a downstream SBE comprising fines agglomeration to recover bitumen.

[0224] In such a system, the dewatering unit may include a primary water separation system to remove water from the aqueous hydrocarbon-containing feed, producing a reduced-water stream and recycled; and a secondary water separation system for receiving the reduced-water stream and removing water therefrom to produce an effluent comprising 40 wt. % water or less.

[0225] Processes will now be described in more detail in which bitumen can be recovered from aqueous streams arising from WBE. Such techniques can operate efficiently in the presence of fines, or may be largely unaffected by the presence of fines.

[0226] Streams derived from WBE processes that may be bitumen-lean are not necessarily utilized to full advantage within WBE. Integration of a WBE with SBE is a way of utilizing aqueous streams that would not necessarily have resulted in bitumen recovery within WBE. Such aqueous streams may be referenced herein as bitumen-lean, as waste-streams, aqueous hydrocarbon-containing streams, or simply as aqueous streams.

[0227] Such aqueous streams may be ones having in excess of 50% water. Such streams may be ones produced or rejected from WBE, or may be streams that are directly derived from oil sand which include a high water content, but which were not necessarily intended for WBE. Certain rejected streams from WBE (generally, bitumen-lean streams), as well as intermediate streams produced in the extraction process which may be intended for further bitumen-recovery steps, may be relatively high in water content, and thus can advantageously be processed further through SBE once the water content of the high water stream streams is reduced to a level acceptable within the SBE, such as for example reduced below 40% water.

[0228] Recovery of bitumen from relatively high fines aqueous feed streams may involve using a combination of SBE and agglomeration of solids. In such a SBE and solids agglomeration process the desired amount of water in the feed mixture may be 5 to 50 wt. % or 5 to 20 wt. %. Thus, SBE and solid agglomeration processes can employ aqueous feed streams, provided the water content is not so high as to negatively impact the agglomeration. Aqueous feed streams may be used, despite a high fines content, and in this way, such aqueous streams that may have previously been considered difficult to recover because of the fines content, can be effectively utilized. High fines content is a characteristic previously considered problematic in conventional methods for extracting hydrocarbon from aqueous feed streams. For example, bitumen-lean streams arising from WBE, which may have previously been directed to tailings ponds, can be used in SBE, provided the water content is in an appropriate range to permit use of the stream without causing excessive dilution to the SBE thereby impeding efficient agglomeration of fines. Thus, bitumen-lean streams arising from conventional WBE, intermediate streams from conventional WBE, or any bituminous aqueous stream can be used in the SBE if pre-conditioned to achieve desired characteristics. The process is described herein for utilization of streams that are high in water content, which may require concentration through pre-treatment in order to be effectively used in SBE.

[0229] Hydrocarbon-containing streams bearing levels of water that are not in excess of a level that would be of detriment to a SBE (such as streams containing less than about 40 wt. % water), can be fed directly into a SBE as described herein, without the need for concentration through a water removal pre-treatment process. Such streams that already contain water at a lower, acceptable level for SBE are encompassed in the processes described herein.

[0230] Pre-treatment of an aqueous hydrocarbon-containing feed to decrease its water content is described above and therefore will not be repeated here.

[0231] The aqueous hydrocarbon-containing feed may comprise from 60 wt. % to 95 wt. % water, from 0.1 wt. % to 10 wt. % bitumen, and from 5 wt. % to 40 wt. % solids.

[0232] The aqueous hydrocarbon-containing feed may comprise middlings from a primary separation vessel. The aqueous hydrocarbon-containing feed may comprise effluent of a froth separation unit. The aqueous hydrocarbon-containing feed may comprise tailings from a TSRU.

[0233] There are many sources of aqueous hydrocarbon-containing feed streams in excess of 50 wt. % water which can be subjected to processing as described herein, so that hydrocarbon may be extracted. Such streams that are referred to as aqueous hydrocarbon-containing feed streams may interchangeably be referenced herein as “high water content streams”. The variety of aqueous hydrocarbon-containing feed streams which could be used as feed streams in the processes described herein contains over 50 wt. % water. Thus, possible streams for processing according to the processes described herein include streams derived either as intermediates, as bitumen-lean streams, or as an end-products of WBE. For example, streams that may not normally have been considered for further bitumen-recovery processing within in a conventional WBE can now be subjected to processing, and recovery of hydrocarbon. While such streams need not be designated as waste streams *per se*, they may be bitumen-lean streams, and/or intermediate streams which would have normally proceeded to further processing within a WBE. Aqueous streams need not be derived from a WBE, but may contain water for other reasons, such as steam exposure, water-heating, slurry transport, or due to mixing of water with oil sand that have not yet been subjected to any extraction process, but which have been rendered aqueous for alternative reasons.

[0234] The water content of many WBE streams is higher than the desired amount for effective fines agglomeration in the process. An advantage of the utilization of high water content streams, as described herein is that pre-treating of such streams can reduce water content to permit such streams to be used as feed streams in SBE, thereby addressing this challenge. Another advantage is that the aqueous hydrocarbon-containing stream with reduced water content will have enough water to provide the needed bridging liquid for the agglomeration process. The treatment process for bitumen-lean streams described herein permits aqueous streams with high fines content to be used as feed streams for the SBE and solids agglomeration process, so as to permit successful recovery of bitumen that would have otherwise been lost.

[0235] Typical aqueous hydrocarbon-containing feed streams for use in the de-watering process include, but are not limited to, middlings derived from a primary separation vessel (PSV), froth treatment tailings, floatation tails which may not yet have been directed to a tailings pond, and/or mature fine tailings (MFT), which may have already been present in a tailings pond. Appropriate aqueous hydrocarbon-containing feed streams may be ones containing bitumen and/or other hydrocarbon components, which may or may not include bitumen.

[0236] Bitumen-lean feed streams arising from conventional WBE are particularly attractive for pre-treating as described herein, to reduce water content prior to use as a feed in an SBE. The pre-treating may have previously been considered as an effective way to recover waste water; however, it has not been viewed as an optimal way to recover bitumen that would have otherwise been lost. By pre-treating a bitumen-lean stream in this way, in preparation for subsequent recovery in a SBE, both a reduction in waste, recovery of waste water, and an increase in recovery of bitumen from bitumen-lean aqueous streams can be realized.

[0237] Advantageously, the middlings from a primary separation vessel used in conventional WBE may be processed less efficiently on the assumption that further hydrocarbon components can be recovered in downstream SBE. This results in an energy saving at this step, as not all bitumen need be removed in a WBE.

[0238] A mixer may be used as the aqueous hydrocarbon-containing stream enters a primary water separation system or vessel. One or more points of entry of the hydrocarbon-containing feed stream may be used on the way to a primary water separation vessel, so as to allow turbulence to occur. Multiple injection points of an aqueous hydrocarbon-containing feed may be used on the way to the primary water separation vessel.

[0239] Flocculants or other additives, such as coagulants or pH modifiers may be added to the aqueous hydrocarbon-containing feed streams. Typically, a pH of 8.5 is achieved, and a drop in pH may be achieved. Thus, pH may be modified from a level above pH 7 to a level below pH 7. A reduction in pH may reduce surface activities of the clays, which may result in precipitation of fines.

[0240] In the primary water separation step for water removal, a clarifier, a settler, thickener, or a cyclone may be used in single or multiple units which may be in communication in serial, or employed in parallel. Thus, the dewatering unit may comprise one or more of such units. The resulting effluent may contain from 30 wt. % to 60 wt. % solids. The hydrocarbon content of the effluent arising from this stage of the process is enriched, relative to the initial aqueous feed. A doubling of the hydrocarbon content, or a further enriched content, may be achieved. However, the effluent from this stage is still pumpable so as to permit transport and movement through to further aspects of the process. The content of solids may in fact be above a level of 60 wt. %, and water content could be lower than 40%, provided the effluent from the underflow derived from the primary water separation is still pumpable or made to be pumpable by the addition of extraction liquor from the SBE.

[0241] When present, a secondary water separation system of the dewatering unit may be employed. Similar types of apparatuses may be employed in such secondary separation, or a filter, filter centrifuge, centrifuge, vacuum filter, or vibration filter may be employed. The system may employ a single dewatering unit, or the dewatering unit may comprise individual components, such as primary water separation system and a secondary water separation system. Each of the primary and secondary water separation systems may have multiple individual components operating in parallel or in serial.

[0242] A feed stream comprising bitumen, water and solids with or without residual solvent is pre-conditioned according to a process described herein. The feed stream may be derived from a mixture of oils and, oversized rejects stream, and high water content streams or blends thereof. An exemplary high water content stream may be one derived from a middling stream of a primary separation vessel, or from secondary flotation tails and/or froth treatment tailings from a WBE. Such feed streams or blends thereof are processed via a single or dual staged water separation system (WSS) in order to be adequately pre-conditioned for use as a feed stream in SBE and agglomeration processes.

[0243] Figure 5 is a schematic representation of the process (5-1000) in which an aqueous hydrocarbon-containing feed stream is conditioned according to a process described herein. The initial aqueous hydrocarbon-containing feed (5-1030) is one derived from a WBE, for example, it may be a bitumen-lean stream derived from a conventional WBE. Advantageously, the feed may have high fines content, as such fines can be subsequently removed. The feed (5-1030) contains 50% to 95% water on a weight basis, and also contains from 0.1 wt. % to 10 wt. % bitumen, and from 5 wt. % to 40 wt. % solids. The step of water removal (5-1032) is conducted in any manner that would be acceptable so as to achieve an effluent (5-1034) having about 40% water, or less, by weight. This effluent goes on to downstream SBE (5-1035), for example using a process that involves solids agglomeration.

[0244] Figure 6 represents processes (6-1100) for pre-treating an aqueous hydrocarbon-containing stream or feed (6-1102) with water content of from 50 wt. % to 95 wt. % water, with from 0.1 wt. % to 10 wt. % bitumen, and with 5 wt. % to 40 wt. % solids.

[0245] The aqueous hydrocarbon-containing stream or feed (6-1102) is passed into a primary water separation system or PWSS (6-1104). In the PWSS, a portion of the water contained in the feed (6-1102) is recovered as recycled water (6-1106). The remaining portion is a reduced-water stream (6-1108) is then fed into a secondary water separation system or SWSS (6-1110) to produce an effluent (6-1112) having the consistency of a pumpable slurry or made to have a consistency of a pumpable slurry by downstream processing. The effluent (6-1112) contains predominantly fine solids and hydrocarbon, and has a water content of up to 40 wt. %. More recycled water (6-1106) is recovered from the secondary water separation system (6-1110). The effluent (6-1112) of the secondary water separation system, having the consistency of a pumpable slurry or made to have the consistency of pumpable slurry, may be combined with oversized rejects (6-1114) and/or recycled extraction liquor from a SBE (6-1116) in proportions which permit the water content of the resulting slurry (6-1118) to remain within the desired level for solids agglomeration in later downstream processing. The recycled extract liquor may be added to the effluent (6-1112) of the secondary water separation system to ensure that the effluent has the consistency of a pumpable slurry.

[0246] The primary water separation system (6-1104) may be a clarifier unit or cyclone which takes advantage of inherent or induced high settling characteristics of the high water content feeds. The primary water separation system my optionally be a thickener unit or more preferably a paste thickener. In contrast to conventional WBE in which additives are employed to disperse fines in water and prevent slime coating of bitumen, flocculants or coagulants may optionally be used to induce the aggregation of fines and hydrocarbons within the WBE or within the clarifier. Large quantities of recycled water, which is low in total suspended solids, may thus be recovered. Advantageously, by recovering water at this stage, efficiencies are introduced, due to the reduced volume forwarded for downstream processing in a SBE.

[0247] The secondary water separation unit (6-1110) may be a filtering device that can provide one or a combination of pressure, centrifugal or vibrational forces for phase separation. A slurry of coarse solids may be added to the secondary water separation system to promote efficient dewatering. In exemplary embodiments, the secondary water separation system (6-1110) may comprise a centrifuge with filtering capacity, shale shaker, or a vacuum belt filter. It may be possible in certain embodiments that the dewatering achieved in the secondary water separation system is enough to allow for direct feed of the effluent (6-1112), without addition of oversize rejects or oil sand, into a SBE.

[0248] As shown in Figure 6, solvent (6-1120) may be added to the feed (6-1102) entering the primary water separation system (6-1104) so as to dissolve bitumen and decrease the feed density sufficiently for selective phase separation under gravity or for application of a centrifugal force field. If solvent is added, an exemplary solvent: bitumen ratio is less than 2:1.

[0249] As a further option, a flocculant (6-1122) with selective reactivity for the fines may be added to aggregate clays contained in the feed (6-1102) thus promoting faster settling or drainage. The flocculant may be added prior to entry of the feed (6-1102) into the primary water separation system (6-1104), via a mixer (6-1121) or may be added directly into the primary water separation system. The resulting reduced-water stream (6-1108) resulting from the primary water separation system (6-1104) is passed through the secondary water separation system (6-1110) and the effluent (6-1112) may be subsequently combined with the oversize rejects (6-1114) to produce a slurry (6-1118) ready for processing via the SBE.

[0250] The resulting slurry (6-1118) may be combined with any other appropriate feed source as a bituminous feed (6-1130) for later downstream processing in a process (6-1132) capable of separating fines out of a high fines content aqueous bituminous feed, such as one capable of agglomerating tailings (6-1134) while forming a hydrocarbon product (6-1136).

[0251] Figure 7 is a schematic illustration of a process (7-1200) incorporating the preparation of a aqueous hydrocarbon-containing stream according to Figure 5 and Figure 6 together with an exemplary SBE and solids agglomeration process for recovery of bitumen. An aqueous hydrocarbon-containing feed is derived (7-1230) from WBE of oil sand and has at least 50% water. The feed may have, for example, from 50 wt. % to 95 wt. % water, from 0.1 wt. % to 10 wt. % bitumen, and from 5 wt. % to 40 wt. % solids. This feed is potentially derived from bitumen-lean streams recovered from WBE, but may also be derived from intermediate streams from a WBE. Further, an aqueous hydrocarbon-containing stream meeting these criteria that has not been prepared through a WBE may nevertheless be used as a feed stream.

[0252] Water may be removed (7-1232) from the aqueous hydrocarbon-containing feed having 50 wt. % to 95 wt. % water, resulting in an effluent comprising 40 wt. % water or less, which goes on to be used (7-1234) as bituminous feed either alone or in combination with further hydrocarbon-containing sources. Other hydrocarbon-containing sources may include oversized rejects, recycled extraction liquor, or other sources of bitumen. The resulting mixture should have the consistency of a pumpable slurry. After extraction liquor is added (7-1212) to form the pumpable slurry, the slurry may be directed to further processing. Fine solids and coarse solids are separated (7-1214) from the slurry as a fine solids stream and a coarse solids stream from the initial slurry. Fine solids are agglomerated (7-1216) from the fine solids stream to form an agglomerated slurry comprising agglomerates and low solids bitumen extract. A low solids bitumen extract is separated (7-1218) from the aggregated slurry. In the depicted embodiment, a second solvent is added (7-1220) to the low solids bitumen extract to recover a bitumen extract that may be essentially free of solids. In this way, a hydrocarbon product is derived from an aqueous hydrocarbon-containing stream.

I.B. Feed Blending or Contacting with Flue Gas

[0253] This section describes feed pre-treatment methods to yield a bituminous feed having properties which are suitable for SBE.

[0254] A method for processing a bituminous feed may comprise: a) providing a first bituminous feed having at least one first bituminous feed property falling outside of a target range; b) selecting a second bituminous feed having at least one second bituminous feed property that has a different value than the at least one first bituminous feed property; c) selecting a ratio of the first bituminous feed to the second bituminous feed; d) forming a third bituminous stream, having at least one third bituminous stream property falling within the target range, by combining the first bituminous feed and the second bituminous feed at the ratio; and e) passing the third bituminous feed to a solvent extraction process for extracting bitumen from the third bituminous feed.

[0255] A method for processing a bituminous feed may comprise: a) providing the bituminous feed having a bituminous feed water content outside of a target range; b) selecting a flue gas from a combustion process having a flue gas water content that is different than the bituminous feed water content; c) forming a resultant bituminous feed with a resultant bituminous feed water content within the target range by contacting the bituminous feed and the flue gas; and d) passing the resultant bituminous feed to a solvent extraction process for extracting bitumen from the resultant bituminous feed.

[0256] SBE with solids agglomeration is sensitive to the quantity of aqueous bridging liquid present in the slurry during solids agglomeration. When the amount of aqueous bridging liquid in the slurry is insufficient, agglomeration does not capture enough of the dispersed fine particles in the liquid suspension, which hampers solid-liquid separation. The amount of aqueous bridging liquid in the slurry may be insufficient when a water to solids ratio of aqueous bridging liquid to slurry is less than 0.05. The ratio may vary with ore grade and the method by which the aqueous bridging liquid is introduced. The aqueous bridging liquid may interchangeably be referred to as bridging liquid. The insufficient aqueous bridging liquid scenario can be mitigated by careful control of the amount of additional aqueous bridging liquid added to the slurry. In the case when excess aqueous bridging liquid is present in the slurry, rapid growth of agglomerates can lead to a reduction in bitumen recovery owing to entrapment of the bitumen within the pores of the agglomerated solids. Rapid growth of agglomerates refers to agglomeration occurring faster than dissolution. The amount of aqueous bridging liquid in the slurry may be excess when a water to solids ratio of aqueous bridging liquid to slurry is more than 0.10. The ratio may vary with ore grade and the method by which the aqueous bridging liquid is introduced. The amount of aqueous bridging liquid can be substantially in excess such that agglomerates fail to form and the solids turn into a paste with an extremely low permeability. The amount of aqueous bridging liquid being substantially in excess may lead to costly process delays. The amount of aqueous bridging liquid being substantially in excess may lead to shut-downs due to the failure of the solid-liquid separation process.

[0257] Figure 20 illustrates the relationship between bitumen recovery from a solvent extraction with solids agglomeration process and water content in the oil sand slurry, using cyclohexane as the solvent. The broken line (20-100) at 90% bitumen recovery shows a target recovery. Three levels of agglomeration are illustrated. First, un-agglomerated solids (20-102) provide good bitumen dissolution, poor bitumen filtration, and poor bitumen recovery. Second, micro-agglomeration (20-104) provides good bitumen dissolution, good bitumen filtration, and good bitumen recovery. Third, macro-agglomeration (20-106) provides good bitumen dissolution, good bitumen filtration, and poor bitumen recovery. Since agglomeration occurs more rapidly than dissolution, by extracting (dissolving) most of the bitumen prior to agglomeration, bitumen inclusion may be reduced. In other words, less bitumen may be entrained when agglomeration occurs more rapidly than dissolution.

[0258] When the water content in the slurry is insufficient, agglomeration does not capture enough of the dispersed fines in the liquid suspension. The amount of water in the slurry may be insufficient when a water to solids ratio is less than 0.05. Agglomeration not capturing enough of the dispersed fines in the liquid suspension may hamper solid-liquid separation, and may result in a low fines capture. A low fines capture may be defined as less than 80% fines capture. Figure 20 shows that for a water to solids ratio of below approximately 6 wt. %, un-agglomerated fines can cause the filter and/or filter bed to plug, leading to poor bitumen recovery.

[0259] When excess water is present in the slurry, rapid growth of agglomerates can lead to a reduction in bitumen recovery owing to entrapment of the bitumen within the agglomerated solids. The amount of water in the slurry may be excess when a water to solids ratio is more than 0.10. Figure 20 shows that as the water to solids ratio increases above approximately 10 wt. %, bitumen recovery decreases. As Figure 20 shows, the decrease in bitumen recovery is most likely due to bitumen inclusion within the larger agglomerates. The use of sludge with excess water as the aqueous bridging liquid may lead to larger macro-agglomerates that are more prone to entrapment of bitumen within the pores of the macro-agglomerates. One method to reduce loss of bitumen in the large macro-agglomerates is to have the oil sand slurry operate at a higher solvent to bitumen ratio such that the concentration of bitumen in the entrapped fluid is significantly reduced.

[0260] The solvent to bitumen ratios within a solvent extraction process remain within prescribed ranges irrespective of the bitumen content of the bituminous feed entering the solvent extraction process. An example of a ratio of solvent to bitumen to be selected as a target ratio during bitumen extraction may be approximately 2:1. A ratio as low as 0.75:1 may be acceptable during the initial dissolution of bitumen since the higher bitumen content may assist in the rate of bitumen dissolution. A ratio as high as 3:1 may be acceptable during solid-liquid separation since the higher solvent content may reduce the viscosity of the oil sand slurry. In other words, the ratio may range from 0.75:1 to 3:1. The aforementioned range may include any ratio within and/or bounded by the range. A SBE running continuously with a bituminous feed with a high bitumen content may result in a lowering of the solvent to bitumen ratio to values where the higher viscosity of the bitumen extract inhibits solid liquid separation. Whether or not a given bitumen content is high may depend on factors such as but not limited to slurry density, slurry temperature, asphaltene content, and solvent wash rate. Conversely, a SBE running continuously with a bituminous feed with a low bitumen content may result in a rise of the solvent to bitumen ratio to values that reduce the rate and the amount of bitumen dissolution and/or may result in undesirable asphaltene precipitation. Whether or not a given bitumen content is low may depend on factors such as but not limited to slurry density, slurry temperature, asphaltene content, and solvent wash rate. One way to manage solvent to bitumen ratio is to maintain an excess supply of bitumen that can be used in areas within the solvent extraction process where the solvent-to-bitumen ratio is above the desired value. This way of managing may not be desired; it may require an inventory of bitumen which is expensive to maintain in order to ensure proper control of the solvent to bitumen ratio.

[0261] Macro-agglomeration processes can generally operate in the presence of a much higher aqueous bridging liquid content than micro-agglomeration processes. However, macro-agglomeration is more suitable for bituminous feeds with a solids composition of greater than 15 wt. % fine solids. One way to introduce a higher concentration of fines into the agglomeration process is to use sludge (water and fine particle slurry) as the aqueous bridging liquid. When sludge is used as the aqueous bridging liquid, the addition of the same amount of sludge per unit weight of bituminous feed may result in the production of macro-agglomerates of the same drainage properties regardless of the fines content of the bituminous feed. Sludge, however, may not be available at a solvent extraction mine site.

[0262] The present section describes methods and systems for processing a bituminous feed to yield a bituminous feed having properties which are suitable for solvent extraction. The methods and systems involve processing one or more bituminous feeds and passing a third bituminous feed or a resultant bituminous feed to a solvent extraction process. Accordingly, the methods and systems may be referred to as a “pretreatment” to SBE. The methods provide a

SBE feed that is more suitable for the SBE than conventional solvent extraction feeds. For example, the methods and systems may provide a solvent extraction feed having a water content within a target range. Figures 20 to 26 depict methods and systems of the present section.

[0263] The methods and systems may include providing (25-602) a first bituminous feed (21-202) having at least one first bituminous feed property falling outside of a target range. The first bituminous feed (21-202) may be a problematic bituminous feed. The at least one first bituminous feed property may interchangeably be referred to as at least one property of the first bituminous feed. The first bituminous feed property may be at least one of a water content, a bitumen content, a fines content of solids, and an asphaltene content. The water content may be a particularly suitable property to measure since water acts as the aqueous bridging liquid that controls the agglomeration process.

[0264] The first bituminous feed (21-202) may comprise excess water that makes it unsuitable for the solvent extraction process. The first bituminous feed (21-202) may include, but is not limited to, mined oil sand with a water content of greater than 6 wt. %, bituminous feeds derived from a WBE, or a bituminous feed from a SBE. The first bituminous feed (21-202) may be one of a stream from a WBE, a tailings stream from a water-based oil sand extraction process, mature fine tailings (MFT) or PFT tailings.

[0265] The at least one first bituminous feed property may be measured by a measuring apparatus (21-204). When the at least one first bituminous feed property is a water content, the water content measurements may be taken by a near-infrared (NIR) analyzer, Karl-Fischer titration, Dean-Stark analysis (D-S), microwave sensors, NMR (nuclear magnetic resonance), or hyperspectral imaging. When the at least one first bituminous feed property is a bitumen content, the bitumen content measurements may be taken by NIR, D-S, or hyperspectral imaging. When the at least one first bituminous feed property is a fines content of solids, the fines content measurements may be taken by sieving, FBRM (focused beam reflectance measurement), PVM (particle visual measurement), inline particle size microscopy, laser diffraction, sedimentation methods (e.g. sedigraph), optical microscopy, electrical impedance (e.g. coulter counter), or hyperspectral imaging. When the at least one first bituminous feed property is a solvent to bitumen ratio, the solvent to bitumen ratio may be measured by a densitometer, an NIR analyzer, or hyperspectral imaging. When the at least one first bituminous feed property is an asphaltene content, the asphaltene content measurement in bitumen may be measured by NIR, optical spectroscopy, fluorescence depolarization spectroscopy, n-paraffin titration, or an asphaltene analyzer.

[0266] The methods and systems may include selecting (25-604) a second bituminous feed (21-203) having at least one second bituminous feed property. The at least one second bituminous feed property may interchangeably be referred to as at least one property of the second bituminous feed. The at least one second bituminous feed property may be at least one of a water content, a bitumen content, a fines content of solids, and an asphaltene content. The water content may be a particularly suitable property to measure since water acts as the aqueous bridging liquid that controls the agglomeration process. The at least one second bituminous feed property may have a different value than the at least one first bituminous feed property.

[0267] Selecting the second bituminous feed (21-203) may include exposing the bituminous feed, processed by the methods and systems, to the environment. Exposing the bituminous feed to the environment may evaporate water from the bituminous feed. Evaporating water from the bituminous feed may lower a water content of the bituminous feed. The second bituminous feed (21-203) may be the bituminous feed after being evaporated. In this way, when it is desired for the second bituminous feed (21-203) to have a low water bitumen content feed, the second bituminous feed (21-203) can be made from the bituminous feed using evaporation.

[0268] The at least one second bituminous feed property may be measured by a measuring apparatus (21-206). When the at least one second bituminous feed property is a water content, the water content measurements may be taken by a near-infrared (NIR) analyzer, Karl-Fischer titration, Dean-Stark analysis (D-S), microwave sensors, NMR (nuclear magnetic resonance), or hyperspectral imaging. When the at least one second bituminous feed property is a bitumen content, the bitumen content measurements may be taken by NIR, D-S, or hyperspectral imaging. When the at least one second bituminous feed property is a fines content of solids, the fines content measurements may be taken by sieving, FBRM (focused beam reflectance measurement), PVM (particle vision measurement), laser diffraction, sedimentation methods (e.g. sedigraph), optical microscopy, canty probes, electrical impedance (e.g. coulter counter), or hyperspectral imaging. When the at least one second bituminous feed property is a solvent to bitumen ratio, the solvent to bitumen ratio may be measured by a densitometer, an NIR analyzer, or hyperspectral imaging. When the at least one second bituminous feed property is an asphaltene content, the asphaltene content measurement in bitumen may be measured by NIR, or an asphaltene analyzer.

[0269] The methods and systems may include selecting (25-606) a ratio of the first bituminous feed (21-202) to the second bituminous feed (21-203). By way of illustration, the following numerical example is provided. Consider that a third bituminous feed having a water content of 5 wt. % is desired and that a first bituminous feed has a water content of 30 wt. % while a second bituminous feed has a water content of 1 wt. %. The following equation may be used:

[0270] (weight fraction of 1^{st} stream) x (wt. % water in 1^{st} stream) + (weight fraction of 2^{nd} stream) x (wt. % water in 2^{nd} stream) = (weight fraction of 3^{rd} stream) x (wt. % water in 3^{rd} stream);

[0271] Using “A” as the weight fraction of the 1^{st} stream, “1-A” as the weight fraction of the 2^{nd} stream, and “1” as the weight fraction of the third stream, the equation becomes:

[0272] A x (wt. % water in 1^{st} stream) + (1-A) x (wt. % water in 2nd stream) = (1) x (wt. % water in 3rd stream); which, in our example, becomes:

[0273] $30A + 1 - A = 5$; solving for A provides:

[0274] $A = 4/29$, meaning that 4 parts (by weight) 1^{st} stream may be combined with 25 parts (by weight) 2^{nd} stream to yield a third bituminous feed with a water content of 5 wt. %. In addition to water content, other properties such as bitumen content, fines content of solids, and asphaltene content, may equally be selected by adjusting in this way.

[0275] The methods and systems may include forming (25-608) a third bituminous feed (21-210) by combining the first bituminous feed and the second bituminous feed at the ratio. The first bituminous feed (21-202) and the second bituminous feed (21-203) may be combined (21-208) in a proportion. The first bituminous feed (21-202) and the second bituminous feed (21-203) may be combined (21-208) in a proportion based on the measurements taken at measuring apparatus (21-204) and measuring apparatus (21-206). The first bituminous feed (21-202) and the second bituminous feed (21-203) may be combined in a combining apparatus (21-208) in a proportion that may yield a third bituminous feed (21-210) having at least one third bituminous stream property falling within the target range. The combining apparatus (21-208) may be any suitable combining apparatus (21-208) such as but not limited to a crusher, a tumble drum, a SAG (Semi-Autogenous Grinding) mill, a pump-box, a superpot, or a pipe junction, such as those described in CA 2,810,730 (Spence *et al.*).

[0276] The third bituminous feed (21-210) may interchangeably be referred to as a resulting bituminous feed or a third bituminous stream. The third bituminous feed (21-210) may have the at least one third bituminous stream property falling within the target range. The at least one third bituminous stream property may interchangeably be referred to as at least one property of the third bituminous stream. The third bituminous stream property may be at least one of a water content, a bitumen content, a fines content of solids and an asphaltene content. The water content may be a particularly suitable property to measure since water acts as the aqueous bridging liquid that controls the agglomeration process. The at least one third bituminous stream property may be suitable for solvent extraction. The at least one third bituminous stream property may be more suitable for solvent extraction than the at least one first bituminous feed property and/or the at least one second bituminous feed property.

[0277] Forming the third bituminous feed (21-210) by combining the first bituminous feed (21-202) and the second bituminous feed (21-203) may include adjusting the blending proportions of the first bituminous feed (21-202) with the second bituminous feed (21-203) to form the third bituminous feed (21-210) having the at least one third bituminous stream property falling within the target range. Combining the first bituminous feed (21-202) with the second bituminous feed (21-203) may include mixing the first bituminous feed stream (21-202) with the second bituminous feed stream (21-203). The second bituminous feed stream (21-203) may have a lower water content than the first bituminous feed (21-202). The water content of the third bituminous feed (21-210) may be more suitable for a solvent extraction process than the first bituminous feed (21-202) and the second bituminous feed (21-203). Combining the first bituminous feed (21-202) with the second bituminous feed (21-203) may include mixing the first bituminous feed (21-202) with the second bituminous feed (21-203) to adjust the solvent to bitumen ratio of a downstream oil sand slurry following solvent addition. Combining the first bituminous feed (21-202) with the second bituminous feed (21-203) may include mixing the first bituminous feed (21-202) with the second bituminous feed (21-203) to adjust the fines content of the solids with the third bituminous feed (21-210); the third bituminous feed (21-210) may be suitable for a solvent extraction with solids agglomeration process. Combining the first bituminous feed (21-202) with the second bituminous feed (21-203) may include mixing the first bituminous feed (21-202) with the second bituminous feed (21-203) to reduce variability in the third bituminous feed (21-210); the third bituminous feed (21-210) may enter the solvent extraction process. Combining the first bituminous feed (21-202) and the second bituminous feed (21-203) may include combining the first bituminous feed (21-202) and the second bituminous feed (21-203) to produce the third bituminous feed (21-210) with a ratio of solvent to bitumen at a level to prevent any precipitation or limit precipitation of asphaltenes to less than 10 weight (wt) % of an asphaltene content in the solvent extraction process. To produce the ratio of solvent to bitumen, the amount of solvent added to the solvent extraction may be adjusted and/or the bitumen content of the third bituminous stream may be adjusted, as described above in the numerical example involving adjusting water content. Combining the first bituminous feed (21-202) and the second bituminous feed (21-203) may reduce the feed variability entering the solvent extraction process; combining the first bituminous feed (21-202) and the second bituminous feed (21-203) may result in a reduced feed variability in the third bituminous feed (21-210) to that present in the first bituminous feed (21-202) and/or the second bituminous feed (21-203) before combining the first bituminous feed (21-202) and the second bituminous feed (21-203). Having less feed variability is beneficial to provide a more uniform process and product.

[0278] The methods and systems may include passing (25-610) the third bituminous stream to a solvent extraction process for extracting bitumen from the third bituminous feed (21-210). Bitumen may be extracted from the third bituminous feed (21-210) during the solvent extraction process (21-212). The third bituminous feed (21-210) may be passed to a solvent extraction process (21-212) forming an oil sand slurry, for instance by a pipeline.

[0279] Passing the third bituminous feed (21-210) to the solvent extraction process (21-212) may not preclude earlier solvent extraction. For example, the first bituminous stream, the second bituminous stream, and/or the third bituminous stream may be solvent extracted to some extent prior to passing the third bituminous stream to the solvent extraction process.

[0280] The solvent extraction process may be a solvent extraction with solids agglomeration process. The solvent extraction process may use a paraffinic solvent. The solids agglomeration process may produce macro-agglomerates or micro-agglomerates. Non-limiting examples of a solvent extraction processes that are solvent extraction with solids agglomeration processes, include those described herein.

[0281] The methods and systems of the present section may be suitable for use with the SBE process described herein because the methods and systems of the present section may be used to reduce the amount of aqueous bridging liquid present in a bituminous feed. In the solvent extraction process described herein, the bitumen may first be dissolved from the bituminous feed prior to agglomeration in order to prevent (or limit) the agglomeration process from reducing the rate of bitumen dissolution into the extraction liquor. The amount of aqueous bridging liquid in the oil sand slurry may be reduced in order to prevent (or limit) the amount of coarse solids that are agglomerated. A reduction in coarse solids agglomeration may result in an increase in bitumen recovery by limiting bitumen entrapment only to the pores of the agglomerates formed with the fine solids.

[0282] The pretreatment may be used to control the amount of bridging liquid present in the oil sand slurry. Mined oil sand from the Athabasca region have a typical water content of 1 to 6 wt. %. At this level of water, additional aqueous bridging liquid may be added to the oil sand slurry in order to optimize the solvent extraction with solid agglomeration process. The amount of water in the oil sand can be much greater than 6 wt. %. For example, the oil sand may be mined from a location of unusually high water saturation, or the oil sand after being mined may be exposed to precipitation that increases the water content of the oil sand. As described above, this excess level of water can negatively impact the solvent extraction process. The wet bituminous feed – interchangeably referred to as a first bituminous feed – may be mixed with a dry bituminous feed – interchangeably referred to as a second bituminous feed – in order to yield a third bituminous feed with a suitable water content for the solvent extraction process. The first and second bituminous feeds may be combined in order to produce the third bituminous feed with a water content in a range of 2 to 25 %, or 4 to 8 wt. %, by combining the two streams in an appropriate proportion. The water content of the third bituminous feed may be any number within or bounded by the preceding water content ranges for the third bituminous feed. The dry bituminous feed may be directly mined or may be rendered dry by exposing it to the environment where the water in the bituminous feed can evaporate over time.

[0283] The pretreatment may be used to control the solvent to bitumen ratio of the oil sand slurry in the solvent extraction process. It is typical in a solvent extraction process that the amount of solvent recycled from the SRU is set by the rate of solids flow into the solvent extraction process and operation conditions (e.g. preferred slurry density and solvent to bitumen ratio). Mined oil sand from the Athabasca region have a typical solids content of approximately 85 wt. % regardless of the amount of bitumen saturation within the oil sand. For this reason, it may be preferred that the amount of solvent recycle remains constant in the solvent extraction process. However, a constant solvent recycle can result in a solvent to bitumen ratio in the oil sand slurry that is not in the target range depending on the bitumen content of the bituminous feed. If the solvent to bitumen ratio is lower than a target range, the higher viscosity bitumen extract may inhibit solid liquid separation. If the solvent to bitumen ratio is higher than a target range, the rate and the amount of bitumen dissolution may be reduced and/or may result in undesirable asphaltene precipitation. The changes in the solvent to bitumen ratio can be limited by blending bituminous feeds in order to reduce that variability of bitumen flow into the solvent extraction process. The second bituminous feed may be used to adjust a solvent to bitumen ratio in the solvent extraction process to within a range of 0.5-5.0 or 1.5-2.5, by blending the two streams in an appropriate proportion. To adjust the solvent to bitumen ratio, the bitumen content of the third bituminous stream may be adjusted, as described above in the numerical example involving adjusting water content. These ranges may be suitable for the solvent extraction process.

[0284] The pretreatment may be used to control the amount of fines processed by the solvent extraction with solids agglomeration process. The macro-agglomeration process can operate in the presence of much higher aqueous bridging liquid content than the micro-agglomeration process. The macro-agglomeration is more suitable for bituminous feeds with a solids composition of greater 15 wt. % fines. A first bituminous feed stream with a low fines content can be mixed with a second bituminous feed stream with a fines content greater than 15 wt. % in order to obtain a third bituminous feed stream that is more suitable for the macro-agglomeration of solids. Low grade oil sand, which are typically discarded in WBE of oil sand, may be a suitable second bituminous feed. The first and second bituminous feeds may be combined in order to produce a third bituminous feed with the fines content in a range of 5-50 or 15-40 wt. %, by blending the two streams in an appropriate proportion as, for example, described above in the numerical example involving adjusting water content. The fines content may be any suitable number within or bounded by the preceding fines content ranges.

[0285] The first bituminous feed may be mixed with dry solids to form a third bituminous feed where the dry solids may be stockpiled dry material. More specifically, the first bituminous feed may be mixed with a dry solids stream from the SBE process (or any suitable dry solids stream, or stockpiled dry material) to form a third bituminous feed comprising a water content less than the first bituminous feed. Alternatively, the first bituminous feed may be mixed with a second bituminous feed and the dry solids stream to form a third bituminous feed comprising a water content less than the first bituminous feed. The third bituminous feed may be directed to the SBE process, or the third bituminous feed may be directed to a SBE process comprising solids agglomeration. The dry solids stream may be obtained from the solids tailings drying step of the SBE process. For example, the dry solids stream may be produced from a fluidized bed dryer used to recover solvent from solvent washed agglomerates of the SBE process. The dry solids stream may have a water content of less than 8 wt. %, or less than 5 wt. %. Mixing the first bituminous feed with the dry solids to reduce the water content of third bituminous feed may have the advantage of producing the desired third bituminous feed in the absence of a second bituminous feed with sufficiently reduce water content. The method may have the additional advantage of producing the desired third bituminous feed with reduced water content without having to add process equipment to dry the bituminous feeds.

[0286] Methods and systems for processing a bituminous feed to yield a bituminous feed having properties suitable for solvent extraction may include methods and systems where water content within the bituminous feed is controlled by contacting the bituminous feed with a flue gas from a combustion process.

[0287] The methods and systems may include providing (26-702) the bituminous feed with a bituminous feed water content outside of a target range of 2 - 25 weight (wt.) % or 4 - 8 wt. %.

[0288] The methods and systems may include selecting (26-704) a flue gas from a combustion process having a flue gas water content that is different than the bituminous feed water content. The combustion process may be local to a solvent extraction process, such as the solvent extraction discussed in the present disclosure. The flue gas may help control the water content within the bituminous feed. The use of flue gas for water content control may reduce the oxygen content of the bituminous feed. The oxygen content of the flue gas may be less than one of 3 vol %, 1 vol. % and 0.1 vol. %. The oxygen content of the flue gas may include any number within the preceding ranges. The flue gas may help control the temperature of the bituminous feed. The use of flue gas for water content control may increase a temperature of the bituminous feed. As described in the present disclosure, water or an aqueous solution may be used as an aqueous bridging liquid.

[0289] The flue gas used may be obtained from a combustion process that is in proximity to the solvent extraction process. For example, the flue gas may be from one of a power generation facility and a steam generation facility. The one of the power generation facility and the steam generation facility may be in proximity to a solvent extraction facility. The solvent extraction process may take place at the solvent extraction facility.

[0290] The flue gas may result from stoichiometric combustion of a fuel in order to minimize the amount of oxygen remaining in the flue gas. The stoichiometric combustion, of the combustion process, may be a substantially stoichiometric combustion. An example of a stoichiometric combustion process is described in WO 2012/003080 (Oelfke *et al.*). In Oelfke *et al.*, exhaust gas from a gas turbine system is cooled and then compressed to form a compressed recycle stream. The gas turbine system preferably has a combustion chamber configured to stoichiometrically combust a compressed oxidant and a fuel in the presence of a portion of the compressed recycle stream. The compressed recycle stream acts as a diluent configured to moderate the temperature of the discharge stream from the combustion chamber. The discharge stream is expanded to generate power, drive the compressor used to compress the recycle stream, and produce the exhaust gas. The remaining portion of the compressed recycle stream is the flue gas stream. Flue gas produced from a combustion process, such as that described by Oelfke *et al.*, may be suitable for use in the present methods and systems because the flue gas may be comprised almost entirely of nitrogen and carbon dioxide gas.

[0291] Figures 22A and 22B compare a conventional natural gas combined cycle (NGCC) facility (Figure 22A) with a NGCC system combined with the compressed recycle stream (Figure 22B).

[0292] As shown in Figure 22A, the natural gas combined cycle system combines the Brayton Cycle with the Rankine Cycle. The Brayton Cycle is comprised at minimum with a compressor (22A-302), a combustion chamber (22A-304) and a turbine (22A-306). Air (22A-308) (in excess of a stoichiometric amount) is compressed by the compressor (22A-302) and is then mixed with natural gas (22A-310) in the combustion chamber (22A-304). The hot discharge gas from the combustion process is expanded in the turbine (22A-306) to drive the compressor (22A-302) and an electrical generator. The exhaust gas from the turbine (22A-306) is then directed to a heat recovery steam generator (HRSG) (22A-312) where the heat from the exhaust gas is used to boil the water in the Rankine Cycle. The steam produced in the HRSG is expanded in a steam gas turbine (SGT) (22A-314) that is used to drive an additional electrical generator. As an example, the flue gas (22A-316) from the HRSG (22A-312) may comprise 4 vol. % CO_2, 8 vol. % H_2O, 74 vol. % N_2, 12 vol. % O_2, 2 vol. % other, and have a temperature of 140 °C.

[0293] As shown in Figure 22B, the NGCC system with the compressed recycle stream uses similar equipment as the conventional NGCC facility but with the addition of a second HRSG system (22B-312b) and a second compressor (22B-302b). A stoichiometric amount of air (22B-308b) is used. The second HRSG (22B-312b) is used to further cool the exhaust gas. It may also cool the exhaust gas sufficiently to condense water (22B-316). The cooled exhaust gas (22B-318) is then compressed and a portion of the compressed recycle gas is used as a diluent stream (22B-320) that is configured to moderate the temperature of the discharge stream from the combustion chamber (22B-302b). The remaining portion of the compressed recycle gas is the flue gas stream (22B-316b). As an example, the flue gas (22B-316b) may comprise

10 vol. % CO_2 and 90 vol. % N_2, have a pressure of 19 bar, and have a temperature of 420 °C. The flue gas produced from the NGCC system combined with the compressed recycle (Figure 22B) has a reduced amount of oxygen and water as compared to the flue gas of the NGCC system alone (Figure 22A).

[0294] The NGCC system with the compressed recycle stream produces a high temperature flue gas stream comprised of very small amounts of oxygen and water. The high temperature flue gas stream can be used to control the water content of a bituminous feed to solvent extraction. The high temperature flue gas stream may have a water content of less than 5 vol. % or less than 1 vol. %. The water content of the high temperature flue gas stream may be any number included within the preceding ranges.

[0295] The flue gas may be used to adjust other properties such as oxygen content and temperature. The flue gas may be used to decrease the oxygen content to below a flammable limit.

[0296] The flue gas may be used to increase the temperature of the bituminous feed to within a range of -20 °C to 120 °C or 0 °C to 80 °C. The flue gas may be used to decrease the water content of the bituminous feed. The flue gas may flow countercurrent to the flow of the bituminous feed when the flue gas is used to decrease the water content of the bituminous feed.

[0297] The flue gas from the combustion process may directly come into contact with the bituminous feed or may be cooled in a heat exchanger prior to coming into contact with the bituminous feed if a cooler flue gas is desired in order to form a resultant bituminous stream with a lower temperature.

[0298] The temperature of the flue gas may be greater than one of water dew point temperature of the flue gas and an acid dew point temperature of the flue gas. The temperature of the flue gas may be greater than one of the water dew point temperature of the acid dew point temperature after the flue gas contacts the bituminous feed. In this way, water or acid condensation after the flue gas contacts the bituminous feed can be mitigated.

[0299] The flue gas may be used to increase the water content of the bituminous feed. The flue gas from the combustion process can be directed to a mass exchanger in order to saturate or partially saturate the flue gas with water. The flue gas may be saturated or partially saturated with water before forming a resultant bituminous feed. The flue gas may be cooled in a heat exchanger prior to coming into contact with the bituminous feed. The temperature of the flue gas may be near or at its water dew point temperature before it contacts the bituminous feed, for instance within 10 % above or below the dew point. The temperature of flue gas may be above its acid dew point temperature. The flue gas may flow concurrent to the flow of the bituminous feed when the flue gas is used to increase the water content of the bituminous feed.

[0300] The methods and systems may comprise forming (26-706) a resultant bituminous feed with a resultant bituminous feed water content within the target range by contacting the bituminous feed and the flue gas. The resultant bituminous feed may be used as the previously described second bituminous feed. When the resultant bituminous feed is used as the previously described second bituminous feed there may be another source for the second bituminous feed than those previously described.

[0301] The methods and systems may comprise passing (26-708) the resultant bituminous feed a solvent extraction process for extracting bitumen from the resultant bituminous feed. The solvent extraction process may include extracting bitumen from the resultant bituminous feed. The solvent extraction process may be a solvent extraction process described in the present disclosure.

[0302] The pretreatment of bituminous feed, by using a flue gas, may have the advantage of controlling the amount of aqueous bridging liquid present in the oil sand slurry. Mined oil sand from the Athabasca region have a typical water content between 1 to 6 wt. %. At this level of water, additional aqueous bridging liquid is typically added to the oil sand slurry in order to optimize the solid agglomeration process. However, in some cases, the amount of water in the oil sand can be much greater than 6 wt. %. For example, the oil sand may be mined from a location of unusually high water saturation, or the oil sand after being mined may be exposed to precipitation that increases the water content of the oil sand. The bituminous feed may comprise a mixture of oil sand with a wet bituminous feed such as tailings from a WBE. Such a bituminous feed mixture may require or benefit from additional drying prior to being directed to the solvent extraction process. This excess level of water can negatively impact the solvent extraction process. For example, when an excess amount of aqueous bridging liquid is present in the oil sand slurry, rapid growth of agglomerates can lead to a reduction in bitumen recovery owing to entrapment of the bitumen within the agglomerated solids. In some cases, the amount of aqueous bridging liquid can be sufficiently high that agglomerates fail to form and the solids turn into a paste with an extremely low permeability. This situation could lead to costly process delays and even shut-downs due to the failure of the solid-liquid separation process. Potential benefits of the pretreatment of the bituminous feed with a flue gas in order to decrease the water content of the bituminous feed may be improved bitumen recovery, improved process reliability, and/or less system down-time.

[0303] Figure 23 illustrates a pretreatment of a bituminous feed to decrease the water content of the bituminous feed. Figure 23 includes the system of Figure 22A and 22B up to the point of producing the flue gas (22B-316b). The flue gas (22B-316b) is contacted with a bituminous feed (23-402) during feed pretreatment (23-404) to form a resultant bituminous feed (23-406) which is passed to solvent extraction (23-408). Waste flue gas (23-410) exits the feed pretreatment (23-404). The flue gas may be used to decrease a water content of the bituminous feed to less than 10 wt. % or less than 6 wt. %.

[0304] Pretreatment of a bituminous feed with a flue gas with a higher water content than the bituminous feed can provide the additional water needed for the agglomeration process. The latent heat provided by the condensing water from the flue gas can contribute to increasing the temperature of the bituminous feed to the level needed for the solvent extraction process.

[0305] Figures 24 to 27 illustrate pretreatment of a bituminous feed in order to increase the water content of the bituminous feed. Figures 24 to 27 include the system of Figure 22B except that the flue gas used for pretreatment of the bituminous feed is taken prior to passing through HRSG (22B-312b). The flue gas (24-500) is directed to a mass exchanger (24-501) in order to saturate or partially saturate the flue gas with water (24-503) to produce saturated flue gas (24-514). Saturated flue gas (24-514) is contacted with a bituminous feed (24-502) during feed pretreatment (24-504) to form a resultant bituminous feed (24-506) which is passed to solvent extraction (24-508). Waste flue gas (24-510) exits the feed pretreatment (24-504). The flue gas may be used to increase a water content of the bituminous feed to higher than 0.5 wt. % or higher than 2 wt. %. The water content may be any number within the aforementioned ranges.

[0306] The following two examples illustrate the effect of water content on bitumen recovery.

Example I.B.1

[0307] Approximately 1400 g of oil sand (bituminous feed) with a high water content (11.9 wt. % water; water to solids ratio of 0.14) was mixed with a cyclohexane-bitumen mixture (extraction liquor) to form an approximately 60 wt. % solids oil sand slurry with a solvent to bitumen ratio of 1 at 1500 rpm for 10 min. Additional cyclohexane (extraction liquor) was added to form an approximately 50 wt. % solids oil sand slurry with solvent to bitumen ratio of 2, and mixed at 1500 rpm for additional 7 min. The agglomerates formed by the high initial water content were filtered from the bitumen extract, washed by cyclohexane and vacuumed-dried for 30 seconds on a Buchner funnel with a wedge wire screen (100 μm slot) under vacuum. The residual bitumen in the washed agglomerates was used to calculate bitumen recovery. The bitumen recovery of processing this oil sand (bituminous feed) with high water content was 51%. The poor recovery was most likely due to entrapment of the bitumen within the over-sized agglomerates (approximately 4.4% of agglomerates were larger than 8 mm) due to an excess amount of water in the oil sand slurry. This result indicated that excess water in this oil sand (bituminous feed) makes it unsuitable for the solvent extraction process.

Example I.B.2

[0308] Approximately 350 g of oil sand (first bituminous feed) with a high water content (11.9 wt. % water) was blended with 1050 g of oil sand (second bituminous feed) with a low water content (1.2 wt. % water). The resultant third bituminous feed had a water to solids ratio of 0.045. The third bituminous feed was mixed with a cyclohexane-bitumen mixture (extraction liquor) to form an approximately 60 wt. % solids oil sand slurry with a solvent to bitumen ratio of 1 at 1500 rpm for 10 min. Additional cyclohexane (extraction liquor) was added to form an approximately 50 wt. % solids oil sand slurry with a solvent to bitumen ratio of 2, and mixed at 1500 rpm for additional 5 min. Water was added to achieve a water to solids ratio of 0.08 and the mixture was then mixed at 1500 rpm for additional 2 minutes. The agglomerates were filtered from the bitumen extract, washed by cyclohexane and vacuumed-dried for 30 seconds on a Buchner funnel with a wedge wire screen (100 μm slot) under vacuum. The residual bitumen in the washed agglomerates was used to calculate bitumen recovery. The bitumen recovery of processing this third bituminous feed was 90%. This result indicated that blending oils sands (bituminous feeds) with excess water (unsuitable for the solvent extraction process) with a low water content oil sand (bituminous feed) can eliminate or reduce the formation of over-sized agglomerates and thus maintain good bitumen recovery.

II. Slurry Preparation and Bitumen Extraction

[0309] **Slurry System.** The slurry may be prepared in a slurry system. The slurry system may comprise a mix box, a pump, a hopper-jet pump assembly (for instance as described in Canadian Patent Application No. 2,900,391), or a combination of these. By slurrying the solvent, or extraction liquor, together with the bituminous feed, and optionally with additional additives, the bitumen entrained within the feed is given an opportunity to become extracted into the solvent phase prior to downstream separation of fine and coarse solid streams and prior to agglomeration.

[0310] The resulting slurry from the slurry system may have a solid content in the range of 5 to 70 wt. %., 30 to 60 wt. %, or 40 to 65 wt. % based on the weight of the oil sand slurry. The oil sand slurry may have a solid content of greater than 65 wt. % based on the weight of the oil sand slurry. 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. For agglomeration within a pipeline, a slurry with a solid content in the range of 5 to 65 wt. % may be suitable for effective agglomeration. For example, suitable agglomerates have been shown to form within a pipeline with a slurry solid content of 20 wt. %.

[0311] In the case of mixing type vessels, a lower solid content may be preferred since that may assist in the proper mixing of the bridging liquid and reduce the mixing energy needed to keep the slurry well mixed. In the case of rolling type vessels, a higher solid content may be preferred since that may increase the compaction forces used in the comminution of agglomerates. Additionally, the increased compaction forces may reduce the amount of hydrocarbons that remain in the agglomerates and produce stronger agglomerates.

[0312] The slurry may have a temperature in the range of 20-100 °C, 20-80 °C, 20-70 °C, 20-60 °C, or 20-40 °C. Temperatures above 60 °C, above 70 °C, above 80 °C, above 90 °C, or above 100 °C may be feasible, and temperatures approaching the boiling point of the solvent may be used, but may be generally avoided due to possible complications which may result from high vapor pressures. A process temperature 10 - 40 °C below the normal boiling point of the solvent may be desirable. An elevated oil sand slurry temperature (e.g. 60 - 80 °C) may be desired to increase the bitumen dissolution rate and reduce the viscosity of the slurry to promote more effective sand digestion and agglomerate formation. An elevated slurry temperature may be desired to improve the solid-liquid separation process. An elevated oil sand slurry temperature may result in a reduced slurry viscosity, which in turn, may improve solid-liquid separation.

[0313] 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. When the temperature of the oil sand slurry may be 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 a 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.

[0314] In some prior art processes, solvent is introduced at the time of agglomeration, which may require more residence time within the agglomerator, and may lead to incomplete bitumen dissolution and lower overall bitumen recovery. The slurry system described herein may advantageously permit contact and extraction of bitumen from solids within the initial slurry, prior to agglomeration. Forming an initial slurry prior to agglomeration may advantageously permit flexible design of the slurry system and may simplify means of feeding materials into the agglomerator.

[0315] The slurry system may receive crushed ore from a surge bin or stock pile, and promote mixing of the crushed ore with a non-aqueous solvent so as to form a slurry. Water may be added to the slurry system so as to achieve the appropriate water content for the agglomeration stage. The slurry system may have a feed section which may comprise a hopper to receive crushed ore from the surge bin and conveyors to move the ore to a subsequent mixing unit. A low oxygen environment may be achieved in the feed section through use of a purge gas, such as natural gas, in the interests of excluding oxygen and avoiding explosive potential. Because a flowable slurry is formed within the mixing unit, the slurry may be pumped or otherwise conveyed in a flowable manner into the agglomerator. Thus, the slurry does not need to be further crushed or screw-fed into the subsequent agglomeration stage. Exemplary mixing units include a mix box, cyclofeeder, tumbler, rotary breaker, a stirred tank or other devices in which the mixing of solvent slurry can be effected. The mixing unit can be configured to feed the resulting slurry to one or more agglomerators using a pump or by gravity. Gravity may be used to deliver the slurry to the agglomerator(s) in any appropriate manner, such as via chutes with flow diverter gates. Flow to the agglomerator may be directed only by gravity, reducing the energy input required to pump flowable fluids.

[0316] Coarse solids or rejects, for example oversized solids which are not further broken down prior to entry within the slurry system, can enter the slurry system but can be separated and sent directly to filtration or solvent recovery instead of being forwarded on to the agglomeration stage. In this way, agglomeration may be optimized for appropriately sized fines and solids. The residence time in the mixing unit may be fixed such that complete or substantial bitumen dissolution occurs before the slurry is delivered to the agglomerator.

[0317] **Solvent.** The solvent is used to extract bitumen from the bituminous feed. The term “solvent” as used herein should be understood to mean either a single solvent, or a combination of solvents.

[0318] To extract bitumen from oil sand using a solvent based extraction process, a solvent may be combined with a bituminous feed. The solvent and bituminous feed may be combined in any suitable mechanism. For example, the solvent and bituminous feed may be combined in an extractor to form an oil sand slurry. Complete or partial bitumen dissolution into the solvent may occur in the extractor. The extractor may comprise at least one of a slurry system and an extraction vessel. The solvent entering the extractor may be recycled to the extractor from one or more downstream steps. The solvent may comprise residual bitumen and residual solid fines.

[0319] The solvent may be capable of dissolving the bitumen in the bituminous feed. Bitumen may be added to the bituminous feed along with the solvent, for instance in a range of between 10 and 70 wt. %, or between 10 and 50 wt. % based on a combined weight of bitumen and solvent that is added to the bituminous feed. Adding bitumen and solvent to the bituminous feed may reduce solvent inventory requirements. In cases where a non-aromatic hydrocarbon solvent is used as the solvent based extraction process solvent, the bitumen added with the solvent may increase the dissolution rate of the incoming bitumen. In cases where a non-aromatic hydrocarbon solvent is used, the bitumen added with the solvent may increase the solubility of the solvent/bitumen towards dissolving additional bitumen in the bituminous feed. In cases where a paraffinic solvent is used as the solvent, the bitumen added with the solvent may avoid or limit precipitation of asphaltenes.

[0320] The solvent may have a final boiling point of less than 200 °C. 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. When a low boiling point solvent is selected, it may be one having a boiling point of less than 100 °C. The solvent may have a boiling point of 30 °C to 90 °C.

[0321] The solvent may or may not include low boiling point solvents such as low boiling point cycloalkanes, or a mixture of such cycloalkanes, which substantially dissolve asphaltenes. The solvent may comprise a paraffinic solvent in which the solvent to bitumen ratio, the temperature, the pressure or a combination thereof are maintained at levels to avoid or limit precipitation of asphaltenes.

[0322] It may desirable to use hydrocarbon solvents that preferentially precipitate asphaltenes from the bitumen. The precipitated asphaltenes may agglomerate with the oileophilic solids within the slurry which can help to produce a bitumen extract with less entrained fine particles.

[0323] 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.

[0324] The solvent may comprise an organic solvent or a mixture of organic solvents. For example, the solvent may comprise a paraffinic solvent, an open chain aliphatic hydrocarbon, a cyclic aliphatic hydrocarbon, or a mixture thereof. Should a paraffinic solvent be utilized, it may comprise an alkane, a natural gas condensate, a distillate from a fractionation unit (or diluent cut), or a combination of these containing more than 40% small chain paraffins of 5 to 10 carbon atoms. This would be considered primarily a small chain (or short chain) paraffin mixture. Should an alkane be selected as the solvent, the alkane may comprise a normal alkane, an iso-alkane, or a combination thereof. The alkane may specifically comprise heptane, iso-heptane, hexane, iso-hexane, pentane, iso-pentane, or a combination thereof. Should a cyclic aliphatic hydrocarbon be selected as the solvent, it may comprise a cycloalkane of 4 to 9 carbon atoms. A mixture of C_4-C_9 cyclic and/or open chain aliphatic solvents would be appropriate. For example, it can be a mixture of C_4-C_9 cyclic aliphatic hydrocarbons and paraffinic solvents where the percentage of the cyclic aliphatic hydrocarbon in the mixture is greater than 50%. Some of these listed solvents may or may not be low boiling point solvents.

Exemplary cycloalkanes include cyclohexane, cyclopentane, or a mixture thereof. 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_4-C_{10} cyclic and/or open chain aliphatic solvents would also be appropriate.

[0325] 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 herein as a small chain (or short chain) paraffin mixture.

[0326] Solvent may be recycled from a downstream step. For instance, as described below, solvent recovered in a SRU, may be used to wash agglomerates, and the resulting stream may be used as solvent. As a result, the solvent may comprise residual bitumen and residual solid fines.

[0327] The solvent may also include additives. These additives may or may not be considered a solvent *per se*. Possible additives may be components such as de-emulsifying agents or solids aggregating agents. Having an agglomerating agent additive present in the bridging liquid and dispersed in the first solvent may be helpful in the subsequent agglomeration step. Exemplary agglomerating agent additives include cements, fly ash, gypsum, lime, brine, water softening wastes (e.g. magnesium oxide and calcium carbonate), solids conditioning and anti-erosion aids such as polyvinyl acetate emulsion, commercial fertilizer, humic substances (e.g. fulvic acid), polyacrylamide based flocculants and others. Additives may also be added prior to gravity separation with the second solvent to enhance removal of suspended solids and prevent emulsification of the two solvents. Exemplary additives include methanoic acid, ethylcellulose and polyoxyalkylate block polymers.

[0328] 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. When it is said that the first solvent and the second solvent may have "similar" boiling points, it is meant that the boiling points can be the same, but need not be identical. For example, similar boiling points may be ones within a few degrees of each other, such as, within 5 degrees of each other would be considered as similar boiling points. The first solvent and the second solvent may be the same according to certain embodiments, in which case, having "similar" boiling points permits the solvents used to have the same boiling point. While the solvent extractions may be initiated independently, there is no requirement for the first solvent to be fully removed before the second solvent extraction is initiated.

[0329] **Extraction Liquor.** The extraction liquor comprises a solvent used to extract bitumen from the bituminous feed.

[0330] The extraction liquor may comprise a hydrocarbon solvent capable of dissolving the bitumen. The extraction liquor may be a solution of a hydrocarbon solvent(s) and bitumen, where the bitumen content of the extraction liquor may range between 10 to 50 wt. %. It may be desirable to have dissolved bitumen within the extraction liquor in order to increase the volume of the extraction liquor without an increase in the required inventory of hydrocarbon solvent(s). In cases where non-aromatic hydrocarbon solvents are used, the dissolved bitumen within the extraction liquor may also increase the solubility of the extraction liquor towards dissolving additional bitumen.

[0331] The extraction liquor may be mixed with the bituminous feed to form a slurry where most or all of the bitumen from the oil sand is dissolved into the extraction liquor. The solids content of the slurry may be in the range of 10 wt. % to 75 wt. %, or 50 to 65 wt. %. A slurry with a higher solids content may be more suitable for agglomeration in rolling type vessels, where the compressive forces aid in the formation of compact agglomerates. For turbulent flow type vessels, such as an attrition scrubber or a pipeline, a slurry with a lower solids content may be more suitable.

[0332] Extraction liquor may be recycled from a downstream step. For instance, as illustrated in Figure 34 and Figure 35, solvent (34-330, 35-430) recovered in the SRU (34-328, 35-428), is used to wash agglomerates, and the resulting stream is then used as extraction liquor. As a result, the extraction liquor may comprise residual bitumen and residual solid fines. The residual bitumen may be partially deasphalted or completely deasphalted bitumen. The residual bitumen increases the volume of the extraction liquor and it may increase the solubility of the extraction liquor for additional bitumen dissolution. Residual solids fines in the extraction liquor may act as emulsion stabilizers. A detailed description of using deasphalted bitumen as the bitumen in the extraction liquor is provided in the Product Cleaning & Bitumen Handling section below. Deasphalted bitumen may allow for operation at higher S:B without having to worry about asphaltene precipitation (or reducing the threat of problematic amounts of asphaltene precipitation).

[0333] ***First Solvent.*** Where two solvents for extracting bitumen are added in different locations, they may be referred to as first and second solvents. The first solvent may comprise an organic solvent or a mixture of organic solvents. For example, the first solvent may comprise a paraffinic solvent, an open chain aliphatic hydrocarbon, a cyclic aliphatic hydrocarbon, or a mixture thereof. Should a paraffinic solvent be utilized, it may comprise an alkane, a natural gas condensate, a distillate from a fractionation unit (or diluent cut), or a combination of these containing more than 40% small chain paraffins of 5 to 10 carbon atoms. These embodiments would be considered primarily a small chain (or short chain) paraffin mixture. Should an alkane be selected as the first solvent, the alkane may comprise a normal alkane, an iso-alkane, or a combination thereof. The alkane may specifically comprise heptane, iso-heptane, hexane, iso-hexane, pentane, iso-pentane, or a combination thereof. Should a cyclic aliphatic hydrocarbon be selected as the first solvent, it may comprise a cycloalkane of 4 to 9 carbon atoms. A mixture of C_4-C_9 cyclic and/or open chain aliphatic solvents would be appropriate. Exemplary cycloalkanes include cyclohexane, cyclopentane, or a mixture thereof.

[0334] If the first solvent is selected as the distillate from a fractionation unit, it may for example be one having a final boiling point of less than 180 °C. An exemplary upper limit of the final boiling point of the distillate may be less than 100 °C.

[0335] A mixture of C_4-C_{10} cyclic and/or open chain aliphatic solvents would also be appropriate. For example, it can be a mixture of C_4-C_9 cyclic aliphatic hydrocarbons and paraffinic solvents where the percentage of the cyclic aliphatic hydrocarbon in the mixture is greater than 50%.

[0336] ***Second Solvent.*** The second solvent may be selected to be the same as or different from the first solvent, and may comprise a low boiling point alkane or an alcohol. The second solvent, when different from the first solvent, may be one that improves the washing of agglomerates. Under certain circumstances, the second solvent is not selected as one that can cause deasphalting. For example, a stream derived from SBE may later be directed to a froth treatment process, or other deasphalting process, within a WBE. In such a case, it is undesirable to cause deasphalting within the SBE (through selection of the second solvent) because deasphalting can be deferred to the later froth treatment stage. Where the product of SBE is later deasphalted and further cleaned in a water-based process (e.g. PFT), the second solvent utilized in SBE should not be one that causes deasphalting (product cleaning), but rather should be selected to accomplish further washing and/or bitumen extraction, without effectively deasphalting the stream during the SBE.

[0337] The second solvent may have an exemplary boiling point of less than 100 °C. The second solvent may be mixed with feed into the solid-liquid separation steps. Because the first solvent is not used in both agglomeration and the solid-liquid separation steps as described in prior art, a second solvent that is miscible with the agglomerate bridging liquid (for example, miscible with water) may be employed at the solid-liquid separation stage. In other words, the two processing steps can be conducted independently and without the solid-liquid separation disrupting the agglomeration process. Thus, selecting the second solvent to be immiscible in the first solvent, and/or having the ability to be rendered immiscible after addition, would be optional criteria.

[0338] The second solvent may comprise a single solvent or a solvent system that includes a mixture of appropriate solvents. The second solvent may be a low boiling point, volatile, polar solvent, which may or may not include an alcohol or an aqueous component. The second solvent can be C_2 to C_{10} aliphatic hydrocarbon solvents, ketones, ionic liquids or biodegradable solvents such as biodiesel. The boiling point of the second solvent from the aforementioned class of solvents may be less than 100 °C.

[0339] The second solvent may be of lower boiling point than the first solvent. The second solvent may be added during the dissolution step, the agglomeration step and/or solid-liquid separation step. The first solvent may be used in the dissolution step because its higher boiling point may allow for higher solvent temperature which may be desirable for thawing frozen bituminous feeds, increasing slurry temperature, and increasing bitumen dissolution rates. The second solvent may be added prior to the agglomeration step to dilute the slurry and increase the solvent to bitumen ratio. The location of the second solvent addition may be where an extraction liquor is added. Exemplary locations for second solvent addition include as the motive fluid for a jet pump and as the wash solvent for oversized reject stream. The second solvent may additionally be used as all or a portion of the wash solvent in the solid-liquid separation step.

[0340] The use of a lower boiling point second solvent in the manner described herein may have the advantage of improving solvent recovery from the solids. For example, a first solvent may be cyclohexane with a normal boiling point approximately 80 °C and the second solvent may be cyclopentane with a normal boiling point of approximately 48 °C. Solids wetted with only cyclohexane may not be sufficiently dried of the solvent during the drying process as a result of the solids temperature being limited to 100 °C or less. The limiting the temperature of the solids to 100 °C or less may be due to the presence of liquid water within the agglomerates and/or the use of steam near atmospheric pressure as the heating and sweeping fluid. In contrast, solids wetted with a blend of cyclohexane and cyclopentane may produce a high enough vapor pressure to allow for the sufficient drying of the solids even when the temperature of the solids is limited to 100 °C or less. The lower dewpoint of the solvent blend compared to that of pure cyclohexane will also limit condensing of solvent in regions where the temperature of the solids is lower.

[0341] ***Ratio of Solvent to Bitumen in Initial, or Agglomeration, Slurry.*** An oil sand slurry may be fed into an agglomerator. The SBE may be adjusted to render the ratio of the solvent to bitumen in the slurry at a level that avoids precipitation of asphaltenes during agglomeration.

[0342] It may be that some amount of asphaltene precipitation is unavoidable, but by adjusting the amount of solvent flowing into the system, with respect to the expected amount of bitumen in the bituminous feed, when taken together with the amount of bitumen that may be entrained in the solvent (or extraction liquor) used, can permit the control of a ratio of solvent to bitumen in the slurry system, the agglomerator, and/or the extraction vessel. When the solvent is assessed for an optimal ratio of solvent to bitumen during agglomeration, the precipitation of asphaltenes can be minimized or avoided beyond an unavoidable amount. Another advantage of selecting an optimal solvent to bitumen ratio is that when the ratio of solvent to bitumen is too high, costs of the process may be increased due to increased solvent requirements.

[0343] An exemplary ratio of solvent to bitumen to be selected as a target ratio during agglomeration may be around, or less, than 2:1. A ratio of 5:1 to 1.5:1 or 3:1 to 1.5:1 or 2:1 to 1.5:1, or less, may also be desired target ratios for agglomeration. A ratio of 1.5:1 or less, and a ratio of 1:1 or less, for example, a ratio of 0.75:1, would also be considered acceptable target ratios for agglomeration. For clarity, ratios may be expressed herein using a colon between two values, such as "2:1", or may equally be expressed as a single number, such as "2", which carries the assumption that the denominator of the ratio is 1 and is expressed on a weight to weight basis.

[0344] Where precipitation in a pipeline is preferred, the solvent to bitumen ratio may be increased past the point of incipient precipitation, a solvent to bitumen ratio of at least 2:1 or greater may be desired.

[0345] In some cases, the entrapment of a significant amount of hydrocarbon fluid within the agglomerates may be unavoidable. This may occur, for example, as a result of the formation of macro-agglomerates and/or due to the presence of excessive amount of bridging liquid. The entrapment of the hydrocarbon fluid may significantly reduce the bitumen recovery of the SBE process. One method to reduce loss of bitumen is to have the oil sand slurry operate at a higher solvent to bitumen ratio such that the concentration of bitumen in the entrapped fluid is reduced. The solvent to bitumen ratio may be greater than 2:1, or greater than 3:1, or greater than 5:1, or greater than 7:1. It may additionally be desirable to limit solvent to bitumen ratio to values that do not significantly reduce the slurry density below the typical values during the extraction and/or agglomeration process.

[0346] For certain choice of extraction solvent, the higher solvent to bitumen ratio may reduce the rate of bitumen dissolution. For example, it has been found that rate of bitumen dissolution within a bituminous feed may decrease as the bitumen content of the extraction liquor is decreased. The reduction in dissolution rate may be compensated for by increasing the residence time of the dissolution process. The residence time of the dissolution process may be increased by extending the solvent wet crushing the bituminous feed and/or by dissolving the bulk of the bitumen within a pipeline where the residence time within the pipeline can be readily increased by extending the length of the pipeline.

[0347] Measurement of the solvent and bitumen content of the extraction liquor and/or bitumen extract could occur directly or by proxy. Direct measurement of solvent and bitumen content could involve evaporating off the solvent and measuring the mass of both liquids, or use of a gas chromatograph, mass balance, spectrometer, or titration. Indirect measurement of solvent and bitumen content could include measuring: density, the index of refraction, opacity, or other properties.

[0348] ***Process Temperatures.*** The process may occur at a wide variety of temperatures. In general, the heat involved at different stages of the process may vary. One example of temperature variation is that the temperature at which the low solids bitumen extract is separated from the agglomerated slurry may be higher than the temperature at which the first solvent is combined with the bituminous feed. Further, the temperature at which the low solids bitumen extract is separated from the agglomerated slurry may be higher than the temperature at which solids are agglomerated. The temperature increase during the process may be introduced by recycled solvent streams that are re-processed at a point further downstream in the process. By recycling pre-warmed solvent from later stages of the process into earlier stages of the process, energy required to heat recycle stream is lower and heat is better conserved within the process. Alternatively, the temperature of the dilution solvent may be intentionally raised to increase the temperature at different stages of the process. An increase in the temperature of the solvent may result in a reduced viscosity of mixtures of solvent and bitumen, thereby increasing the speed of various stages of the process, such as washing and/or filtering steps.

[0349] ***Heating Bituminous Feed With Steam.*** Steam may be added to the bituminous feed before combining with the solvent, to increase the temperature of the bituminous feed to a temperature of from 0 °C to 60 °C. Steam may be of particular benefit when oil sand is mined in cold conditions, such as during winter time. The steam may be added to heat the oil sand or other bituminous feed to a temperature of from 0 °C to 30 °C. The temperatures recited here are simply approximate upper and lower values. Because these are exemplary ranges, provided here primarily for illustration purposes, it is emphasized that values outside of these ranges may also be acceptable. A steam source for pre-conditioning the initial slurry entering the separator may be an optional component of the system. Other methods of heating the bituminous feed or the solvent (or solvent/bitumen combination) used to form the initial slurry may be incorporated into the process.

[0350] During the winter, a bituminous feed may be at a low temperature below 0 °C due to low temperature of the ambient outdoor surroundings, and the addition of steam to heat the feed to a level greater than 0 °C would be an improvement over a colder temperature. During hot summer conditions, the temperature of the bituminous feed may exceed 0 °C, in which case, it may not be beneficial to heat the bituminous feed. Addition of steam may be desirable for processing efficiency reasons, and it is possible that the upper limit of the ranges provided may be exceeded.

[0351] Steam pre-conditioning of the oil sand before making contact with solvent in the slurry system may have the beneficial effect of raising the temperature of the input bituminous feed. The amount of steam added is lower or equal to the amount of water required for agglomeration. Slurrying the input feed with a low boiling point solvent is promoted without the use of a pressurized mixing system. Since steam pre-conditioning permits the use of low boiling point solvents, a higher level of solvent recovery from tailings can be realized with reduced energy intensity relative to conventional processes.

[0352] During the winter, incoming oil sand may be about -3 °C. At this temperature, the separation process would require more heat energy to reach the process temperatures between about 0 °C and 60 °C, or more particularly for an exemplary processing temperature of about 30 °C. The solvent boiling point may be less than about 100 °C. For a low boiling point solvent, this heating obtained through steam pre-conditioning may be adequate to meet the processing requirement. For example, by heating the oil sand in a pre-conditioning step, a temperature can be achieved that is higher than could be achieved by heating the solvent alone, and adding it to a cold bituminous feed. In this way, optimal process temperatures can be achieved without any need to use a pressurized mixing system for solvent heating. Therefore, the steam not only provides water, but also some of the heating required to bring the components of the initial slurry to a desired temperature.

[0353] Once included as steam in a pre-conditioning step, the water content of the initial slurry may be about 11 wt. % or less, and when expressed as a percent of solids, about 15 wt. % is an upper limit to the optimal level.

[0354] If steam pre-conditioning does not occur, water may be added at the agglomeration step. In instances where steam pre-conditioning is used, about half of the water requirement may be added as steam, and further amounts of water can be added when the fine solids stream is transferred into the agglomerator.

[0355] Where no steam pre-conditioning is employed, a slurry comprising the bituminous feed together with the solvent may be prepared within the slurry system. A solvent vapor may be added to the bituminous feed in the slurry stage to capture the latent heat at atmospheric pressure without need to pressurize the mixing vessel.

[0356] ***Low Oxygen for Initial Slurry.*** The slurry may be formed in a low oxygen environment. A gas blanket may be used to provide this environment, or steam may be used to entrain oxygen away from the bituminous feed prior to addition of solvent. The gas blanket, when used, may be formed from a gas that is not reactive under process conditions. Exemplary gasses include, but are not limited to, nitrogen, methane, carbon dioxide, argon, steam, or a combination thereof.

II.A Integration of WBE and SBE Systems

[0357] It is desirable to optimize efficiencies of geographically proximal WBE and SBE systems by integrating streams from one system into the other, in situations where such streams may be used effectively, for example to increase bitumen recovery, produce a cleaner product, and/or increase thermal efficiencies.

[0358] There is described herein a process for extracting bitumen from oil sands into a bitumen-rich stream, the process comprising: (a) separating bitumen from oil sands by addition of water to form a bitumen-enhanced stream and a bitumen-lean stream; (b) mixing the bitumen-lean stream with additional oil sands to form a mixed stream; (c) adding solvent to the mixed stream to extract bitumen from the mixed stream into the solvent, thereby forming a bitumen-depleted stream and an extracted bitumen stream; and (d) mixing the extracted bitumen stream with the bitumen-enhanced stream to form a bitumen-rich stream.

[0359] Processes are described herein which integrate SBE procedures with certain aspects of WBE procedures for extraction of hydrocarbon from mineable deposits. Hydrocarbon-containing streams from WBE processes can be directed to SBE processes, and/or streams from SBE processes can be directed to water-based processes. This may have the possible advantages of reducing and/or eliminating process equipment currently used in either the WBE process or SBE process.

[0360] Furthermore, the integration of these extraction processes may also lead to an overall reduction in water use in the WBE process per unit of bitumen produced. Other benefits may include reduced tailings volumes, improved operation of both the water-based and SBE processes, and increased overall bitumen recovery from oil sands. Other possible integration opportunities include directing the bitumen product derived from SBE to the WBE process. For example, solvent extracted bitumen product may be directed to the froth treatment stage of WBE process for further processing. This integration may result in the advantage of producing a cleaner pipelineable product from the solvent extracted bitumen, which is optimally fungible, with 300 ppm or less of total solids content.

[0361] A reduction in fresh water withdrawal from nearby rivers may be realized. Improved tailings management versus currently practiced WBE process could also be an advantage of the processes and systems described herein. Further, the integration of WBE and SBE processes may have the advantage of reduced energy intensity, and commensurate cost reductions. Heat generated during SBE may be captured to heat water used in the WBE process and vice versa. Further, heated streams may be combined with cold streams to achieve process efficiencies.

[0362] A process for extracting bitumen from oil sands into a bitumen-rich stream may comprise (a) separating bitumen from oil sands by addition of water to form a bitumen-enhanced stream and a bitumen-lean stream; (b) mixing the bitumen-lean stream with additional oil sands to form a mixed stream; (c) adding solvent to the mixed stream to extract bitumen from the mixed stream into the solvent, thereby forming a bitumen-depleted stream and an extracted bitumen stream; and (d) mixing the extracted bitumen stream with the bitumen-enhanced stream to form a bitumen-rich stream.

[0363] Bitumen may be extracted from oil sand into a bitumen-rich stream. The process may involve separating bitumen from oil sand by addition of water to form a bitumen-enhanced stream and a bitumen-lean stream. This may be done, for example, using WBE, and the bitumen-enhanced stream may be, for example froth, sales bitumen product, FSU overflow, or SRU underflow. Additionally, the bitumen-enhanced stream may be directed to SBE for use as a bituminous feed.

[0364] The bitumen-lean stream may be mixed with additional oil sand to form a mixed stream. The bitumen-lean stream may be partially dewatered before mixing with additional oil sand, for example, to a level of 40% water by weight or less.

[0365] Solvent may be added to the mixed stream to extract bitumen from the mixed stream into the solvent, thereby forming a bitumen-depleted stream and an extracted bitumen stream. This may be done, for example, in a SBE, and the bitumen-lean stream may be derived from, middlings, primary separation tailings, flotation tailings, mature fine tailings, froth treatment tailings (such as from FSU underflow or TSRU), or other streams derived from WBE, such as a reject stream from a slurry preparation system of a WBE.

[0366] The extracted bitumen stream may then be mixed with the bitumen-enhanced stream to form a bitumen-rich stream. Solvent may be removed from the extracted bitumen stream before mixing with the bitumen-enhanced stream. Once formed, the bitumen-rich stream may be subsequently processed to remove residual solids and water therefrom to produce a product cleaned bitumen, which may be upgraded on site. Such processing may occur for example in a froth treatment unit of a WBE to produce a product cleaned bitumen. The bitumen-rich stream may be processed to meet fungible specifications so as to produce a fungible bitumen product. An exemplary mode of treatment for the bitumen-rich stream is within PFT, which can achieve a fungible bitumen product. Advantageously, the bitumen-rich stream can be mixed with the bitumen-lean stream before being directed to PFT, and the bitumen-lean stream can be partially dewatered before being mixed in this way.

[0367] The bitumen-enhanced stream may be referred to as "sales bitumen product", in instances wherein mixing the extracted bitumen stream yields a bitumen-rich stream that is fungible.

[0368] The bitumen-depleted stream may be one comprising agglomerated fines, optionally derived from the mixed stream after adding solvent to the mixed stream, forming agglomerates in a SBE. Such agglomerates may be washed on a filter using countercurrent washing. Heat may be recovered from a SRU of the SBE.

[0369] Where WBE is used to form the bitumen-enhanced stream, and SBE is used to form the bitumen-depleted and extracted bitumen streams, it is possible to consolidate a solvent recovery step of the WBE with a solvent recovery step of the SBE to realize efficiency in the process. The WBE may employ a primary separation vessel for recovering bitumen froth and an FSU for producing the bitumen-enhanced stream. When SBE is employed, it may be SBE with solids agglomeration.

[0370] Accordingly, an aspect described herein relates to the integration of water-based processes for extraction of bitumen with solvent-based processes for extraction of bitumen in order to capture synergies between the two extraction processes. Advantages of WBE may include: the dominate use of water, which is relatively an inexpensive and environmentally benign liquid; and the production of a fungible bitumen product when PFT is used to treat the bitumen froth. Advantages of SBE may include: good recovery of bitumen from streams containing a large amount of fines; reduced volume of tailings produced compared to WBE tailings; and that solvent extracted bitumen can have a reduced solids and water content compared to bitumen froth, for example, containing 2 wt. % or less of entrained solids and 1 wt. % or less of entrained water in the final product.

[0371] Figure 3 is a schematic representation of a process (3-800) in which WBE streams are directed into a SBE. Recovery of bitumen from oil sand into a bitumen-rich stream is achieved. The bitumen is separated (3-802) from oil sand by addition of water to form a bitumen-enriched aqueous stream and a first bitumen-lean stream. The first bitumen-lean stream is mixed (3-804) with additional oil sand to form a mixed stream. Subsequently solvent is added (3-806) to the mixed stream to extract bitumen from the mixed stream into the solvent, forming a second bitumen-lean stream and an extracted bitumen stream. The extracted bitumen stream is then mixed (3-808) with the bitumen-enriched aqueous stream to form a bitumen-rich stream.

[0372] Figure 4 illustrates numerous exemplary feed streams derived from WBE, which can be directed to and further extracted within SBE. Such streams include, but are not limited to, middlings of the primary separation vessel, flotation tails, and froth treatment tailings, such as FSU underflow. In this illustration, an "X" is shown for each process component of a water-based process which could be impacted by either elimination or reduction by forwarding such streams into the SBE.

[0373] Figure 4 depicts an example of the integration of the WBE with the SBE, and shows that many of the common unit processes used to handle bitumen-lean streams produced in the WBE may be eliminated and the bitumen-lean streams can be directed to SBE in order to extract the bitumen within. The bitumen-lean streams may be combined with additional oil sand, which are minimally altered or unaltered, prior to entry into a SBE. The bitumen-lean streams may be conditioned so that the resulting slurry with the oil sand has a water content that does not impede solvent extraction. The ratio of water to solids within a bitumen-lean stream and oil sand slurry may be conducive to the formation of agglomerates in SBE with solids agglomeration such as a process described herein. As described below with reference to Figure 4, the residual solids and water that are contained in the solvent extracted bitumen stream are removed by mixing the stream with bitumen froth and directing the combined streams to the froth treatment unit of the WBE.

[0374] Figure 4 shows a process (4-900) which is typical of those processes used for WBE of bitumen from oil sand comprises the initial input of ore (4-901) from oil sand, or another bitumen-containing product. Primary water-based separation occurs in a primary separation vessel or PSV (4-902). The primary separation vessel typically produces three streams, a bitumen enriched stream containing some fines (4-903) that is typically directed as froth (4-904) to further treatment, a middling stream (4-906) with a considerable fines content, and an underflow of tailings (4-908a). Middlings (4-906) may be directed to secondary floatation (4-910) from which residual froth (4-912) can be removed and re-directed to the PSV or directed to froth treatment. An underflow of tailings (4-908b) from secondary floatation (4-910) can be directed to a further settling unit (4-914) from which an underflow of coarse tailings (4-916) is derived. The remaining fines-containing stream (4-918) can be directed to subsequent floatation (4-920), from which residual froth (4-912) is redirected to the PSV or directed toward downstream froth treatment, while fine tailings (4-922) or "floatation tails" go on to processes of fines capture (4-924), for example using centrifugation or other means such as consolidated tailing (CT) technology.

[0375] In a typical WBE, froth (4-904) is directed to froth treatment where the FSU (4-930) is used to isolate bitumen from the water and solids that carried over to the froth stream. The tailings-containing FSU underflow (4-932) is directed to a TSRU (4-934), in the presence of dilution water (4-936) where applicable. The solvent-containing FSU overflow (4-938) can be sent for solvent removal and recovery in the SRU (4-940). A fungible bitumen product (4-942) may be formed upon solvent removal.

[0376] The integration of WBE and SBE is not limited by type of SBE. However, a SBE (4-944) may involve extraction with a solvent together with a solids agglomeration process in order to produce a low solids bitumen product (4-943) and agglomerated tailings (4-946), which is relatively low in water (also referred to as "dry tailings").

[0377] The nature of this integrated system is to form a closed loop. The SBE results in a low solids bitumen product (4-943) that can then be fed back into the WBE at one or more entry points. For example, the bitumen product (4-943) of SBE may be included with the product of the SRU (4-940) of a WBE, or can be combined with a bitumen enriched stream (4-903) for formation of froth (4-904), at which stage, further cleaning or deasphalting can occur.

[0378] Bitumen-lean streams (for example the middlings stream), derived from a primary separation unit of a WBE, usually contain a sufficient amount of bitumen that requires additional recovery stages to be conducted in order to recover residual bitumen. However, such secondary and tertiary recovery stages can be expensive, energy intensive, and may result in an increase in water usage in the extraction process. Furthermore, such additional recovery stages recover much less than 90% of the residual bitumen in the tailings streams. By contrast, SBE may result in bitumen recoveries in excess of 90% even for feeds containing a bitumen content lower than 10 wt. %. Thus, as described herein, bitumen-lean streams from a WBE can be additionally processed in a SBE in order to maximize recovery of residual bitumen.

[0379] Bitumen extracted from a SBE is likely to contain fines and water droplets that need to be removed in order to yield a fungible bitumen product. PFT, as a component of WBE, is a proven technology that can yield a fungible bitumen product. Residual bitumen from the bitumen-lean streams that has been extracted in a SBE can thus be redirected back to a WBE in order to produce a fungible bitumen product. In particular, directing a stream resulting from SBE to PFT of the WBE can result in a high quality bitumen product.

[0380] In general, WBE streams that are lean in bitumen content, and that are likely to be high in fines content, are directed to a solvent based extraction process in order to recover the residual bitumen within. Recovered residual bitumen is made into a fungible bitumen product when mixed with a WBE stream, such as bitumen froth, prior to PFT or the bitumen product after PFT.

[0381] Bitumen-lean streams derived from a WBE may be dewatered in a water separation system before being directed to the SBE, for example as described above in section **I.A**.

[0382] Closed loop integration of WBE with SBE may be accomplished. The product of a SBE is fed into a WBE to achieve an enhanced result in outcome of the WBE. The aspects described herein relating to closed loop integration of the SBE with WBE may permit the combining of SBEs and streams with WBE processes and streams, in order to combine the unique advantages of each extraction process. The utilization of SBE processes to recover bitumen within intermediate streams or tailings of a WBE, and subsequently feeding the bitumen, so recovered, back into a step of a WBE may offers advantages for this closed loop integration scheme such as an overall increase in bitumen recovery and production of a high quality bitumen product. Additional advantages of such an integrated process may include reduced utilization or outright elimination of process equipment typical of WBE, and a commensurate reduction in water use. Other potential benefits include reduced tailings volumes resulting from WBE, and a more robust WBE system, especially for extraction feed streams produced using a no-reject slurry systems. Furthermore, clarification steps within a SBE may be reduced or eliminated in integrated processes, because product cleaning or deasphalting can be affected in the froth treatment process.

[0383] Operations for WBEs and SBEs may be able to integrate streams or other operational aspects when these systems are geographically proximal and/or when a product of one system can be readily utilized by the other system. Integrating such processes can introduce efficiencies, for example increase bitumen recovery, production of a cleaner or otherwise desirable product, and reduction of heat loss by heat integration.

[0384] Processes and systems are described herein which integrate SBE procedures with WBE procedures used in extraction of hydrocarbon from mineable deposits.

[0385] Process streams from WBE processes can be directed to appropriate entry points in a SBE. Extraction of bitumen from high fines streams is challenging in WBE. By directing such streams to a SBE that promotes agglomeration of fines, the separation of hydrocarbon from high fines streams can be conducted with less water use. For example, high fines streams from a WBE can be directed into a SBE involving a water separation system (WSS), to ultimately produce a bitumen product and agglomerated tailings. Exemplary streams derived from WBEs which may be directed in this manner include middlings, flotation tails, and froth treatment tailings, for example the underflow from a froth separation unit, mature fine tailings from tailings ponds, as well as other hydrocarbon-containing streams. Such streams include, but are not limited to streams high in fines which are susceptible to agglomeration.

[0386] Aspects of the process which permit the elimination of certain conventionally used components from WBE may advantageously permit cost reduction through removal of such components (when an existing operation is retroactively fitted to include the SBEs), or may stream-line new operations which would not initially require certain equipment that would have normally been required in a typical WBE site. As illustrated in Figure 7, the elimination of process equipment from the WBE may involve elimination or reduction in the number of floatation vessels which are used in secondary and tertiary recovery of bitumen after a primary separation process in WBE. The floatation step required in a WBE can be reduced or eliminated, by directing such streams into the SBE process. In addition to improved bitumen recovery, this integration could eliminate the need to capture fines from the floatation tailings, which require energy intensive processing, such as centrifugation, or consolidated tailing (CT) technology to decrease water content. Further, the underflow derived from a FSU of WBE froth treatment technology, could be directed into the SBE, thereby reducing or eliminating the need for a TSRU within the WBE and/or use of dilution water at this particular stage for treating the FSU underflow.

[0387] Advantageously, the SBE components of the overall process may be used to process such high fines streams, and may then produce a bitumen product that can be further cleaned in a manner similar to bitumen froth produced in the WBE. Advantageously, the level of fines in solvent extracted bitumen would be low, and tailings derived from the product cleaning step would be minimized.

[0388] The bitumen product derived from the SBE can be directed to WBEs processes for further processing. For example, the solvent extracted bitumen may be directed to the froth treatment stage of the WBE process to undergo further product cleaning. Before being directed to the froth treatment stage of the WBE, the solvent extracted bitumen may first be mixed with process water or streams derived from the WBE such as bitumen froth, middlings, flotation tailings, or mature fine tailings. The resulting mixture yields a froth-like material that can be processed in a froth treatment unit such as PFT. In this case, the PFT has the advantage of producing a cleaner pipelineable product from the solvent-based extracted bitumen product, which is optimally fungible, with less than 300 ppm solids. Furthermore, when the solvent extracted bitumen is mixed with low hydrocarbon-containing streams such as middlings, fine tailings, and mature fines tailings to produce a hydrocarbon-rich bitumen froth that is then directed to a froth treatment stage, the froth treatment stage may provide the added advantage of increasing the recovery of bitumen that would have been lost in those low hydrocarbon streams. In yet another advantage of mixing the solvent extracted bitumen with low hydrocarbon-containing streams and then directing the resulting bitumen froth-like material to a PFT stage, the froth treatment stage may provide the added advantage of producing tailings that are more amendable to dewatering and reclamation than the original low hydrocarbon-containing streams. A low hydrocarbon-containing stream, such as middlings, fines tailings and mature fine tailings, may first be partially dewatered before mixing with the solvent extracted bitumen product.

[0389] Potential benefits of certain aspects of an integrated system which combines WBE processes with SBE processes may include less water usage, reduced tailings volumes, and more robust extraction systems for both water-based and SBE with increased overall bitumen recovery. Furthermore, a product cleaning step may not be necessary within the SBE process in those instances where product cleaning of the solvent extracted product stream occurs within the froth treatment stage of the WBE.

[0390] Additional advantages of integrating WBE and SBE may include the benefit that heat integration can be introduced between components of the two extraction processes. Utilization of waste or heat generated by one step of a process for introducing heat into another step of the process can reduce costs and lower energy intensity of the overall process. For example, particular streams that would normally have required de-watering in the WBE process can be utilized directly in the SBE. By utilizing such streams directly, nearly all of their energy may be integrated into the SBE.

[0391] ***Reusing Heat in Integrated System.*** River-derived process or cooling water may be directed from a WBE to capture heat from a SBE. Major sources of heat in a SBE are hot streams from the bitumen product and TSRUs. Hot waste streams from WBE may be added to feed streams in the SBE for preconditioning. In particular, the TSRU tailings from WBE may be added to the oil sand feed for heat, or may be added to the mix box or agglomerator feed in the SBE to provide required moisture content when forming agglomerates.

[0392] The re-use of heat, water, and solvent in the integrated system may have the benefit of reducing the overall energy intensity of a bitumen extraction system, compared with conventional systems in which WBE is employed, and also relative to the use of a SBE alone.

[0393] ***Recovery of Heat Loss from Steam.*** A modeling of the energy intensity for producing bitumen from a water-based system, versus the energy intensity for producing bitumen from an integrated system having both WBE features and SBE features would reveal that energy attributable to steam, typically lost in the WBE can be nearly entirely re-utilized for heat capture in the integrated system. Further, energy losses attributable to steam produced within the SRU and TSRU of the SBE can be reduced if the integrated system directs the steam to the WBE or upstream of the SBE.

[0394] ***Reducing Solvent Recovery Requirement from WBE.*** The required heat for the extraction processes may be additionally reduced when the FSU tailings from the WBE are mixed with the solvent-wetted solids of the SBE. The combined streams can then be processed in the TSRU of the SBE. In this way the tailings solvent recovery requirement of the WBE could be of reduced importance, or eliminated if the entire FSU tailings stream is combined with solvent-wetted solids.

[0395] ***Optimized System Layout and Component Proximity.*** By setting up the various system components to conduct the processes described herein with advantageous proximity, further efficiencies may be realized. The distance between the distinct processing aspects can be optimized so as to limit heat loss and/or to address economic considerations in those instances where an existing WBE operation is to be retroactively fitted for SBE operations.

[0396] ***Building Integrated Systems for Optimal Layout.*** While retroactive fitting of an existing WBE system can be conducted, efficiencies may be optimized by building an integrated system from the beginning. In this way, the location of SBE equipment can be determined without deference to the existing location of WBE components. A system is provided herein which encompasses components in which WBE steps are conducted, and components in which SBE steps are conducted. This system results in a site that integrates both processes for optimal efficiency, stream proximity, heat re-use, and solvent re-use. In this embodiment for example, a middlings stream derived from a primary separation vessel of a WBE may be directed directly into the SBE in relative close proximity.

[0397] ***Potential Advantages of Component Proximity and/or Optimal Layout of Extraction processes.*** The extraction of bitumen from low quality ore in a WBE typically results in poor bitumen recovery and low quality bitumen froth. Low quality ores may be ones in which the bitumen is either low in quantity (less than 10 wt. % bitumen), poor in quality, or in which bitumen is entrained in such a manner that renders it difficult to extract. High fines content in resulting process streams may be characteristic of low quality ores. Poor bitumen recovery is defined as the recovery of less than 90% of the ore's bitumen in the bitumen froth and low quality froth is defined as froth with a bitumen content of less than 55 wt. %.

[0398] In typical WBE facilities, the method for improving recovery and froth quality of extracted low quality ores involves blending said ores with higher quality ores. The blending of the low quality ores with high quality ores results in an average grade ore that gives consistently higher bitumen recoveries and froths that have approximately 60 wt. % bitumen content. However, the blending of varying ores has significant CAPEX and OPEX implications such as mining logistics complexity and truck requirements.

[0399] Efficiencies can be realized if the SBE and the WBE are in close proximity to each other so that the SBE can initially treat low quality ores rather than the WBE. By providing low quality ores to a SBE first, prior to conducting any WBE steps, the SBE serves to extract bitumen therefrom at a higher level of bitumen recovery (greater than 90%) and product quality. Additional advantages may include; the volume of water used in extraction is reduced and the formation of fines and coarse tailings is reduced. Thus, a greater proportion of hydrocarbon entrained in such a low quality ore can be extracted in a more efficient manner using an integrated system.

[0400] The bitumen product resulting from the SBE may require further cleaning in order to be pipelineable and/or fungible when held to high standards of purity. Efficiencies can be realized if the SBE and the WBE are in close proximity to each other so that transportation is inexpensive to direct solvent extracted bitumen product to a nearby PFT unit of a WBE for product cleaning of the solvent extracted bitumen to the fungible specifications. Further, if the heat entrained in the product or stream derived from the SBE can be captured and contributed into the WBE through integration, then less heat input from other sources would be needed in the WBE.

[0401] When the WBE and the SBE are combined into an integrated process that accepts a stream from the WBE into the SBE, there are various optional efficiencies, as indicated in Figure 4 with "X" showing at different stages, to mean that certain process components become eligible for reduced use or elimination altogether when these two processes are integrated in this way. Secondary floatation (4-910), subsequent floatation of fines (4-920) derived from coarse tailings, and processes of fines capture (4-924) may be reduced or eliminated from the process, if the streams conventionally directed to these processes were to instead be directed to a SBE (4-944). The middling stream (4-906) derived from the primary separation vessel (4-902) could be sent directly to the SBE (4-904). The settled mixture (4-918) remaining from the further settling unit (4-914) could be sent directly into SBE, which would have the effect of eliminating the production of fine tailings (4-922) from the further floatation, and the need for specialized equipment for subsequent processes of fines capture (4-924).

[0402] By integrating the processes in a manner consistent with Figure 4, secondary recovery, occurring in secondary floatation (4-910), and tertiary recovery, occurring in (4-920), can be reduced are eliminated in the WBE since the bitumen-lean streams are directed to a SBE (4-944). Additional oil sand (4-945) can be included into the SBE (4-944) together with the high fines bitumen-lean streams, which can be one of or a combination of the middlings (4-906), PSV tailings (4-908a), flotation tailings (4-908b) (4-918), fine tailings (4-922), froth treatment tailings (4-929) and FSU underflow (4-932). In combining oil sand with a high fines bitumen lean stream (4-939), a slurried mixture can be directed into SBE. The product of a SBE (4-944) can ultimately be characterized as solvent extracted agglomerated tailings (4-946) and a low solids bitumen product (4-943). In the integrated scheme, the need for TSRU (4-934) can be reduced or eliminated, as the FSU underflow, which is a high fines bitumen lean stream (4-939) could be directed to SBE (4-944) instead of to the TSRU. This also negates the requirement to add dilution water (4-936), which would have been needed for FSU underflow (4-932) to proceed to TSRU (4-934).

[0403] Tailings derived from primary separation (4-908a) in the WBE system, which may have been considered too energy intensive a process to direct to further purification in WBE can now be further processed through the SBE system in such an integrated process. The SBE can assist in deriving further amounts of bitumen from coarse tailings.

[0404] The low solids bitumen product (4-943) resulting from the SBE (4-944) process may require further cleaning in order to be pipelineable and/or fungible when held to high standards of purity. For this reason, the low solids bitumen product (4-943) is directed to the froth treatment unit (4-948) of the WBE. It is preferable that the froth treatment unit (4-948) be a PFT unit capable of producing a fungible bitumen product. The low solids bitumen product (4-943) is mixed with a bitumen enriched stream (4-903) to form bitumen froth (4-904) prior to froth treatment. The mixture then undergoes a PFT in order to produce a fungible bitumen product (4-942). Alternatively, in the situation where bitumen product (4-942) produced by the PFT process may have a solids and water content that is much less than the fungible limit, the low solids bitumen product (4-943) from the SBE may bypass the PFT process and directly mix with the fungible bitumen product (4-942) and still yield a combined stream that meets the fungible specifications.

[0405] The low solids bitumen product (4-943) generally contains very low water content. Thus, this product may first be mixed with a water-containing stream before being directed to the froth treatment unit (4-948) of the WBE. The addition of water to the process may improve the froth treatment process. The water-containing stream may comprise low hydrocarbon-containing streams, such as a middling stream (4-906), tailings (4-908b), a fines-containing stream (4-918), or fine tailings (4-922), and mature fine tailings. In these cases, the froth treatment stage may provide the added advantage of increasing the recovery of the bitumen that would have been lost in those low hydrocarbon streams.

[0406] The FSU of a WBE system is generally in communication with a SRU (4-940), which receives a bituminous solvent-containing stream, relatively free of fines and water. This SRU serves to remove solvents, resulting in a bitumen product. This type of solvent removal can also be conducted within the SBE. Thus, in an integrated system, the SRU may be a consolidated unit, accepting streams from both the WBE and the SBE.

[0407] SBEs (4-944) which tolerate a bitumen feed having water entrained therein can be extracted according to the described method. This permits a feed containing more water than typical oil sand to be processed with the SBE (4-944), and even permits enrichment of an aqueous stream with additional oil sand (4-945).

II.B. Extracting Hydrocarbons from PFT Tailings by Directing Tailings into an SBE

[0408] Described in this section is a process for recovering hydrocarbon from a tailings stream from a PFT process. The process may comprise: accessing a hydrocarbon-containing froth treatment tailings stream from a PFT process; combining the froth treatment tailings stream with a solvent and additional oil sand to form a slurry; agitating the slurry to dissolve hydrocarbon into the solvent and to agglomerate fines within the slurry; separating the extracted hydrocarbon from the agglomerated fines to form a low solids extracted hydrocarbon stream and an extracted tailings stream; and recovering the solvent from the extracted tailings stream. The froth treatment tailings stream may be derived from a FSU underflow of the PFT process, or from a TSRU of PFT. Further, the froth treatment tailings stream may be partially dewatered to form a dewatered tailings stream before combining with the solvent, for example, the stream may be dewatered to less than 40 wt. % water.

[0409] The slurry formed may have a water content of from 5 wt. % to 25 wt. %.

[0410] The solvent may be an aromatic solvent, such as toluene or benzene, and may have bitumen entrained therein, for example at an initial level in the solvent of 10 wt. % or greater. For example, the solvent may be a cycloalkane with entrained bitumen.

[0411] The extracted tailings stream may comprise agglomerated fines. The process may further entail removal of the solvent from the low solids extracted hydrocarbon stream to form a bitumen product.

[0412] Separating the extracted hydrocarbon from the agglomerated fines may comprise washing agglomerated fines on a filter, for example with countercurrent washing with progressively cleaner solvent.

[0413] Approximately 10% of the bitumen extracted in a conventional WBE is lost in the tailings of PFT. Although a majority of these hydrocarbons are asphaltenes, they still have sufficient amount of value to justify recovery, which would result in an increase the overall volume of bitumen produced. The aspect of the process described herein relates to the use of SBE to recover the hydrocarbons in PFT tailings. It is desirable to further increase recovery of hydrocarbons from PFT tailings by directing such tailings into a SBE and solids agglomeration process. Advantageously, when the SBE used involves fines agglomeration, the extraction of residual hydrocarbons from the tailings and the formation of agglomerates from solids in the tailings can occur simultaneously during the agglomeration step. In this way, the agglomerated solids may be readily separated from the bitumen extract.

[0414] A conventional WBE may include flotation separation steps that result in the formation of a bitumen froth. The bitumen within the bitumen froth includes about 5 to 15 wt. % asphaltenes. To remove solids and water from the bitumen froth, solvent deasphalting is conducted within a froth treatment unit. In the froth treatment unit, the bitumen froth is mixed with a deasphalting solvent and is subjected to one or more settling stages. The solvent can be, for example, a paraffinic hydrocarbon solvent having a chain length from about 5 to about 8 carbons. An exemplary solvent combination may be a mixture of pentane and hexane. The precipitated asphaltenes flocculate with the solids and water droplets resulting in large flocs that rapidly settle out of the hydrocarbon solution as the froth settling unit (FSU) underflow. The residual solvent within the FSU underflow is typically recovered and recycled, to avoid release to the environment. Separation of the solvent can occur, for example, in a TSRU. Conventionally, the solvent is recycled and the tailings that exit the TSRU are disposed of as a waste product.

[0415] In an exemplary process, the PFT tailings may comprise FSU underflow. Additionally, the PFT tailings may comprise tailings from a TSRU. Advantageously, when froth separating unit (FSU) underflow is employed as the PFT tailings that are directed to a SBE and solids agglomeration process, this allows exclusion of the TSRU component from a conventional froth treatment processes. The residual PFT tailings solvent recovery would occur in the SRUs of the SBE described herein. Thus, in a conventional process that would typically treat underflow from a FSU using TSRU, the use of the FSU underflow in the SBE negates the requirement for recovery of solvent in a TSRU of the froth treatment unit.

[0416] PFT tailings may be contacted with additional oil sand and a solvent (or solvent mixture), or extraction liquor, capable of dissolving asphaltenes to form a slurry. The slurry may be mixed to dissolve the hydrocarbons and to agglomerate fines within the slurry. The extracted hydrocarbon solution can then be separated from the majority of the solids and water, including the solids and water originally present in the PFT tailings.

[0417] The PFT tailings stream may be dewatered to a water content of less than about 40 wt. %. The dewatered tailings stream is mixed with additional oil sand and a solvent to form a slurry. The fines within the slurry are agitated to agglomerate with each other, and then most of the solids are separated from the extracted hydrocarbon solution. The agglomerating stage of the process advantageously permits a majority of the fines present in the froth treatment tailings to agglomerate with the fines from the additional oil sand, so that the agglomerates can be easily separated from the extracted hydrocarbon solution. The recovered hydrocarbon solution, which is low in solids content, can then proceed through the later stages of a SBE, ultimately forming a bitumen product, of which a portion would have otherwise been lost as a waste product of the WBE.

[0418] Figure 8 is a schematic representation of an exemplary process (8-1300) in which PFT tailings are directed to a SBE to recover bitumen. The process permits recovery of hydrocarbon from said tailings. A froth treatment tailings stream from a PFT process is accessed (8-1302). The froth treatment tailings stream is combined (8-1304) with a solvent and additional oil sand to form a slurry. The solvent may comprise a combination of different solvents, and may be an extraction liquor which contains bitumen entrained within the solvent. The slurry is agitated (8-1306) to dissolve hydrocarbons into the solvent and agglomerate the fines. The extracted hydrocarbons are separated from the solids (8-1308) to form a low solids extracted hydrocarbon stream and an extracted tailings stream. The solvent is then recovered (8-1310) from the extracted tailings stream.

[0419] Figure 9 is a schematic representation of an embodiment of the process (9-1400) depicted in Figure 8, in which hydrocarbons from PFT tailings are extracted in a SBE and solids agglomeration process. The process involves providing bitumen froth (9-1402) to a PFT process (9-1404) within which separation occurs, and PFT tailings (9-1406) are produced. PFT tailings (9-1406) are then directed into a SBE (9-1408) that employs fines agglomeration. In another embodiment of this process, underflow (9-1426) from a froth settling unit (FSU) (9-1428) bypasses the TSRU of the PFT plant (9-1404) and serves in lieu of the PFT tailings as input into the SBE (9-1408), as illustrated by the dashed line representing underflow (9-1426) being directed into slurry preparation unit (9-1412).

[0420] The PFT tailings (9-1406) and/or FSU underflow (9-1426) are combined with oil sand (9-1410) and an extraction liquor (9-1411) in a slurry preparation unit (9-1412) to form a slurry. The fines within the slurry are agglomerated within the agglomerator (9-1413) to allow for easy solid-liquid separation within the filter (9-1414). Solvent (9-1422 and 9-1416) from the SRUs (9-1424 and 9-1417) can be used in a countercurrent washing of the solids on a filter (9-1414). Solvent is recovered from the solvent-wet solids in a TSRU (9-1419) to form dry tails (9-1420). Solvent is recovered from the bitumen extract in a SRU (9-1417) to form a low solids bitumen product (9-1418). The process described herein permits integration PFT tailings (9-1406) of a WBE into a SBE (9-1408), to recover further amounts of bitumen therefrom, which would have otherwise been difficult or inefficient to recover.

II.C. Directing a Bitumen-Rich Stream into a SBE

[0421] It is desirable to direct bitumen-rich aqueous streams, derived from WBE, into a SBE process, as a source of bitumen for the solvent used in an extraction liquor. In this way, the amount of bitumen recycled within the SBE process can be reduced or eliminated while maintaining the advantages provided by having pre-dissolved bitumen within the solvent used in the SBE process. Further, the increased bitumen yield (lower recycle bitumen) of the SBE process translates to a significant reduction in the energy requirement, on a production basis, of the tailing solvent recovery unit.

[0422] Bitumen-rich streams derived from the WBE process can be used to replace recycled bitumen. In this way, most or all of the bitumen processed in the SBE process will add to the bitumen yield of the process. Additionally, fewer solids will be processed in the SBE process per unit of bitumen produced.

[0423] The bitumen-rich aqueous streams can also provide the water needed for SBE, for example when a solids agglomeration step employs a bridging liquid. Additionally, the SBE process may also act to separate most of the solids and water associated with the bitumen-rich aqueous streams from the resulting bitumen extract. In this way, the SBE process can act in place of the froth treatment unit of a conventional WBE process.

[0424] Described in this section is a process for recovering bitumen from oil sand, which includes extracting bitumen from oil sand in WBE to form a bitumen-enhanced stream and a bitumen-lean stream; mixing the bitumen-enhanced stream with a solvent to form an extraction liquor; mixing the extraction liquor with additional oil sand to form a slurry comprising solids and bitumen extract; separating the solids from the slurry to form a low solids bitumen extract; and recovering solvent from the low solids bitumen extract to form a solvent extracted bitumen product.

[0425] The oil sand initially extracted may be of a high to medium bitumen content and a low to medium fines content. Further, the additional oil sand mixed with the extraction liquor for extraction may be of low to medium bitumen content and of high to medium fines content. The WBE used to produce the bitumen-enhanced stream may employ a flocculant or a coagulant to induce aggregation of fines and hydrocarbon within the WBE. The water used in the WBE may have a sodium ion content of 1000 wppm or greater, on a weight basis, and/or may have a calcium ion content of 100 wppm or greater (also on a weight basis). Further, the water may have a pH of less than 8.

[0426] The bitumen-enhanced stream may have bitumen to solids ratio greater than the oil sand, for example, a bitumen: solids ratio of greater than 0.5:1. The bitumen-enhanced stream may have a bitumen content of 50 wt. % or greater, and/or may have a water content of 30 wt. % or less. The bitumen-enhanced stream may be bitumen froth derived from the WBE. The bitumen-enhanced stream may be partially dewatered prior to mixing with the solvent. The extraction liquor may also be partially dewatered prior to mixing with additional oil sand. The bitumen-lean stream may also be partially dewatered.

[0427] The solvent mixed with the bitumen-enhanced stream may comprise dissolved bitumen. The extraction liquor may have a bitumen content of 40 wt. % or less.

[0428] Fines may be agglomerated within the slurry.

[0429] In the solvent extracted bitumen product, there may be, for example, from between 0.1 to about 2 wt. % solids on a bitumen basis. The process may direct the solvent extracted bitumen product to a product cleaning step to produce a fungible bitumen product. Exemplary cleaning steps may include gas flotation, membrane filtration, or a combination thereof. A fungible bitumen product so formed may have less than 300 wppm solids on a bitumen basis. The solvent extracted bitumen product may be passed to an upgrader for further processing.

[0430] Accordingly, this section relates to a process directing a bitumen-rich stream into a SBE. The bitumen-rich stream may be derived from a conventional WBE, and thus its utilization may capture synergies between the WBE and SBE.

[0431] This integration may address the issue of the source of "recycle bitumen" (RB) needed to form "bitumen product" (BP). Typically, a ratio of RB: BP employed in SBEs can be as high as 3:1. Recycling such a large amount of bitumen entrained in the solvent has several advantages. Importantly, the recycle bitumen (RB) reduces the required inventory of solvent needed for bitumen extraction from the oil sand. In a SBE, the extraction liquor that is mixed with the oil sand may contain as much as 50 wt. % bitumen, the remainder being attributable to solvent. Herein the term extraction liquor refers to the solution of bitumen with the solvent prior to extraction. Further, when a non-aromatic or partially aromatic solvent is used, such as naphtha, cycloalkanes, paraffinic solvents or crude distillates, the presence of dissolved bitumen within the extraction liquor advantageously increases the ability of the extraction liquor to dissolve additional bitumen into the liquor. Another advantage of having dissolved bitumen in the extraction liquor is that the presence of bitumen reduces the liquor's vapor pressure, which can allow for higher operating temperatures for the SBE. Yet another possible advantage of having a significant amount of bitumen in the extraction liquor is that the recycle bitumen dampens variability in the solvent to bitumen ratio of the slurry due to sudden changes in the bitumen content of the bituminous feed. For example, a change the bitumen content of a bituminous feed from 11 wt% to 9 wt. %, a 22% change, will increase the solvent to bitumen ratio of the slurry from 1.5:1 to 1.6:1 for the same extraction liquor composition. The solvent to bitumen ratio only increases by 7%.

[0432] Although the recycling of bitumen has its advantages, it does mean that the extraction and solid-liquid separation equipment employed in the SBE must be sized to process a majority of bitumen that is not produced. This is costly because the process equipment used in solvent extraction of oil sand have certain sealing and safety requirements to ensure that solvent remains contained. These requirements are significantly more expensive to meet than are the requirements of WBE equipment. Thus, it is desirable to reduce the amount of recycle bitumen while maintaining the advantages provided by having dissolved bitumen in the extraction liquor.

[0433] The integration described in this section may additionally address the issue of directing large solid streams to a SBE. Solids that are directed to a SBE necessarily come into contact with solvents that absorb into the pores of the solids and coat the surface of the solids. In order for these solids to be introduced back into the environment, almost all the solvent must be removed from them. Unfortunately, a tremendous amount of energy is usually required to evaporate the solvent from the solids in typical TSRUs of a SBE. This energy requirement has been one of the major factors preventing the wide application of SBE technology to the oil sand industry. Thus, it is also desirable to reduce the amount of solids processed within a SBE per unit of bitumen produced.

[0434] WBE may be used to extract from oil sand a bitumen-rich stream comprising a bitumen to solids ratio that is greater than that of the oil sand. Specifically the bitumen-rich stream has a bitumen to solids ratio of greater than 0.2:1. The water extracted bitumen-rich stream is mixed with a solvent to produce the extraction liquor that is then used to solvent extract bitumen from additional oil sand.

[0435] WBE may also be used to extract from oil sand a bitumen-rich stream comprising a majority bitumen with water and solids making up the minority components of the stream. The water extracted bitumen-rich stream is mixed with a solvent to produce the extraction liquor that is then used to solvent extract bitumen from additional oil sand. The bitumen-rich stream may be a bitumen froth stream from a WBE.

[0436] Utilization of a bitumen-rich stream from WBE, as a source of bitumen for the extraction liquor of a SBE has advantages over the conventional option of further processing said bitumen-rich stream in the WBE. For example, a reduction in water use and/or required water quality within the WBE may be realized since the bitumen-rich stream will be further processed in a SBE. Another advantage includes that the bitumen yield of a SBE can be three-fold higher, or even greater, than conventional SBE where bitumen in the extraction liquor is bitumen that is recycled within the process. While the cost of the SBE facilities is high, this increased yield may more than offset the added cost associated with operating and integrating water-based and SBE facilities.

[0437] An amount of the solids within the oil sand are separated from the bitumen-rich stream prior to the bitumen-rich stream mixing with the solvent. Advantageously, these separated solids will not add to the load on the TSRU of the SBE. Furthermore, in the cases where the oil sand processed in the WBE are high or medium grade oil sand, or more preferably only high grade oil sand, the separated solids are mostly coarse sands grains that may be easily dewatered and prepared for reclamation.

[0438] In the exemplary SBE and solids agglomeration processes described above, a bridging liquid (i.e. water) is added to the extraction process in order to agglomerate fines for improved solid-liquid separation. Water may be added, for example, in the form of steam to heat the initial slurry or as a component of an input stream. The bitumen-rich stream, derived from WBE, may have a water content from 40 to 20 wt. %, and thus can serve as the water source needed for solids agglomeration in the SBE.

[0439] The majority of the water and solids within the bitumen-rich stream can bind with the solids of the solvent extracted oil sand. Thus, the SBE can effectively displace or reduce the function of the froth treatment unit used in a conventional WBE. The produced bitumen from the SBE, which comprises bitumen from the bitumen-rich stream as well as bitumen derived directly from solvent extraction of oil sand, may have a BS&W of approximately 2 to 3 wt. %, or more preferably between 0.1 to 2wt. %. This bitumen quality is similar to the quality of bitumen produced from the naphthenic froth treatment process of a conventional WBE.

[0440] Advantageously, product cleaning of bitumen froth may be combined with additional bitumen extraction from oil sand. The produced bitumen ultimately formed as a result of the solvent extraction steps, as is, may be sent to an upgrader. An additional product cleaning step may be utilized to advantageously remove residual solids and water in order for the produced bitumen to meet the fungible specification. Gas flotation or membrane filtration may be used as suitable product cleaning methods.

[0441] Figure 10 shows a flow chart of the steps involved in the embodiment in which a bitumen-rich stream of a WBE is directed to SBE. The process (10-1500) permits recovery of bitumen from oil sand. The process comprises: extracting (10-1502) bitumen from oil sand in a WBE to form a bitumen–rich stream and a bitumen-lean stream. The bitumen-rich stream is defined as a stream with a bitumen to solids ratio that is greater than that of the oil sand. Instead of further processing the bitumen-rich stream within a WBE, such as a naphthenic froth treatment unit, the bitumen-rich stream is directed to a SBE. The bitumen-rich stream is mixed (10-1504) with a solvent to form an extraction liquor. The solvent may be derived from a recycled source of solvent, and may be interchangeably referred to as an extraction liquor. The bitumen-rich stream may optionally mix with a solvent with recycled bitumen entrained therein. The extraction liquor is then mixed (10-1506) with additional oil sand to form a slurry comprising solids and bitumen extract. The solids are then separated (10-1508) from the slurry to form a low solids bitumen extract. Solvent is then recovered (10-1510) from the bitumen extract to form a solvent extracted bitumen product.

[0442] Figure 11 illustrates a process (11-1600) in which extraction liquor (11-1602) used in a solvent-base extraction process (11-1604) is produced by mixing solvent (11-1614) with a bitumen-enhanced stream (11-1606), which may specifically be froth, derived from a WBE (11-1608). High grade (low fines) oil sand (11-1610) may preferentially be directed to the WBE (11-1608) in order to reduce the required intensity of the process when compared with the intensity of the process if a lower grade oil sand are used. Low grade oil sand (11-1612) and/or medium grade oil sand can be directed to the SBE (11-1604) to maximize bitumen recovery. The bitumen-enhanced stream (11-1606) from the WBE (11-1608) is mixed with the solvent (11-1614) in an extraction liquor mixing vessel (11-1616) to form an extraction liquor (11-1602). The solvent (11-1614) may have recycled bitumen dissolved therein.

[0443] The bitumen-enhanced stream (11-1606) may be dewatered prior to solvent addition. The extraction liquor (11-1602) comprising bitumen from the bitumen-enhanced stream (11-1606) may be dewatered prior to mixing with the oil sands (11-1610). The dewatering of either the bitumen-enhanced stream (11-1606) and/or the extraction liquor (11-1602) may reduce the rate and degree of undesirable solids agglomeration during the dissolution period of the SBE process. As described above, solids agglomeration during the dissolution process may lead to significant entrapment of bitumen within the agglomerates. All or a portion of the separated water may be directed to the SBE as the bridging liquid during the agglomeration stages of the SBE process.

[0444] The extraction liquor (11-1602) derived from the mixing vessel (11-1616) is mixed with oil sand (11-1612) in the SBE to extract bitumen from the low grade oil sand (11-1612). The solvent (11-1614) is eventually recovered from the bitumen extract and solvent wet solids formed in the SBE (11-1604), yielding a bitumen product (11-1618) and dry tailings (11-1620). Some of the recovered solvent is then redirected back to the extraction liquor mixing vessel (11-1616), while the bitumen product can be directed to further processing, rendering a fungible product, and/or can be utilized as is. Dry tailings (11-1620) resulting from the SBE will generally have a low bitumen, low solvent, and low water content, and are suited for storage, for example as backfill to a spent mine. In this way, the volume of water wet tailings (11-1622) formed as a result of WBE, can be reduced when the bitumen-enhanced stream (11-1606) is ultimately processed by the SBE (11-1604).

Solvent Wet Crushing of Bituminous feed

[0445] Dry crushing of a bituminous feed may be performed with either a double roll crusher or primary sizer. The typical maximum lump size from these primary size reduction methods is in the range of 16" to 24". Due to the sticky nature of some bituminous feeds, and the high throughput required, further dry reduction is not commercially practiced.

[0446] Wet sizing of a bituminous feed with water has been proposed and implemented. In prior art descriptions, water may be added to the bituminous feed to facilitate the secondary size reduction. Additional water may be added to facilitate the final size reduction step.

[0447] Solvent may be added to the bituminous feed to facilitate the secondary and tertiary size reduction process. The solvent, similar to the role water plays in conventional wet sizing, may serve as the primary lubricating fluid during the size reduction process. Additionally, the solvent may provide flow enhancement by flushing undersized particles through the sizer opening faster than would occur without liquid addition. Using a solvent, or a solvent comprising bitumen mixture as the wet sizing may provide additional benefits for the SBE process. For example, corrosion of the wet sizing device may be less of a concern for the solvent wet sizing process due to the reduce concentration of water and oxygen within the wet sizing device. Solvent addition instead of water reduces or eliminates the formation of agglomerates in this stage. The lower density of the solvent may enable a similar volumetric fluid addition compared to the case with water as the lubricating fluid, but at a lower mass rate than water. The higher lubricity of the solvent/bitumen mixture and its low viscosity promotes flow through the secondary and tertiary sizers such that a lower total quantity of fluid may be required. These advantages also permit all the fluid to be added in the first stage of wet sizing which reduces the need for controlling flow between the two size reduction steps, reduces capital and simplifies operation.

II.D Jet Pump for Slurry Conditioning and Bitumen Dissolution

[0448] A jet pump may be used in the SBE to condition the slurry. With reference to Figure 27, a bituminous feed may be fed (27-102) into a jet pump. A motive fluid, comprising a solvent for extracting bitumen, may be provided (27-104) to the jet pump for mixing with the bituminous feed. A conditioned slurry may be discharged (27-106) from the jet pump. The conditioned slurry may be agglomerated (27-108) to create an agglomerated slurry.

[0449] With reference to Figure 28, bituminous ore (28-202) from a mine may be conditioned (28-204) for use, for instance, by crushing and/or screening to an appropriate maximum ore lump size. An appropriate maximum size may be less than a mixing chamber diameter of the downstream jet pump. For instance, at least 90 wt. % of the bituminous feed may have a maximum dimension of less than 150 mm. In other cases, at least 96 wt. % of the bituminous feed may have a maximum dimension of less than 100 mm in diameter. Conditioned ore (28-206) may be sent to a surge bin or stockpile (28-208) and may then be fed into an inerting system (28-210) where inert gas is added. The inerting system (28-210) may act as a boundary between general purpose and electrically classified zones. The inerting system (28-210) may have two main purposes: to remove sufficient oxygen through a venting stream to prevent flammable mixtures from occurring; and to admit ore into the extraction process while preventing solvent vapor from escaping to the atmosphere.

[0450] The inerted ore (also referred to herein as a bituminous feed) (28-212) may enter a hopper (28-214). A hopper wash solvent may be added to the hopper (28-214) to initiate bitumen dissolution. The hopper wash solvent may also assist solids flow to a jet pump suction and thaw or heat the bituminous feed. The hopper wash solvent may be added to the bottom section of the hopper to assist in solids flow to the jet pump suction. The hopper wash solvent may be added to the hopper as a high velocity jet to assist in solids flow. The hopper wash solvent may be provided to the hopper at a temperature above a bituminous feed temperature. The hopper wash solvent may be added to the bottom portion of the hopper at a temperature above the normal boiling point of the solvent due to the hydrostatic head at the bottom of the hopper. The hopper wash solvent may be added to the hopper to substantially increase the temperature of the bituminous feed. The hopper wash solvent may be added to the hopper as a solvent vapor in order to impart the solvent latent heat to the bituminous feed. The hopper wash solvent vapor may be preferentially introduced to the bottom section of the hopper in order to minimize solvent loss to the vapor space above the hopper. Solvent vapor may be available at a pressure of, for instance, 30 PSIA.

[0451] The hopper wash solvent may also be used to fill void spaces in the bituminous feed by displacing the inerting gas which may otherwise affect jet pump performance. The bituminous feed from the hopper may have a solid content in the range of 30 to 85 wt. %. The bituminous feed from the hopper may have a solid content of less than 85 wt. % to ensure that all the pores of the bituminous feed is filled with liquid in order to minimize carry under of non-condensable gases to the jet pump suction. It is advantageous to remove the non-condensable gas from the bituminous feed since the non-condensable gas occupies volume and reduces the volumetric flow rate of the bituminous feed. It is also advantageous to remove non-condensable gas from the bituminous feed since the non-condensable gas may negatively impact the operation of the filtration system downstream of the hopper. The hopper wash solvent may be a mixture of bitumen and lighter hydrocarbons, or may be lighter hydrocarbons alone. The hopper wash solvent may comprise fine particles along with the bitumen and lighter hydrocarbon. A combined bituminous feed (28-212) and hopper wash solvent level in the hopper (28-214) may be maintained at a height in the hopper (28-214) to provide a sufficient net positive suction head (NPSH) for the jet pump to limit cavitation as well as to provide sufficient residence time in the hopper for initial dissolution to occur. It may be preferable that the bituminous feed from the hopper flows primarily to the bottom of the hopper by the action of gravity. The hopper (28-214) may be vibrated to assist solids feeding. The hopper wash solvent may be added to the hopper (28-214) in any suitable manner, for instance as a central jet or a liquid along the hopper walls, or as part of a final feed sizing step. The level may be monitored by a level sensor or any other suitable device performing this function.

[0452] Bituminous feed (28-216) from the hopper (28-214) may be introduced into the jet pump (28-218). One or more pre-treatment steps may be present between the hopper (28-214) and the jet pump (28-218). The following background on jet pumps is provided. A motive fluid is pumped at a certain rate (Qn) through a nozzle at a high pressure (Pn). This high-pressure liquid passes through the nozzle, which converts the fluid from a low velocity, high static pressure flow to a high velocity, low static pressure flow (Ps). This lower static pressure (Ps) actually creates the suction for the material to be pumped to be fed into the system (via the hopper) at a certain flow rate (Qs) into a mixing chamber. The feed material in the suction can be a liquid, solid, slurry, or a combination thereof. An energy transfer occurs in a mixing chamber from the high energy to the low energy stream, resulting in a medium-high energy discharge stream (Qd, Pd). The volume of motive fluid used is primarily proportional to the size of the nozzle as well as the differential pressure (Pn - Ps). When the two streams (motive and suction) come into contact with each other, vigorous mixing occurs, which may cause ablation of the ore fed through the hopper in the suction chamber. "Ablation" refers to the breaking down of ore lumps. Overall, the hopper may comprise approximately 85 wt. % (or approximately 80 to 90 wt. %) solids, based on the weight of the hopper contents, so that the subsequent solids concentration in the discharge may be in the range of 30 wt. % to 70 wt. % or 10 wt. % to 40 wt. %, based on the total weight of the discharge, as described below. The following three references are mentioned, which describe jet pumps: Practical Solids-Handling Jet Pumps, A.W. Wakefield, Symposium on Jet Pumps and Ejectors, London, November 1, 1982, Paper 12; Performance of Solids-Handling Jet Pumps at Low Reynolds's Numbers, A.W. Wakefield, 2nd Symposium on Jet Pumps & Ejectors and Gas Lift Techniques, March 24-26, 1975, Paper A3; and Slurry Handling Design of Solid Liquid Systems; Edited by Nigel P. Brown and Nigel I Heywood; ISBN 1-85166-645-1 (Chapter 18: Jet Pumps, A.W. Wakefield).

[0453] The jet pump (or pumps if configured in a multiple unit, parallel configuration) may be located and oriented in several ways. The jet pump may be positioned within the hopper, arranged vertically. Motive fluid may progress to a lower section of the hopper, make a U-turn, and enter the jet pump nozzle. This configuration may have the advantage of using the hopper as a secondary containment in the case of erosive wear through the jet pump body, but possibly at the cost of added complexity for maintenance.

[0454] Alternately, the jet pump may be mounted horizontally below the hopper, and configured with isolation valves at motive fluid connection, jet pump discharge, and suction connection to the hopper. This permits maintenance to be performed without withdrawing a submerged unit from an enclosed space of the sealed hopper.

[0455] Additional connections may be provided to drain the jet pump body, flush out remaining hydrocarbons and slurry to improve jet pump maintenance safety. The jet pump may be configured with a mixing and diffusing section contained within a secondary containment shell. An annular space between the jet pump and the containment may be monitored for the presence of pressure or liquid in order to detect leakage prior to any loss of containment to atmosphere.

[0456] The bituminous feed (28-216) may have a solids content of 60 to 85 wt. %, based on the total weight of the bituminous feed. A motive fluid (28-220) may be added to the jet pump (28-218). The motive fluid (28-220) comprises a solvent for extracting bitumen (also referred to as dissolution) as described above with reference to the solvent based extraction process. The motive fluid (28-220) may have viscosity of less than 20 cP, or less than 10 cP. The motive fluid (28-220) may have a viscosity of less than 300 cP to allow for an effective jet pump operation. The motive fluid (28-220) may be provided to the jet pump at any suitable pressure, for instance at a pressure of between 50 psig and 300 psig, or between 100 and 200 psig. A higher viscosity may serve as impediment to flow and subsequently, the jet pump action. The motive fluid (28-220) may be provided to the jet pump at any suitable temperature, for instance at a temperature above an atmospheric boiling point of the solvent, as long as the pressure is sufficiently maintained for safety considerations. The jet pump (28-218) may introduce shear which breaks down the ore lumps, increasing a surface area to volume ratio, enabling higher mass transfer and more rapid dissolution of the bitumen. Energy imparted to the bituminous feed (28-216) by the jet pump (28-218) may be used to transport the bituminous feed to the next process step. A jet pump discharge may enter a conventional slurry pump (28-219) for additional pressure boost. The slurry pump can act to reduce the backpressure on the jet pump exit enabling the jet pump performance to move along the characteristic M curve (ratio of bituminous feed to motive fluid) and so adjust the density of a slurry exiting the jet pump. The jet pump discharge may be operated at a temperature below the vapor point of the solvent to limit vapor bubbles in the discharge line.

[0457] The jet pump may be operated at the point of cavitation at the motive fluid nozzle exit, or along the way into a mixing section to increase agitation and ablation of the bituminous feed. The jet pump may be operated at the point of cavitation by sufficiently increasing the pressure of the motive fluid. When a jet pump is operating at the point of cavitation and beyond, the slope of the slurry flow rate versus motive fluid pressure curve tends to zero and eventually goes negative. The reduction in flow rate with the increase in motive fluid pressure may be due the higher fraction of the jet pump occupied by cavitation bubbles. To increase ablation of the bituminous feed within the jet pump, it may be desirable to operate the jet pump at the point of cavitation but not beyond the point where the slurry flow begins to decrease. To maximize ablation of the bituminous feed with the jet pump, it may be desirable to operate the jet pump at the conditions where the slope of the slurry flow rate versus motive fluid pressure curve is negative. In this operating condition, the reduction of slurry flow rate within an individual jet pump can be compensated for by operating multiple jet pumps in parallel. Two or more jet pumps may be installed in parallel to receive the bituminous feed. Under process conditions when a significant amount of jet pump ablation is not desired, a reduced number of jet pumps may receive the bituminous feed and may operate without inducing cavitation. Alternatively, under process conditions when significant amount of jet pump ablation is desired, all the jet pumps may be made to receive the bituminous feed in order to maintain slurry flow rates as each jet pump operates in cavitation mode.

[0458] The jet pump may be operated at a temperature of less than 100 °C. The jet pump may be operated at a temperature to facilitate the onset of cavitation. A conditioned slurry (28-222) may be discharged from the jet pump (28-218). The conditioned slurry (28-222) may have a solids content of 20 to 70 wt. %, or 10 to 40wt. % in the case of diluted slurries, based on the weight of the conditioned slurry. The conditioned slurry may be sent to a second jet pump hopper for further processing or to a pump box for additional capacitance, dissolution time, and density control. In the case where multiple jet pumps are in use, the discharge from the multiple jet pumps may be combined in a single pump box prior to directing the combined slurry to a centrifugal pump and/or dissolution pipeline. The use of the pump box may allow for a slurry with a uniform density to be directed to the centrifugal pumps.

[0459] The main purpose of the jet pump described herein is to allow for the rapid ablation of the bituminous feed within a high throughput and compact device. For this reason, it may be preferable to design the jet pump with a larger mixing zone in order to maximize ablation while reducing discharge pressure. The reduced discharge pressure of the jet pump may be acceptable since a centrifugal pump can be placed immediately downstream of the jet pump. In addition to rapid ablation, the jet pump may reduce the required residence time within the dissolution pipeline. The dissolution system of the SBE process may comprise at least a jet pump, a centrifugal pump and a dissolution pipeline which all act jointly in the dissolution of bitumen from the bituminous feed. One may contemplate the design of the jet pump, the centrifugal pump and the dissolution pipeline of the dissolution system in order to optimize the system around various design parameters such as jet pump efficiency, centrifugal pump head and dissolution pipeline length. The combination of jet pump, centrifugal pump, and dissolution pipeline may all work together as an integrated system which ensures the proper ablation of the bituminous feed and dissolution of the bitumen.

[0460] The conditioned slurry (28-222) may be agglomerated (28-224) to create an agglomerated slurry (28-226). A bitumen extract may be separated and recovered from the agglomerated slurry (28-226).

[0461] The agglomerated slurry (28-226) may be sent to a filter, such as sealed vacuum filter system, for instance as described in United States Provisional Patent Application No. 62/193,267, entitled "Method of Filtering an Oil Sand Slurry", and filed on July 16, 2015.

[0462] Figure 29 illustrates the same features as Figure 28 and includes additional features between the jet pump and the agglomeration. Therefore, summarizing the features common to Figures 31 and 32, with reference to Figure 29, bituminous ore (29-302) from a mine may be conditioned (29-304) for use. Conditioned ore (29-306) may be sent to a surge bin or stockpile (29-308) and may then be fed into an inerting system (29-310) where inert gas is added. Bituminous feed (29-312) may enter a hopper (29-314). A hopper wash solvent may be added to the hopper (29-314). Bituminous feed (29-316) from the hopper (29-314) may be introduced into the jet pump (29-318). A motive fluid (29-320), comprising a solvent for extracting bitumen, may be added to the jet pump (29-318). The bituminous feed (29-316) spends a residence time with the hopper wash solvent in the hopper (29-314), where dissolution may occur. In addition, further dissolution and ablation occurs as the slurry is exposed to high shear and energy within the jet pump (29-318). A conditioned slurry (29-322) may be discharged from the jet pump (29-318). The conditioned slurry may be given a residence time in the pipe to ensure substantially complete dissolution of bitumen prior to an agglomeration step. This pipe may be referred herein as a dissolution pipeline. The residence time could be between 0 and 5 minutes, or between 0.5 minutes and 2 minutes. Additional solvent may be added along the dissolution pipeline to further dilute the slurry. The additional solvent may be added to the dissolution pipeline as a high velocity jet in order to further aid in the ablation of the bituminous feed comprising the slurry. The additional solvent may be added to the dissolution pipeline as a liquid or a vapor or a two phase mixture. The addition of solvent as a vapor may increase the thermal energy imparted to the slurry as result of the transfer of the solvent vapor's latent heat to the slurry. The solvent vapor may be added to the dissolution pipeline at a location immediately downstream of the centrifugal pumps. In this way, the solvent vapor may be added to the dissolution pipeline at an elevated pressure and temperature compared to the average pressure of the dissolution pipeline. Static mixers may be added in one or more locations within the dissolution pipeline to further aid in the ablation of large bituminous feed lumps.

[0463] The conditioned slurry (29-322) may be sent to a screen (29-324) to remove oversized particles (29-326), such as clay lumps, undigested ore, rocks, or other debris (29-328), and produce a screened conditioned slurry (29-330) The screen size openings may be nominally in the 2-10 mm range or in the 2-6 mm range, to limit bitumen loss during agglomeration and/or to assist post-agglomeration filtration, for instance in a vacuum filter system. The screen size openings may be nominally 6 mm in size. The oversized particles may be sized greater than 5 mm, or greater than 25 mm, or greater than a value there between. The screen may be static, vibrating, or rotating. The screen (29-324) may be a static screen in order to minimize the required maintenance of the screen (29-324). Oversized particles are those particles that have a size greater than the screen openings and hence, may not go through the screen. The screen may comprise a first screen with first openings and a second screen with second smaller openings. The first openings of the first screen may be 15-50 mm and the second openings of the second screen may be 4-15 mm.

[0464] The screened conditioned slurry (29-330) may be fed to a second hopper (29-332) for a residence time to allow for solids-liquid separation by gravity sedimentation. A supernatant (29-334) may be removed from the hopper (29-332) and fed to a second jet pump (29-336) as a second motive fluid. A second bridging liquid (29-338) may be mixed (29-340) with the supernatant (29-334) to become the motive fluid to the second jet pump (29-336). The second bridging liquid (29-338) may be added as an aqueous stream or as a combination of an aqueous stream and a separate hydrocarbon stream pre-processed to form an emulsion. The second motive fluid may comprise 30-70 wt. % bitumen based on a weight of the second motive fluid. The second motive fluid may also comprise 0-30 wt. % fines.

[0465] A bottom bituminous stream (29-342) from the second hopper (29-332) may also be introduced into the second jet pump (29-336). The second jet pump (29-336) mixes the bottom stream (29-342) and the supernatant (29-334) to produce a second conditioned slurry (29-344). The second conditioned slurry (29-344) may be passed through a slurry booster (29-346) to agglomeration (29-348) as described herein. Alternately, or in addition, a portion of the supernatant from the second jet pump (29-336) may be used as hopper wash for the first jet pump (29-318). A portion of the screened conditioned slurry may be passed back to the jet pump as additional motive fluid.

[0466] A hopper wash solvent volume may be adjusted according to a conditioned slurry volume, to control an overall density of the conditioned slurry.

II.D Oversize Reject Handling and Scrubbing

[0467] Figure 30 illustrates some of the same features as Figure 28 and includes additional features between the jet pump and the agglomeration. With reference to Figure 30, bituminous feed (30-412) may enter a hopper (30-414), which may feed a jet pump (30-418). A motive fluid (30-420), comprising a solvent for extracting bitumen, may be added to the jet pump (30-418) via a motive fluid pump (30-421). The motive fluid pump (30-421) may also supply hopper wash solvent (30-490) to the hopper (30-414) as an upper hopper wash solvent (30-492) or a lower hopper wash solvent (30-494) in respective upper and lower regions of the hopper. Both upper and lower wash solvents may provide flow assurance of solids in the hopper, addition of heat, and dissolution of bitumen. The lower wash solvent may also provide a disintegration action to mitigate any bridging and packing to ensure flow into the jet pump. In addition, the upper and lower wash solvents may be added in single or multiple locations or ports.

[0468] A conditioned slurry (30-422) may be discharged from the jet pump (30-418) and passed through a slurry boost pump (30-423) to a screen (30-425) to remove oversized particles (30-426), such as clay lumps, undigested ore, rocks, or other debris. The screen size openings may be nominally in the 2-10 mm range or in the 2-6 mm range, to limit bitumen loss during agglomeration and/or to assist post-agglomeration filtration, for instance in a vacuum filter system. The screen size openings may be nominally 6 mm in size. The oversized particles may be sized greater than 5 mm, or greater than 25 mm. The screen may be static, vibrating, or rotating. The screen may be a static screen in order to minimize the required maintenance of the screen. Oversized particles are those particles that have a size greater than the screen openings and hence, may not go through the screen. The screen may comprise a first screen with first openings and a second screen with second smaller openings. The first openings of the first screen may be 15-50 mm and the second openings of the second screen may be 4-15 mm. The screen may be a screened design to have no vapor space above or below said screen. The screened conditioned slurry may discharge into a pump box or a hopper where there is no vapor space between the screen and the pump box or hopper. The displaced liquid from either the pump box or hopper may be taken off by a surge tank with a vapor space to allow for the liquid height of the surge tank to change.

[0469] The screened condition slurry may discharge into a pump box or a hopper with a vapor space at a reduced speed so as to minimize gas entrainment into the jet pump or hopper. The screened conditioned slurry falling velocity is reduced by adding internal structures in the vapor space of the pump box and/or hopper to reduce the slurry's momentum. The internal structures may be added to slow gravity feed the screened conditioned slurry to the pump box or hopper. The internal structures may be common structures such as baffles and/or shelves. Baffles may be added within the slurry phase of the pump box or hopper to minimize plunging and allow for time for gas disengagement.

[0470] The screened conditioned slurry (30-496) from the screen (30-425) may enter a pump box (30-427). A slurry (30-429) may progress from the pump box (30-427) to a slurry pump (30-474). A portion of the screened conditioned slurry (30-496) may be used for hopper wash service to support flow assurance in the hopper (30-414).

[0471] A portion of the conditioned slurry (30-422a) may be recirculated to the jet pump feed hopper (30-414) to increase the energy dissipated on the solids enhancing ablation of large lumps, thus reducing the amount of material that is rejected on the screen (30-425), and accelerating the dissolution of bitumen from the ore. In order to keep the density of the condition slurry (30-422) constant, since more liquid is returned into the hopper through the recirculated conditioned slurry (30-422a), the hopper wash (30-492) rate may be reduced.

[0472] Oversized particles (30-426) may be washed on the screen (30-425) by a wash fluid (30-431). The screen may comprise two or more screens with differently sized openings. For instance, the first screen may have openings of 25 mm (or 15-30 mm), and the second screen may have openings of 10 mm (or 5-15 mm). The two oversize streams may be combined, or treated separately. Optionally, the particles screened by the second screen may be sent to an agglomerator or filtration (such as by a pan filter). The wash fluid (30-431) may comprise a washing solvent and, optionally, bitumen and fine particles. The wash fluid may comprise a first solvent and/or a second solvent. The wash fluid may comprise an extraction liquor. The wash fluid may provide the primary method of adding a first and/or second solvent to the SBE process in order to control the solvent to bitumen ratio in the dissolution and/or agglomeration processes. This wash fluid (30-431) may also assist in moving conditioned slurry (30-422) through the screen (30-425), minimizing the necessary screen size. The wash fluid (30-431) may comprise an aqueous or non-aqueous solvent. In a case where the screen is a rotating trommel, heavy chains or other devices may be used to assist breaking up soft oversized particles.

[0473] Washed oversized particles (30-426) from the screen (30-425) may be sent to a scrubbing device (30-433) using second wash fluid (30-435) jets to remove bitumen or bitumen coated particulates that may have adhered to the components such as rock or clay lumps. The scrubbing device may be considered to be a secondary and/or additional ablation unit that is able further ablate the bituminous feed beyond the ablation that occurs upstream of the scrubbing device. The scrubbing device may also acts as a buffer to the upstream ablation process by providing additional ablation and/or fully ablating the bituminous feeds during periods of upstream and/or transients in the upstream ablation process.

[0474] The scrubbing device may be capable of selectively reducing the size of the bitumen containing portions of the bituminous feed such as clay lumps and agglomerates and not reduce the size of solid rocks that are free of bitumen internally. The scrubbing device may have a high turndown ratio in order to handle large variation in oversize particles to the unit. The device may be compact so as to not significantly impact the layout of the facility. The scrubbing device may be preceded by a wet sizing device, such as a wet crusher, to reduce the oversize particles to four inch in size or below four inch in size.

[0475] An example of such a suitable scrubbing device is the Hydro-Clean (WS Tyler, Conyers, Georgia, US). The scrubbing device may be a series of high pressure stationary or rotating jets, operating at sufficient pressure to turn over large lumps, wash all sides of large lumps, and ablate softer material. The second wash fluid (30-435) may be a first solvent, a second solvent, and/or a bitumen extraction liquor. The second wash fluid may be a first solvent and/or a second solvent that is substantially free of bitumen. The second wash fluid (30-435) may be aqueous or non-aqueous. Where the second wash fluid (30-435) is non-aqueous, it may comprise a non-aqueous solvent, and optionally bitumen and fine particles.

Where the second wash fluid (30-435) comprises an aqueous fluid, the conditioned slurry may be used as the bridging liquid (30-481). When the second wash fluid (30-435) comprises a non-aqueous solvent, a recycle stream (30-451) may be used as part of combined slurry (30-453) or as hopper wash fluid (30-492). The second wash fluid may be sprayed at a pressure between 50 psi and 3500 psi.

[0476] Remaining oversized material (30-439) may be washed on a secondary screen (30-441) with clean solvent (also referred to as liquid wash) (30-443) to remove residual bitumen, and prepare the oversized particles for solvent removal.

[0477] If the high pressure liquid wash for the oversize materials is performed with a non-aqueous or hydrocarbon solvent, the liquid and liberated fines (30-437) may be drained from the scrubbing device, and co-mingled with the screened conditioned slurry in the pump box (30-427). Liquid and liberated fines may be sent back to the hopper (30-414) as hopper wash solvent, or as part of the motive fluid for the jet pump (30-418). The liquid and liberated fines may be sent immediately upstream of the oversize reject screen. Alternately, if the wash is performed with an aqueous solvent, the liquid stream (30-437) may be recycled as part of the bridging liquid for agglomeration.

[0478] Washed oversized particles (also referred to as a disposal stream) (30-445) may be sent for solvent removal (30-447) prior to disposal (30-498). Steam (30-449) may be added to the washed oversized particles (30-445) to evaporate the solvent.

[0479] Alternatively, the liquid wash (30-443) on the secondary screen (30-441) may be hot water. In this case, the heat of the water evaporates solvent, preparing the oversized material for direct disposal. Waste water from this step may be used as the bridging liquid for agglomeration as described herein.

[0480] Liquid recycle stream (30-451) may be co-mingled with slurry in the pump box (30-427), co-mingled with the higher density slurry (30-429) to form a combined slurry (30-453). The combined slurry (30-453) may be agglomerated as described herein. The combined slurry (30-453) may be used as motive fluid in the jet pump (30-418) if it is a dilute slurry and in all other cases, used as hopper wash solvent, or as other diluting, washing, or mixing service in the process. If the liquid wash (30-443) is water, liquid recycle stream (30-451) may be used in whole or in part as the bridging liquid (30-481).

[0481] The combined slurry (30-453) may be passed through a slurry pump (30-474). A bridging liquid (30-481) may be added to the combined slurry (30-453) to assist agglomeration. A static mixer (30-482) may be used to increase water dispersion of the combined slurry (30-453) to accelerate agglomeration, followed by filtration in a filter, for instance a pan filter (30-483), to and produce dry tailings (30-485), a lean extract (30-486), and a rich extract (30-487). Presence of a jet pump may eliminate or reduce the need for a static mixer for agglomeration, due to the high shear and energy therein.

[0482] A purpose of the jet pump and hopper wash solvent is to reduce the volume and cost of other systems required for ablation and dissolution. In the event that additional dissolution is required, a heated dissolution solvent (30-497) can be added into the pipeline prior to agglomeration. Due to the relatively higher pressure in the pipeline, the heated dissolution solvent can be added at a temperature above its atmospheric boiling point. This heated dissolution solvent, heat, and additional retention time may complete the dissolution to a desired extent. This heated dissolution solvent may be added in prior to or post the pump box, i.e. before the agglomerator, as described above, and in or after the discharge from the jet pump. The dissolution solvent may comprise bitumen and a lighter hydrocarbon. The heated dissolution solvent may be added at a temperature of 30 °C to 120 °C.

[0483] In order to mitigate recycling solids to obtain appropriate slurry density for a downstream filter system, a section of the pipeline containing agglomerated slurry may have a screen section, arranged in a pipe-in- pipe fashion. The screen size may be chosen to retain agglomerated solids, such as normally 100 to 200 microns. Liquid may be removed from the agglomerated slurry while still under pressure, and be measured and controlled to provide the agglomerated slurry in a higher solids concentration to the filter system. This hot, pressurized rich extract may be recycled to the prior steps as hopper wash or motive fluid for the jet pump. A potential benefit of the higher density to the filter system is a reduction in filter system requirements. Other separation devices such as cyclones may be used

[0484] With reference to Figure 31, bituminous feed (31-512) may enter a hopper (31-514), which may feed a jet pump (31-518). A motive fluid (31-520), comprising a solvent for extracting bitumen, may be added to the jet pump (31-518) via a motive fluid pump (31-521). The motive fluid pump (31-521) may also supply hopper wash solvent (31-590) to the hopper (31-514) as an upper hopper wash solvent (31-592) or a lower hopper wash solvent (31-594). The hopper wash may alternatively be supplied in a different composition and temperature than the motive fluid.

[0485] A conditioned slurry (31-522) may be discharged from the jet pump (31-518) and pass through a slurry boost pump (31-523) to a screen (31-525) to remove oversized particles (31-526), such as clay lumps, undigested ore, rocks, or other debris.

[0486] The screened conditioned slurry (31-596) from the screen (31-525) screen may enter a second hopper (31-527) for solid-liquid separation. A higher density slurry (31-529) may progress from the second hopper (31-527) to a second jet pump (31-560) toward agglomeration.

[0487] Oversized particles (31-526) may be washed on the screen (31-525) by a wash fluid (31-531). The wash fluid (31-531) may be clean, or include a portion of bitumen and other materials, such as fine particles. This wash fluid (31-531) may also assist in moving conditioned slurry (31-522) through the screen (31-525), minimizing the screen size. The wash fluid (31-531) may comprise an aqueous or non-aqueous solvent. In a case where the screen (31-525) is a rotating trommel, heavy chains or other devices may be used to assist breaking up soft oversized particles.

[0488] Washed oversized particles (31-526) from the screen (31-525) may be sent to a scrubbing device (31-533) using high-pressure liquid solvent (31-535) jets to remove bitumen or bitumen coated particulates that may have adhered to the non-ablatable components such as rock. An example of such a device is the Hydro-Clean (WS Tyler, Mentor, Ohio, US). Liquid and liberated fines (31-537) may be drained from the scrubbing device and added to the second hopper (31-527).

[0489] Remaining oversized material (31-539) may be washed on a second screen (31-541) with new solvent (31-543) to remove residual bitumen, and prepare the oversized particles for solvent removal.

[0490] Washed oversized particles (31-545) may be sent for solvent removal (31-547) and disposal (31-598). Steam (31-549) may be added to the washed oversized particles (31-545) to evaporate the solvent. Solvent based liquid (31-551) may be combined into the second hopper (31-527).

[0491] Alternatively, the liquid wash (31-543) on the second screen (31-541) may be hot water. In this case, the heat of the water evaporates solvent, preparing the oversized material for direct disposal. Waste water from this step may be used as the bridging liquid for agglomeration as described herein. Water based liquid (31-551) may be added to the pipeline as bridging liquid (31-581) or as bridging liquid (31-570) to the jet pump motive fluid (31-566).

[0492] Supernatant (31-566) may be passed through a motive fluid pump (31-568), combined with bridging liquid (31-570), and fed as motive fluid to the second jet pump (31-560). The intense mixing of the second jet pump may effectively disperse the bridging liquid with the solids in the slurry (31-529). A second jet pump discharge (31-572), which may comprise about 20-60 wt. % solids, based on the weight of the discharge, may be passed to a slurry pump (31-574). A bridging liquid (31-581) may be added to assist agglomeration. A static mixer (31-582) may be used for increased water dispersion to aid agglomeration, followed by filtration in a filter, for instance a pan filter (31-583), to produce dry tailings (31-585), a lean extract (31-586), and a rich extract (31-587). In this configuration as well, the presence of jet pump may eliminate or reduce the need for a static mixer for agglomeration, due to the high shear and energy therein.

[0493] Supernatant (31-576) may be passed through a motive fluid recycle pump (31-578), heated (31-580), and recycled as motive fluid (31-520) for the first jet pump (31-518), or as hopper wash solvent (31-590).

[0494] Wet crushing or sizing may be used in the hoppers (28-214, 29-314, 30-414, or 31-514) or to crush oversized particles (30-426 or 31-526). The addition of fluid to the bituminous feed can assist in throughput through sizing devices, reduce buildup of ore, and reduce frictional wear on grinding surfaces.

III. Solids Agglomeration

[0495] Agglomeration can be used with SBE to improve solid-liquid separation.

[0496] ***Bridging Liquid.*** During solvent extraction with agglomeration, the bituminous feed, or oil sand slurry, may be mixed with an aqueous bridging liquid in order to agglomerate the solids within the bituminous feed, or oil sand slurry, and form an agglomerated slurry. The formed agglomerates within the agglomerated slurry may be sized on the order of 0.1-1.0 mm, or on the order of 0.1-0.5mm, or on the order of 0.1-0.3 mm. At least 80 wt. % of the formed agglomerates may be 0.1-1.0 mm, or 0.1-0.5mm, or 0.1 to 0.3 mm in size. Agglomerate size may be influenced by the particle size of the bituminous feed. Feed with a D50 in the area of 125 microns may have a smaller agglomerate PSD than if the bituminous feed has a D50 of 350 microns. 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, aqueous bridging liquid addition, and residence time of the agglomeration process. The agglomerated slurry may have a solids content of 20 to 70 wt. %. It may be desired to have the agglomerated slurry with the highest feasible solids content in order to minimize fluid handling and improve filter operation. 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. %.

[0497] A bridging liquid is a liquid with affinity for the solids particles in the bituminous feed, and which is immiscible in a solvent which may be the first solvent, or even an extraction liquor. In some embodiments, the agglomerating of solids comprises adding an aqueous bridging liquid to the fine solids stream and providing agitation. Exemplary bridging aqueous liquids may be water that accompanies 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, emulsions, or any other acceptable aqueous solution capable of adhering to solid particles within an agglomerator in such a way that permits fines to adhere to each other. Exemplary bridging liquids may be water, water that accompanies the bituminous feed and/or recycled water from other aspects or steps of oil sand processing. The bridging liquid may 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 and/ or any other acceptable aqueous solution capable of adhering to solid particles in such a way that permits fines to adhere to each other. The bridging liquid may be referred to interchangeably herein as a “binding liquid”.

[0498] Contaminated water is used herein as the bridging liquid or as part of the bridging liquid. The contaminated water may be, for instance, from a water-based hydrocarbon extraction process or from an in-situ thermal hydrocarbon recovery facility. The contaminated water may include solids and/or dissolved solids. Contaminated water requiring treatment prior to use within in-situ thermal hydrocarbon recovery and/or WBE may be used. Exemplary wastewaters are concentrated brine from water treatment plants and boilers of the in-situ thermal hydrocarbon recovery processes and tailings produced from water-based hydrocarbon extraction processes.

[0499] Bitumen extract recovered after solid-liquid separation may contain aqueous liquid which separates from the hydrocarbon phase in a process vessel and/or holding tanks. This aqueous liquid may be used as a bridging liquid. For example, a layer substantially comprising an aqueous liquid may form at the bottom of the bitumen extract holding tanks. This aqueous liquid may be collected and used as a bridging liquid for the agglomeration process. The condition of the bitumen extract may be changed to induce the separation of aqueous liquids from the bitumen extract. The condition of the bitumen extract may be changed, for example, by altering its temperature, by adding solvent, by adding a chemical additive, or by electrical fields.

[0500] An exemplary aqueous liquid may be mine runoff water that is conventionally produced during the mining of the bituminous feed. Similar to the conventional handling of mine runoff, the water may be temporarily stored in constructed ponds. The ponds may be constructed as part of the mine plan and facility layout to collect mine and plant water runoff to be used in the SBE process. The ponds may be constructed in a conventional manner. All or a portion of the runoff water may then be directed to the SBE process as the bridging liquid of the process. The remaining runoff water may be handled and treated similar to conventional handling and treatment of runoff water.

[0501] Steam may be the source of the bridging liquid. The use of steam as the source of the bridging liquid has the advantage that steam can impart its latent heat to bituminous feed to further heat the bituminous feed during the agglomeration process. Since the quality of the steam used for a bridging liquid need not be of high quality, the steam may be produced at a quality of 75% or less. The use of lower quality steam may reduce the required complexity of the boiler system producing the steam. Blowdown from a conventional steam boiler system can alternatively, or in addition, be used as the bridging liquid for the SBE process.

[0502] The total amount of bridging liquid added to the slurry may be controlled in order to optimize bitumen recovery and the rate of solid-liquid separation, and may also be controlled with an account of the value provided by the upgrading of the contaminated water to high quality water. In some embodiments the value will depend on the measured properties described herein. By way of example, the total amount of bridging liquid added may be such that a ratio of bridging liquid plus connate water from the bituminous feed to solids within the agglomerated slurry is in the range of 0.02 to 0.15 or in the range of 0.05 to 0.11. The amount of bridging liquid that is added at a stage may be the same for each stage, or may be different. In one embodiment, the bridging liquid to solids ratio may be obtained by feedback control.

[0503] The aqueous bridging liquid may be added to the bituminous feed in a concentration of less than 20 wt. % of the slurry, less than 10 wt. % of the bituminous feed, between 1 wt. % and 20 wt. %, or between 1 wt. % and 10 wt. %. For some embodiments the bridging liquid may be added in a concentration of less than 50 wt. % of the oil sand feed, or less than 25 wt. %.

[0504] In one embodiment, the bridging liquid comprises fine particles (for instance less than 44 μm) suspended therein. These fine particles may serve as seed particles for the agglomeration process. The bridging liquid may comprise less than 40 wt. % solid fines. The agglomerated slurry may have a solids content of 20 to 70 wt. %. The bridging liquid may be in the form of an emulsion, for instance as described below.

[0505] The bridging liquid and fines particles slurry is also referred to herein as sludge from a WBE. Suitable sludge streams include, but are not limited to, WBE streams such as middling from primary separation, secondary and tertiary separation tailings, froth treatment tailings, mature fine tailings from tailings ponds, or a new stream resulting from passing any of these streams through a thickener, hydrocyclone, or other processes. For example, middlings passed through a cyclone might generate an overflow stream and an underflow stream. Either stream could be used in this process as bridging liquid. Sludge may also be produced within the solvent extraction with solids agglomeration process by mixing bridging liquid with agglomerated tailings. In this way, a portion of the agglomerated solids are recycled through the process. The use of bridging liquid with a significant solid content, such as that which is described above, may allow for greater control of the agglomeration process. Previous work has shown that when sludge is used as the bridging liquid, the addition of the same amount of sludge per unit weight of oil sand feed resulted in the production of agglomerates of the same drainage properties regardless of oil sand quality.

[0506] The bridging liquid may be added after the production of the oil sand slurry or before the production of the oil sand slurry. In the former scenario, the bitumen is first extracted from the bituminous feed prior to agglomeration in order to prevent (or limit) the agglomeration process from hampering the dissolution of bitumen into the extraction liquor, which may increase bitumen recovery. In the latter scenario, the bridging liquid may be directly mixed with the bituminous feed before or at the same time as the extraction liquor in order to minimize the dispersion of fines, which may reduce the solids content of the bitumen extract after the agglomeration process. The control system described herein can be used to control where in the solvent extraction with solids agglomeration process the bridging liquid is added based on the output of the process. The bridging liquid may comprise less than 40 wt. % solids fines. The agglomerated slurry may have a solids content of 20 to 70 wt. %.

[0507] The bridging liquid may be added to the extraction liquor in a concentration of less than 50 wt. % of the emulsion. In another embodiment, the bridging liquid is added to the extraction liquor in a concentration of less than 25 wt. %. In one embodiment, the bridging liquid is added in a concentration of between 5 wt. % and 50 wt. % or between 10 wt. % and 25 wt. %. In one embodiment, the bridging liquid may comprise fine particles (sized less than 44 μm) suspended therein. These fine particles may serve as seed particles for the agglomeration process. In one embodiment, the bridging liquid has a solids content of less than 40 wt. %. In one embodiment, the agglomerated slurry has a solids content of 20 to 70 wt. %.

[0508] The composition of the bridging liquid, for example salinity and/or fines content, may be the same or different depending on which stage along the along the slurry flow path the bridging liquid is added.

[0509] ***Agitation.*** Agglomeration 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 feed need only be severe enough and of sufficient duration to intimately contact the emulsion with the solids in the 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 feed is, in one embodiment, greater than 40 wt. % so that compaction forces assist agglomerate formation. The agitation of the 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 comminution of agglomerates. These agitation parameters can be adjusted in the control system of some embodiments.

[0510] ***Agglomerate Size.*** Embodiments described herein may be used for the formation of macro-agglomerates or micro-agglomerates from the solids of the bituminous feed. Macro-agglomerates are agglomerates that are predominantly greater than 2 mm in diameter. These agglomerates comprise both the fine particles (less than 44 μm) and sand grains of the oil sand. Micro-agglomerates are agglomerates that are predominately less than 1 mm in diameter and they principally comprise fine particles of the oil sand. It has been found that for the SESA process described herein, the formation of micro-agglomerates are more suitable for maximizing bitumen recovery for a range of oil sand grades. It has also been found that for the SBE process with agglomeration described herein, the formation of micro-agglomerates are more suitable for maximizing bitumen recovery for a range of oil sand grades.

[0511] ***Agglomerator.*** As used herein, "agglomerate" refers to conditions that produce a cluster, aggregate, collection or mass, such as nucleation, coalescence, layering, sticking, clumping, fusing and sintering, as examples.

[0512] Agglomeration of fines derived from the initial slurry occurs within an agglomerator. The initial slurry comprises bituminous components together with solids, fines and water. These components, together with the solvent, are subjected to agglomeration within the agglomerator by imparting agitation within the agglomerator. Agitation is imparted through such motion as tumbling, rotation, or directed flow. Within an agglomerator, purge gas may again be used so as to maintain a low oxygen environment within. An agglomerator may comprise a plurality of vessels, such as tanks or rotating drums, set up in parallel or in series. The use of vessels in parallel can advantageously be configured to any appropriate volume required at a given location. An exemplary amount of oil sand to be processed may be for example 5000 tonnes per hour per agglomerator vessel. Thus, in a system where two agglomerator vessels are configured in parallel, approximately 10,000 tonnes per hour can be processed. In alternative embodiments the agglomeration takes place in a pipeline.

[0513] The agglomerator may include a discharge screening system. After agglomeration, streams may be screened to separate agglomerates from solvent, and agglomerates are processed further for bitumen recovery, while solvent with bitumen entrained therein is further processed through solvent recovery steps.

[0514] Agglomeration may occur in a drum-style unit, or may occur in a shaker or within any alternative vessel into which agitation can be introduced. The agglomerator may have an integral trommel screen at the discharge which rotates with the agglomerator. The screen separates oversized reject materials, for example, solids greater than an average particle size of about 50mm as well as petrified wood, twigs or other material that can potentially upset downstream processing.

[0515] The step of agglomerating solids may comprise adding water as bridging liquid to the fine solids stream and providing suitable mixing or agitation. The type and intensity of mixing will dictate the form of agglomerates resulting from the particle enlargement process.

[0516] The step of agglomerating solids may comprise adding steam to the bituminous feed. The addition of steam may be beneficial to the bituminous feed because it may begin solids nucleation prior to the step of agglomerating.

[0517] Agitation could be provided in colloid mills, shakers, high speed blenders, disc and drum agglomerators, or other vessels capable of producing a turbulent mixing atmosphere. The amount of bridging liquid is balanced by the intensity of agitation to produce agglomerates of desired characteristics. As an example of appropriate conditions for a drum or disc agglomerator, agitation of the vessel may typically be about 40% of the critical drum rotational speed while a bridging liquid is kept below about 20 wt. % of the slurry. The agitation of the vessel could range from 10% to 60% of the critical drum rotational speed, and the bridging liquid may be kept between about 10 wt. % to about 20 wt. % of solids contained in the slurry, in order to produce compact agglomerates of different sizes.

[0518] In one embodiment, the formed agglomerates are sized on the order of 0.1-1.0 mm, or on the order of 0.1-0.5mm, or on the order of 0.1-0.3 mm. In one embodiment, at least 80 wt. % of the formed agglomerates are less than 2mm, or 0.1-1.0 mm, or 0.1 to 0.5mm, or 0.1 to 0.3 mm in size. The rate of agglomeration may be controlled by a balance between intensity of agitation within the agglomeration vessel, shear within the vessel which can be adjusted by for example 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. %.

[0519] ***Extraction Step may be Separate from Agglomeration Step.*** Solvent extraction may be conducted separately from agglomeration in certain embodiments of the process. Unlike certain prior processes, where the solvent is first exposed to the bituminous feed within the agglomerator, certain embodiments described herein include contact of the extraction liquor with bituminous feed prior to the agglomeration step. This has the effect of reducing residence time in the agglomerator, when compared to certain previously proposed processes which have extraction of bitumen and agglomeration occurring simultaneously. Experience demonstrates there is an optimal residence time range for agglomeration of the solids. A residence time that is below the optimal residence time range leads to insufficient agglomeration of the solids which in turn hinders solid-liquid separation. On the other hand, a residence time that is above the optimal residence time range leads to excessive agglomerate growth which in turn results in poor bitumen recovery. The experimental example described below demonstrates the effects of agglomeration residence time on the solvent extraction with solids agglomeration process. Performing extraction upstream of the agglomerator may permit the use of enhanced material handling schemes whereby flow/mixing systems such as pumps, mix boxes or other types of conditioning systems can be employed. Performing extraction upstream of the agglomerator may prevent (or limit) the agglomeration process from hampering the dissolution of bitumen into the extraction liquor. Additionally, performing extraction upstream of the agglomerator may allow for separately optimizing the extraction residence time and the agglomeration residence time.

[0520] Because the extraction may occur upstream of the agglomeration step, the required residence time in the agglomerator may be reduced. One other reason for this reduction is that by adding components, such as water, some initial nucleation of particles that ultimately form larger agglomerates can occur prior to the agglomerator.

[0521] ***Dilution of Agglomerator Discharge to Improve Product Quality.*** Solvent may be added to the agglomerated slurry for dilution of the slurry before discharge into the primary solid-liquid separator, which may be for example a deep cone settler. The solvent may be a first solvent or second solvent or mixtures thereof. This dilution can be carried out in a staged manner to pre-condition the primary solid-liquid separator feed to promote higher solids settling rates and lower solids content in the solid-liquid separator's overflow. The solvent(s) with which the slurry is diluted may be derived from recycled liquids from the liquid-solid separation stage or from other sources within the process.

[0522] When dilution of agglomerator discharge is employed in this embodiment, the solvent to bitumen ratio of the feed into the agglomerator is set to obtain from about 10 to about 90 wt. % bitumen in the discharge, and a workable viscosity at a given temperature. In some embodiments the agglomeration takes place within a pipeline. In certain cases, these viscosities may not be optimal for the solid-liquid separation (or settling) step. In such an instance, a dilution solvent of equal or lower viscosity may be added to enhance the separation of the agglomerated solids in the clarifier, while improving the quality of the clarifier overflow by reducing viscosity to permit more solids to settle. Thus, dilution of agglomerator discharge may involve adding the solvent, or a separate dilution solvent, which may, for example, comprise an alkane.

[0523] ***The effects of agglomeration residence time on the solvent extraction with solids agglomeration process.*** 350g of oil sand and 235.07g of extraction liquor were placed into the Parr reactor vessel. The solids and solvent were mixed at 1500 rpm for 5 minutes to fully homogenize the mixture and to fully extract the bitumen that was in the oil sand. After 5 minutes of mixing, 16.8g of water was quickly poured into the vessel through a sample port. The mixture was then mixed at 1500 rpm for a given agglomeration residence time to agglomerate the solids. The agglomeration times tested were 0.5, 1, 2, 5, 15, and 30 minutes.

[0524] After the agglomeration process, the impeller was turned off and the agglomerates were allowed to settle for over 1 minute. The supernatant (bitumen extract) was poured into a separate container and the wet solids were transferred to a Buchner funnel. The solids rested on a filter paper with a nominal pore size of 170 μm. The filter's effective area was approximately 8 cm^2. The solids bed height was 10.8 cm. A portion of the collected supernatant was poured on top of the solids until a liquid height of 1.9 cm formed above the solids surface. A light vacuum was then applied to the Buchner funnel and the initial drainage rate of the liquid was recorded.

[0525] The remaining supernatant was poured onto the solid bed and allowed to filter through. 211 mL of pure cyclohexane was then filtered through the solid bed in order to wash the agglomerates. The solid bed was then allowed to drain of liquid under a light vacuum for about 30 seconds. The bitumen content of the washed solids was then measured to determine the bitumen recovery of the solvent extraction process.

[0526] Figure 47 plots the bitumen recovery and the initial liquid filtration rate as a function of the agglomeration residence time. The figure shows that the bitumen recovery reaches a maximum and then decreases as the agglomeration time increases for batch experiments conducted with the extraction time kept constant at 5 minutes. The decrease in recovery beyond the maximum recovery is most likely due to excessive agglomerate growth that lead to entrapment of the bitumen extract within the agglomerates. However, this growth of agglomerates does result in a continuous increase in the initial filtration rate as the agglomeration time increases. The reduction in bitumen recovery due to excessive agglomeration growth can be partially offset by increasing the solvent to bitumen ratio during agglomeration.

III.A Bridging Liquid Emulsion

[0527] In one aspect, the present section provides a method of processing a bituminous feed, the method comprising: a) contacting the bituminous feed with a bridging liquid-in-extraction liquor emulsion, to form a slurry, wherein the extraction liquor comprises a solvent; b) agglomerating solids within the slurry, using agitation, to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract; and c) separating the agglomerates from the low solids bitumen extract.

[0528] With reference to Figure 32, a bituminous feed is contacted with a bridging liquid-in-extraction liquor emulsion to form a slurry (32-102). Solids in the slurry are agglomerated, using agitation, to form an agglomerated slurry comprising agglomerated solids and a low solids bitumen extract (32-104). The agglomerates are then separated from the low solids bitumen extract (32-106). Emulsifying the bridging liquid prior to contacting it with the bituminous feed may reduce the amount of energy required for the agglomeration process. Other potential benefits may include the production of smaller and more uniform agglomerates. The former may lead to higher bitumen recoveries and the latter may improve the solid-liquid separation rate.

[0529] Figure 33 is a schematic of a disclosed embodiment with additional steps including emulsion formation and downstream solvent recovery. The bridging liquid (33-202) is dispersed within the extraction liquor (33-204) using an emulsifier (33-206) to form a water-in-oil type emulsion. This step may be performed off-site. The emulsion (33-208) and an oil sand slurry (33-212) are fed into an agglomerator (33-210). One or more agglomerators may be used.

[0530] In one embodiment, dry oil sand (33-214) is first contacted with an extraction liquor (33-216) that is free of any bridging liquid in a slurry system (33-217). The mixture is well mixed in order to dissolve all (or nearly all) of the bitumen within the oil sand. This oil sand slurry (33-212) is then mixed with the emulsion (33-208) to agglomerate the fine particles. In this embodiment, the bitumen is first extracted from the oil sand (33-214) prior to agglomeration in order to prevent (or limit) the agglomeration process from hampering the dissolution of bitumen into the extraction liquor. The composition of the extraction liquor used to produce the oil sand slurry (33-212) may be the same or different from the extraction liquor used to produce the emulsion. In another embodiment, the emulsion may be directly mixed (33-218) with the oil sand (33-214) and potentially additional extraction liquor (33-216) so that extraction and agglomeration occur simultaneously.

[0531] The agglomerated slurry (33-220), comprising agglomerates and a low solids bitumen extract, is sent to a solid-liquid separator (33-222) to produce a low solids bitumen extract (33-224) and agglomerates (33-226). The low solids bitumen extract is sent to a SRU (33-228) to recover solvent (33-230) leaving a bitumen product (33-234). The agglomerates are sent to a TSRU (33-236) to recover solvent (33-238) leaving dry tailings (33-240).

[0532] Figure 34 is a schematic of a disclosed embodiment, where the emulsion is mixed directly with the oil sand. Figure 34 also includes additional steps including emulsion formation and downstream solvent recovery. The bridging liquid (34-302) is first dispersed within the extraction liquor (34-304) using an emulsifier (34-306) to form the emulsion (34-318). The emulsion (34-318) is fed into a slurry system (34-317). Dry oil sand (34-314) is fed into the slurry system (34-317) and mixed with the emulsion (34-318) to form an oil sand slurry (34-312), which is fed into the agglomerator (34-310). Extraction liquor (34-316) may also be added directly to the slurry system (34-317). The emulsifier can be a separate equipment from the agglomerator or it can be incorporated within the slurry system and agglomerator. For example, the jet pump acts as an emulsifier if the mixing energy is strong enough that the bridging liquid emulsifies before the agglomerates nucleate and grow. A static mixer can also act as an internal emulsifier for the same reason.

[0533] The agglomerated slurry (34-320), comprising agglomerates and a low solids bitumen extract, is sent to a solid-liquid separator (34-322) to produce a low solids bitumen extract (34-324) and agglomerates (34-326). The low solids bitumen extract (34-324) is sent to a SRU (34-328) to recover solvent (34-330) leaving a bitumen product (34-334). The agglomerates (34-326) are sent to a desolventizer (34-336) to recover solvent (34-338) leaving dry tailings (34-340). Make-up extraction liquor may also be added.

[0534] The solvent (34-330) removed from the low solids bitumen extract (34-324) is used in the solid-liquid separator (34-322). The solid-liquid separator (34-322) produces extraction liquor (34-304) for addition to the emulsifier (34-306), as described above.

[0535] Figure 35 is a flow chart of a disclosed embodiment, where the emulsion is mixed with the oil sand after the oil sand has been slurried with additional extraction liquor. Figure 35 also includes additional steps including emulsion formation and downstream solvent recovery. The bridging liquid (35-402) is first dispersed within the extraction liquor (35-404) using an emulsifier (35-406) to form the emulsion (35-418). The emulsion (35-418) is fed into the agglomerator (35-410). Dry oil sand (35-414) and extraction liquor (35-416) are fed into the slurry system (35-417) to form oil sand slurry (35-412) which is fed into the agglomerator (35-410).

[0536] The agglomerated slurry (35-420), comprising agglomerates and a low solids bitumen extract, is sent to a solid-liquid separator (35-422) to produce a low solids bitumen extract (35-424) and agglomerates (35-426). The low solids bitumen extract (35-424) is sent to a SRU (35-428) to recover solvent (35-430) leaving a bitumen product (35-434). The agglomerates (35-426) are sent to a desolventizer (35-436) to recover solvent (35-438) leaving dry tailings (35-440).

[0537] The solvent (35-430) removed from the low solids bitumen extract (35-424) is used in the solid-liquid separator (35-422). The solid-liquid separator (35-422) produces extraction liquor (35-404) for addition to the emulsifier (35-406) or the slurry system (35-417), as described above. Make-up extraction liquor may also be added.

[0538] ***Forming the Emulsion.*** The emulsion comprises a bridging liquid dispersed in an extraction liquor, both of which are described below. The emulsion may be formed with various known liquid-in-liquid emulsifiers. Exemplary devices include, but are not limited to, tubular mixers, static mixers, blenders, and liquid jet mixers. In one embodiment, the emulsion forming device is an ultrasonic emulsifier. This device is expected to produce micron size bridging liquid droplets with a lower power requirement than a conventional homogenizer. In one embodiment, the bridging liquid droplets within the emulsion are 1 to 100 μm in size, or 1 to 10 μm in size. In one embodiment, at least 80 wt. % of the bridging liquid droplets within the emulsion are 1 to 100 μm in size, or are 1 to 10 μm in size.

[0539] The bridging liquid may be added to the extraction liquor in a concentration of less than 50 wt. % of the emulsion. The bridging liquid may be added to the extraction liquor in a concentration of less than 25 wt. %. The bridging liquid may be added in a concentration of between 5 wt. % and 50 wt. % or between 10 wt. % and 25 wt. %.

[0540] Using such an emulsion may enable the formation of macro-agglomerates or micro-agglomerates from the solids of the bituminous feed. Macro-agglomerates are agglomerates that are predominantly greater than 2 mm in diameter. These agglomerates comprise both the fine particles (less than 44 μm) and sand grains of the oil sand. Micro-agglomerates are agglomerates that are predominately less than 1 mm in diameter and they principally comprise fine particles of the oil sand. It has been found that for the SESA process described above, the formation of micro-agglomerates are more suitable for maximizing bitumen recovery for a range of oil sand grades. In one embodiment, the agglomerated slurry has a solids content of 20 to 70 wt. %. The ratio of emulsion to slurry may be in a range of 1.5 to 0.1 by weight.

[0541] ***Unstable or Stable Emulsion.*** In one embodiment, an unstable emulsion is used. An unstable emulsion may reduce the energy needed for the bridging liquid to contact and attach with the solid particles. It has been shown that for stable emulsions, kinetic restriction from such factors as electrical double layer interactions and film thinning considerations can lead to increased power consumption in the solids agglomeration process [see *Int. J. of Min. Proc.* Vol. 4 pp173-184]. An "unstable emulsion", as used herein, means an emulsion that begins to segregate during the agglomeration process. However, it is not desirable to have the unstable emulsion segregate much faster (for instance an order of magnitude faster) than the agglomeration process, since this would defeat the purpose of using an emulsion. The time scale of agglomeration, in one non-limiting example, may be on the order of minutes, for instance 2 to 5 minutes.

[0542] In another embodiment, a stable emulsion is used. In this embodiment, a stable emulsion is desirable in order to keep the bridging liquid droplets within the emulsion small and discreet during the agglomeration process. The stability of the emulsion may be provided by the interaction between the bridging liquid and the asphaltenes dissolved within the extraction liquor. Additional stabilizing agents may include alkaline solution additives such as NaOH, Na_2CO_3 and NH_4OH. Residual solids fines, which may be found in the extraction liquor, may also act as emulsion stabilizers. Such fines may also serve as nuclei for solids agglomeration. A “stable emulsion”, as used herein, means an emulsion that will not segregate during the agglomeration process. The “stable emulsion” may be thermodynamically or kinetically stable. A surfactant may be added to the emulsion to facilitate formation of the emulsion.

[0543] ***Potential Advantages of Emulsion.*** There may be advantages of emulsion embodiments described herein as compared to SESA. It is believed that the bridging liquid to solids contact, which is needed for agglomeration, can be enhanced if the bridging liquid is first emulsified in the extraction liquor prior to mixing it with the oil sand solids. Similar advantages have been realized in the agglomeration of coal fine particles (see U.S. Patent No. 3,856,668 (Shubert) and U.S. Patent No. 4,209,301(Nicol *et al.*)).

[0544] Previous solids agglomeration processes have required large energy inputs. Embodiments described herein are expected to reduce the total energy needed to form the agglomerates. The reduction in energy may be a result of both a reduction in the required time and the required power needed for the agglomeration process. A reduction in residence time may translate to smaller and less expensive vessels. A reduction in the power requirement means that that the torque requirements of motors used in certain types of agglomeration vessels can be reduced. In the case of rotating type vessels, the required amount of milling may be reduced. Furthermore, the wear of the internals of the vessels may be reduced due to a reduction in the required mixing intensity.

[0545] The emulsified bridging liquid is expected to more quickly and more uniformly distribute within the oil sand slurry. For this reason, the amount of bridging liquid needed to agglomerate the fine particles within oil sand slurry can be less than that which would be required if the bridging liquid was not emulsified. A reduced amount of bridging liquid may result in smaller agglomerates which have been shown to result in higher bitumen recovery values. The improved distribution of bridging liquid within the oil sand slurry is also expected to result in a narrower particle size distribution for the agglomerates. Agglomerates that are more uniform in size may have higher drainage rates for solid-liquid separation methods such as filtration and screening. In cases where the bridging liquid is added to the oil sand slurry without being emulsified, excess water addition typically leads to excessive agglomerate growth and poor bitumen recovery. The emulsified bridging liquid may result in acceptable agglomerate formation even when the amount of bridging liquid added results in a bridging liquid content that would, in the conventional situation, lead to excessive agglomerate growth. Without intending to be bound by theory, a possible explanation for this behavior is that a portion of the emulsified bridging liquid droplets may be sufficiently small to render those droplets stable in the slurry. The surface tension forces of these stable droplets may be sufficient to reduce the likelihood of them coalescing with larger agglomerates or with each other when they come into contact as a result of random motion.

[0546] ***Laboratory Experiments***. Experiments were conducted to test the effectiveness of using a bridging liquid-in-extraction liquor emulsion to agglomerate oil sand solids within a slurry. The liquid drainage rate of the formed agglomerates was used as the experimental measurement to determine the effectiveness of the agglomeration process. The agglomerates were also visually inspected for their size and uniformity.

[0547] Athabasca oil sand was treated in a Soxhlet extractor, with toluene as the extraction solvent, to remove bitumen and water from the solids. The oil sand solids were dried overnight in an oven (100 °C) and then used as the solids in the agglomeration process. Pure cyclohexane was used as the extraction liquor and distilled water was used as the bridging liquid. Bitumen was excluded from the solids and the solvent in order to allow for visual inspection of the agglomeration process. For each experiment, a total of 350g of solids, 311.5g of cyclohexane, and 38.5g of water were used. This composition translated to a solids content of 50 wt. % and a water to solids ratio of 0.11 for the agglomerated slurry.

[0548] A Parr reactor (series 5100) (Parr Instrument Company, Moline, IL, USA) was used as the agglomerator. The reactor vessel was made of glass that permits direct observation of the mixing process. A turbine type impeller powered by an explosion proof motor of 0.25 hp was used. The mixing and agglomeration speed of the impeller were set to 1000 rpm. This rotation speed allowed the slurry to remain fluidized at all conditions of the experiments. The agglomeration experiments were conducted at room temperature (22 °C).

III.A.1 Agglomeration by Adding Bridging Liquid Directly to Solids Slurry.

[0549] 350g of oil sand solids and 311.5g of cyclohexane were placed into the Parr reactor vessel. The solids and solvent were mixed at 1000 rpm for 1 minute to fully homogenize the mixture. After 1 minute of mixing, water was quickly poured into the vessel through a sample port. The mixture was then mixed at 1000 rpm for an additional 2 minutes to agglomerate the solids.

[0550] After the agglomeration process, the impeller was turned off and the agglomerates were allowed to settle for over 1 minute. The supernatant was poured into a separate container and the wet solids were transferred to a Buchner funnel. The solids rested on a filter paper with a nominal pore size of 170 μm. The filter's effective area was approximately 8 cm^2. The solids bed height was 10.8 cm. A portion of the collected supernatant was poured on top of the solids until a liquid height of 1.9 cm formed above the solids surface. A light vacuum was then applied to the Buchner funnel and the initial drainage rate of the liquid was recorded. The initial drainage rate for solids agglomerated by adding bridging liquid directly to the solids slurry was 0.37 mL/(cm^2sec).

III.A.2: Agglomeration by First Emulsifying Bridging Liquid with Solvent and then Adding Emulsion to Solids Slurry.

[0551] 38.5g of water was added to 115.5g of solvent in a glass bottle. The mixture was then emulsified by placing the glass bottle in an ultrasonic bath for 10 minutes. 350g of oil sand solids and 196g of cyclohexane were placed into the Parr reactor vessel. The solids and solvent were mixed at 1000 rpm for 1 minute to fully homogenize the mixture. After 1 minute of mixing, the emulsion was quickly poured into the vessel through a sample port. The mixture was then mixed at 1000 rpm for an additional 2 minutes to agglomerate the solids.

[0552] After the agglomeration process, the impeller was turned off and the agglomerates where allowed to settle for over 1 minute. The supernatant was poured into a separate container and the wet solids were transferred to a Buchner funnel. The solids rested on a filter paper with a nominal pore size of 170 μm. The filter's effective area and the funnel's cross-sectional area were approximately 8 cm. The solids bed height was 10.8 cm. A portion of the collected supernatant was poured on top of the solids until a liquid height of 1.9 cm formed above the solids surface. A light vacuum was then applied to the Buchner funnel and the initial drainage rate of the liquid was recorded. The initial drainage rate for solids agglomerated by first emulsifying the bridging liquid with solvent and then adding emulsion to solids slurry was approximately 2.1 mL/(cm^2sec). This drainage rate was approximately 5.7 times greater than that of agglomerates formed without first emulsifying the bridging liquid.

III.B Staged Addition of Bridging Liquid

[0553] The present section provides a method of processing a bituminous feed. The bituminous feed is contacted with an extraction liquor to form a slurry. A bridging liquid is added to the slurry in at least two stages and solids within the slurry are agitated to form an agglomerated slurry comprising agglomerated solids and a low solids bitumen extract. The bridging liquid is added to the slurry in regions having higher shear rates than a median shear rate within the slurry. The agglomerates are then separated from the low solids bitumen extract. Potential benefits may include the production of smaller and more uniform agglomerates. The former may lead to higher bitumen recoveries and the latter may improve the solid-liquid separation rate.

[0554] The present section provides a method of processing a bituminous feed, the method comprising: a) contacting the bituminous feed with an extraction liquor to form a slurry, wherein the extraction liquor comprises a solvent; b) adding a bridging liquid to the slurry in at least two stages and agitating solids within the slurry to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract; said bridging liquid being added to the slurry in regions having higher shear rates than a median shear rate within the slurry; and c) separating the agglomerates from the low solids bitumen extract.

[0555] With reference to Figure 36, a bituminous feed may be contacted with an extraction liquor to form a slurry (36-102). A bridging liquid may be added to the slurry in at least two stages and solids within the slurry are agitated to form an agglomerated slurry comprising agglomerated solids and a low solids bitumen extract (36-104). The bridging liquid may be added to the slurry in regions having higher shear rates than a median shear rate within the slurry. The agglomerates may then be separated from the low solids bitumen extract (36-106). Potential benefits may include the production of smaller and more uniform agglomerates. The former may lead to higher bitumen recoveries and the latter may improve the solid-liquid separation rate.

[0556] The total amount of bridging liquid added may be such that a ratio of bridging liquid plus connate water from the bituminous feed to solids within the agglomerated slurry is in the range of 0.02 to 0.15 or in the range of 0.05 to 0.11. The amount of bridging liquid that is added at a stage may be the same for each stage, or may be different.

[0557] The composition of the bridging liquid, for example salinity and/or fines content, may be the same or different depending on which stage along the along the slurry flow path the bridging liquid is added. Additionally, the amount of the bridging liquid that is added to the slurry at each stage of bridging liquid addition may be the same or different. For example, the bridging liquid added during a first stage may have a salinity that is at least 10% higher or lower than a salinity of a bridging liquid added during a second, subsequent stage. In another example, the bridging liquid added during a first stage may have a suspended solids content that is at least 10 % higher or lower than a suspended solids content of a bridging liquid added during a second, subsequent stage.

[0558] Figure 37 is a schematic of a disclosed embodiment with additional steps including downstream solvent recovery. The extraction liquor (37-202) is mixed with a bituminous feed (37-204) from oil sand in a slurry system (37-206) to form a slurry (37-208). The extraction liquor comprises a solvent and is used to extract bitumen from the bituminous feed. The slurry is fed into an agglomerator (37-210). Extraction may begin when the extraction liquor (37-202) is contacted with the bituminous feed (37-204) and a portion of the extraction may occur in the agglomerator (37-210). A bridging liquid (37-212) is added to the agglomerator (37-210) to assist agglomeration of the slurry. Some form of agitation is also used to assist agglomeration as described below.

[0559] The agglomerated slurry (37-214), comprising agglomerates and a low solids bitumen extract, is sent to a solid-liquid separator (37-216) to produce a low solids bitumen extract (37-218) and agglomerates (37-220).

[0560] The following additional steps may also be performed. The low solids bitumen extract (37-218) is sent to a SRU (37-222) to recover solvent (37-224) leaving a bitumen product (37-226). The agglomerates (37-220) are sent to a TSRU (37-228) to recover solvent (37-230) leaving dry tailings (37-232).

[0561] In one embodiment, the bituminous feed is dry oil sand, which is contacted with extraction liquor that free of bridging liquid in a slurry system to produce a pumpable slurry. The slurry may be well mixed in order to dissolve the bitumen. The bridging liquid is then added to the slurry in order to agglomerate the fine solids within the slurry. The rate of agglomeration may be controlled by a balance among agitation, fines content of the slurry, and bridging liquid addition. In this embodiment, the bitumen is first extracted from the bituminous feed prior to agglomeration in order to prevent (or limit) the agglomeration process from hampering the dissolution of bitumen into the extraction liquor.

[0562] In one embodiment, the formed agglomerates are sized on the order of 0.1-1.0 mm, or on the order of 0.1-0.5mm, or on the order of 0.1-0.3 mm. In one embodiment, at least 80 wt. % of the formed agglomerates are 0.1-1.0 mm, or 0.1-0.5mm, or 0.1 to 0.3mm in size.

[0563] Figure 38 illustrates an embodiment where the bridging liquid is added to an agglomeration vessel at multiple locations within the vessel. As illustrated, the bituminous feed (38-302) is added to an agglomerator (38-304). Bridging liquid (38-306) is added at multiple stages along the flow path of the slurry. For example, multiple bridging liquid inlet ports may be arranged sequentially along the agglomerator. The agglomerated slurry (38-308) is also shown.

[0564] After each stage of bridging liquid addition, the slurry may be well agitated so that the bridging liquid comes into contact with the solids within the slurry in order to form agglomerates. In one embodiment, the residence time between each stage of bridging liquid addition is sufficient to allow agglomeration of some of the fine particles within the slurry. The residence time between each stage of bridging liquid addition may be greater than 30 seconds.

[0565] After each stage of bridging liquid addition and the resulting formation of agglomerates, the formed agglomerates may be removed from the slurry. Exemplary methods for removing the agglomerates include gravity separation or screening within the agglomerator. Agglomerates that are larger than 1 mm are typically undesirable due to the increased chance of bitumen entrapment within the large agglomerates. These large agglomerates that are removed from the agglomerator may be separately comminuted by various methods known in the art to obtain agglomerates of the preferred size. For example, the agglomerates may be comminuted within attrition scrubbers or rod mills.

[0566] In one embodiment, the bridging liquid is added to the slurry at relatively high agitation or mixing energy regions in order to improve the dispersion of the bridging liquid within the slurry. Therefore, the bridging liquid may be added to the slurry in regions having higher shear rates than a median shear rate within the slurry. An example of a region of high shear rate within an agglomerator is adjacent the propellers of a mixing vessel such as an attrition scrubber. The propellers themselves may contain suitable injection ports designed for injecting bridging liquid, at high shear, into the slurry. In another example, the bridging liquid may be added to the slurry within the pumps used to transport the slurry.

[0567] The staged addition of bridging liquid may be used to assist in more uniformly agglomerating solids. The amount of bridging liquid added at each stage of bridging liquid addition may be selected to obtain the desired agglomerate size.

[0568] Figure 39 illustrates an embodiment where the bridging liquid is added to an agglomeration vessel "continuously". As illustrated, the bituminous feed (39-402) is added to an agglomerator (39-404). Bridging liquid (39-406) is added "continuously" along the flow path of the slurry. As used herein "continuously" means that the bridging liquid is added at stages separated by residence times that are significantly shorter than the residence time needed for agglomerate formation. For examples, the residence times between each bridging liquid stage may be less than 15 seconds, or less than 5 seconds. The agglomerated slurry (39-408) is also shown. The bridging liquid may be added intermittently along the flow path of the slurry.

[0569] Figure 40 illustrates an embodiment where the bridging liquid is added to multiple agglomerators. As illustrated, the bituminous feed (40-502) is added to a first agglomerator (40-504a), to which bridging liquid (40-506a) is added. The slurry (40-503a) exists the first agglomerator (40-504a) and enters the second agglomerator (40-504b), to which bridging liquid (40-506b) is added. The slurry (40-503b) exists the second agglomerator (40-504b) and enters the third agglomerator (40-504c), to which bridging liquid (40-506c) is added. The agglomerated slurry (40-508) is also shown. The use of multiple agglomerators allows for distinct stages of agglomeration to occur within each vessel. For example, one agglomerator may be used for the initial nucleation of agglomerate particles. A second agglomerator may be used to grow the agglomerates. A third agglomerator may be used for comminution of agglomerates. Since these stages of agglomeration may occur in separate vessels, the operator may have a greater level of control of the processes.

[0570] Figure 41 illustrates an embodiment where agglomerates are removed from the slurry after they form and before the injection of additional bridging liquid. As illustrated, the bituminous feed (41-602) is added to a first agglomerator (41-604x), to which bridging liquid (41-606x) is added. The slurry (41-610) exits the first agglomerator (41-604x) and enters a solid-liquid separator (41-612) (examples of which are described below) separating agglomerates (41-614) from the reduced-solids slurry (41-616). The reduced-solids slurry (41-616) is fed into the second agglomerator (41-604y), to which bridging liquid (41-606y) is added. The agglomerated slurry (41-608) is also shown. More than two agglomerators and more than one solid-liquid separator could be used.

[0571] Exemplary methods for removing the agglomerates include, but are not limited to, gravity separators such as thickeners or enhanced gravity separators such as hydrocyclones. The agglomerates may be removed from the slurry in order to reduce their additional growth. It has been shown in previous studies that in order to maximize bitumen recovery, it is desirable to keep the agglomerates average particle size to as low a value as possible commensurate with achieving economically viable solid liquid separation. If the agglomerates were to remain within the slurry, after subsequent bridging liquid additions, un-agglomerated fine particles would preferentially attach to the agglomerates, thus increasing the chances of bitumen entrapment within the growing agglomerates. Additionally, a portion of the agglomerates that are removed from the agglomerators may be separately comminuted by various methods known in the art to obtain agglomerates of the preferred size. For example, the agglomerates may be comminuted within attrition scrubbers or rod mills.

[0572] The agglomeration processes herein described may be used for the formation of macro-agglomerates or micro-agglomerates from the solids of the bituminous feed. Macro-agglomerates are agglomerates that are predominantly greater than 2 mm in diameter. These agglomerates comprise both the fine particles (less than 44 μm) and sand grains of the oil sand. Micro-agglomerates are agglomerates that are predominately less than 1 mm in diameter and they principally comprise fine particles of the oil sand. It has been found that for the SESA process described above, the formation of micro-agglomerates are more suitable for maximizing bitumen recovery for a range of oil sand grades.

[0573] The step of adding the bridging liquid may include: i) adding a first portion of the bridging liquid to the slurry; ii) agitating solids within the slurry to form agglomerates; iii) removing agglomerates from the slurry to form a solids-reduced slurry; iv) adding a second portion of the bridging liquid to the solids-reduced slurry; and v) agitating solids within the solids-reduced slurry to form agglomerates. The first portion of the bridging liquid may be added to a first agglomerator, the second portion of the bridging liquid may be added to a second agglomerator, and agglomerates may be removed to form the solids-reduced slurry using a solid-liquid separator. The bridging liquid added during a first stage may have a salinity that is at least 10% higher or lower than a salinity of a bridging liquid added during a second, subsequent stage. The bridging liquid added during a first stage may have a suspended solids content that is at least 10 % higher or lower than a suspended solids content of a bridging liquid added during a second, subsequent stage. Multiple agglomeration vessels may aligned in series and or parallel to produce agglomerates.

[0574] ***Potential Advantages of Bridging Liquid Stage Addition.*** There may be advantages of stage addition of bridging addition, for instance as compared to SESA. It is believed that adding the bridging liquid at multiple stages along the flow path of oil sand slurry can lead to an agglomeration process that is more controllable and yield agglomerates of more uniform size. It is also believed that adding the bridging liquid at multiple stages along the flow path of oil sand slurry will reduce the overall energy requirement of the agglomeration process.

[0575] The high energy requirements of solids agglomeration process is a well-known limitation. Embodiments described herein are expected to reduce the total energy needed to form the agglomerates. The reduction in energy is due to the lower power requirement needed for the agglomeration process. The reduction in power, in turn, is due to the staged addition of bridging liquid. Since the bridging liquid is added in stages, the viscosity of the oil sand slurry does not increase as much as it would if all the bridging liquid was added at once. A reduction in the power requirement means that that the torque requirements of motors used in certain types of agglomeration vessel can be reduced. In the case of rotating type vessels, the required amount of milling can be reduced. Furthermore, the wear of the internals of the vessels will be dramatically reduced due to a reduction in the required mixing intensity.

[0576] Without intending to be bound by theory, it is believed that staged addition of bridging liquid helps balance the rate of agglomeration with the rate of mixing. In the presence of a significant amount of bridging liquid, the agglomeration of the solids occur at a rate that is much more rapid than the rate of mixing of the slurry. In fact, the agglomeration process itself tends to hamper mixing by increasing the effective viscosity of the slurry. The staged addition of the bridging liquid may modulate the rate of agglomeration at any particular location in the vessel. Thus, the mixing of the slurry can match the agglomeration process to ensure that the slurry remains relatively homogeneous. The addition of bridging liquid in high mixing energy regions of the slurry assist bridging liquid dispersion throughout the slurry. Additionally, removing the agglomerates from the slurry after each stage of bridging liquid addition reduces the viscosity of the slurry and prevents (or limits) excessive growth of the formed agglomerates.

[0577] Another potential advantage of certain embodiments is the shifting of the growth of agglomerates to a layering mechanism rather than a coalescence mechanism. The layering mechanism refers to agglomerate growth where the individual fine particles stick on the surface of already formed agglomerates. The coalescence mechanism refers agglomerate growth where two or more agglomerates stick together. The layering mechanism should result in more compact agglomerates with less bitumen extract entrapped therein. In the cases where the formed agglomerates remain in the slurry, these agglomerates act as seed particles and shift the agglomeration process to more of a layering mechanism than a coalescence mechanism, which may dominate the agglomerate growth mechanism if all the bridging liquid was introduced in a single stage.

[0578] ***General Experimental Observations.*** Preliminary batch tests of solvent extraction have shown that bitumen recovery increased by as much as five percentage points when the bridging liquid was added into the process vessel at intermittent time intervals during the agglomeration process compared to the case where all the bridging liquid was added at the beginning of the agglomeration process. The improved bitumen recovery performance demonstrated by the staged bridging liquid addition is also supported by observations made during batch testing of the solids agglomeration process within a mixing vessel. In these tests, a translucent organic fluid was used as the continuous phase with sand and clay as the solids, and water as the bridging liquid. When the water was added all at once to the slurry comprising the organic fluid and solids, large agglomerates quickly formed and began to segregate from the slurry. The slurry remained segregated until sufficient mixing energy was applied to the slurry to break up the initially formed agglomerates and disperse the water. The particle size distribution of the agglomerates formed in this suboptimal case was found to be broad with a significant amount of agglomerates being outside the size range for optimal bitumen recovery and solid-liquid separation. For the tests where the water was added gradually and near the mixing impellers for increased mixing energy, the water rapidly dispersed and minimal segregation of agglomerates was observed. The particles size distribution of these agglomerates was found to be narrow, and as a result the bridging liquid can be used more efficiently to obtain the desired agglomerate size.

[0579] ***Batch Experiments***. Experiments were conducted to test the effectiveness of using staged addition of bridging liquid in order to agglomerate oil sand solids within a slurry. The initial liquid drainage rate of the formed agglomerates and bitumen recovery from the oil sand were used as the experimental measurements to determine the effectiveness of the solvent extraction with agglomeration process. The agglomerates were also visually inspected for their size and uniformity.

[0580] Medium grade Athabasca oil sand was used in these experiments. The oil sand had a bitumen content of 9.36 wt. % and a water content of 4.66 wt. %. The percentage of fines (< 44 μm) that make up the solids was approximately 25 wt. %. The oil sand was kept at -20 °C until it was ready for use. A solution of cyclohexane and bitumen was used as the extraction liquor. The percentage of bitumen in the extraction liquor was 24 wt. %. Distilled water was used as the bridging liquid. For each experiment a total of 350g of oil sand, 235.07g of extraction liquor, and a total of 16.8g of water were used. This composition translated to a solids content of 50 wt. % and a water to solids ratio of 0.11 for the agglomerated slurry.

[0581] A Parr reactor (series 5100) (Parr Instrument Company, Moline, IL, USA) was used as the extractor and agglomerator. The reactor vessel was made of glass that permits direct observation of the mixing process. A turbine type impeller powered by an explosion proof motor of 0.25 hp was used. The mixing and agglomeration speed of the impeller were set to 1500 rpm. This rotation speed allowed the slurry to remain fluidized at all conditions of the experiments. The agglomeration experiments were conducted at room temperature (22 °C).

[0582] The agglomerated solids produced in these experiments were treated in a Soxhlet extractor combined with Dean-Stark azeotropic distillation, to determine the material contents of the agglomerated slurry. Toluene was used as the extraction solvent. The oil sand solids were dried overnight in an oven (100 °C) and then weighed to determine the solids content of the agglomerated slurry. The water content was determined by measuring the volume of the collected water within the side arm of the Dean-Stark apparatus. The bitumen content of the agglomerated slurry was determined by evaporating the toluene and residual cyclohexane from an aliquot of the hydrocarbon extract from the Soxhlet extractor.

[0583] The initial liquid drainage rate was calculated by measuring the time needed to drain 50 mL of bitumen extract above the bed of agglomerated solids.

III.B.:1 Agglomeration by Adding all the Bridging Liquid at One Stage.

[0584] 350g of oil sand and 235.07g of extraction liquor were placed into the Parr reactor vessel. The solids and solvent were mixed at 1500 rpm for 5 minutes to homogenize the mixture and to extract the bitumen that was in the oil sand. After 5 minutes of mixing, 16.8g of water was quickly poured into the vessel through a sample port. The mixture was then mixed at 1500 rpm for an additional 2 minutes to agglomerate the solids.

[0585] After the agglomeration process, the impeller was turned off and the agglomerates were allowed to settle for over 1 minute. The supernatant (bitumen extract) was poured into a separate container and the wet solids were transferred to a Buchner funnel. The solids rested on a filter paper with a nominal pore size of 170 μm. The filter's effective area was approximately 8 cm^2. The solids bed height was 10.8 cm. A portion of the collected supernatant was poured on top of the solids until a liquid height of 1.9 cm formed above the solids surface. A light vacuum was then applied to the Buchner funnel and the initial drainage rate of the liquid was recorded. The initial drainage rate for solids agglomerated by adding all the bridging liquid at one stage to the solids slurry was 0.35 mL/(cm^2sec).

[0586] The remaining supernatant was poured onto the solid bed and allowed to filter through. 211 mL of pure cyclohexane was then filtered through the solid bed in order to wash the agglomerates. The solid bed was then allowed to drain of liquid under a light vacuum for about 30 seconds. The bitumen content of the washed solids was then measured to determine the bitumen recovery of the solvent extraction process. The bitumen recovery from this solvent extraction with solids agglomeration process was 87 %.

III.B.2: Agglomeration by Adding all the Bridging Liquid at One Stage.

[0587] The same conditions as Example *III.B.1* was repeated with the agglomeration time extended to 15 minutes instead of 2 minutes. The initial drainage rate for solids agglomerated by adding all the bridging liquid at one stage and extending the agglomeration time increased to 1.6 mL/(cm^2sec). However, the bitumen recovery for this extraction process dropped to 83.8%

III.B.3: Agglomeration by Using Staged Addition of Bridging Liquid to Solids Slurry.

[0588] 350g of oil sand and 235.07g of extraction liquor were placed into the Parr reactor vessel. The solids and solvent were mixed at 1500 rpm for 5 minutes to fully homogenize the mixture and to fully extract the bitumen that was in the oil sand. After 5 minute of mixing, 5.6 g of water was poured into the vessel through a sample port and the mixture was mixed for 30 seconds. Subsequently, 5.6 g of water was poured into the vessel and the mixture was mixed for an additional 30 seconds. Lastly, 5.6 g of water was poured into the vessel and the mixture was mixed for 1 minutes. All mixing was done at room temperature.

[0589] After the agglomeration process the impeller was turned off and the agglomerates were allowed to settle for over 1 minute. The supernatant (bitumen extract) was poured into a separate container and the wet solids were transferred to a Buchner funnel. The solids rested on a filter paper with a nominal pore size of 170 μm. The filter's effective area was approximately 8 cm^2. The solids bed height was 10.8 cm. A portion of the collected supernatant was poured on top of the solids until a liquid height of 1.9 cm formed above the solids surface. A light vacuum was then applied to the Buchner funnel and the initial drainage rate of the liquid was recorded. The initial drainage rate for solids agglomerated by adding bridging liquid in three separate stages to the solids slurry was 1.04 mL/(cm^2sec).

[0590] The remaining supernatant was poured onto the solid bed and allowed to filter though. 211 mL of pure cyclohexane was then filtered through the solid bed in order to wash the agglomerates. The solid bed was then allowed to drain of liquid under a light vacuum for about 30 seconds. The bitumen content of the washed solids was then measured to determine the bitumen recovery of the solvent extraction process. The bitumen recovery from this solvent extraction with solids agglomeration process was 86.3 %.

[0591] The drainage rate of the agglomerates formed by using staged addition of the bridging liquid was approximately 3 times greater than that of agglomerates formed when all the bridging liquid is added in one stage (compare Example III.B.3 to Example III.B.1). The drainage rate of the single stage agglomeration process can be increased by extending the agglomeration time (see Example III.B.2) in order to form larger agglomerates. However, the larger agglomerates results in a reduction in the bitumen recovery. In contrast, the staged addition of bridging liquid resulted in an increase in drainage rate without a significant reduction in bitumen recovery. Visual inspection of Example III.B.3 agglomerates did not reveal significantly larger agglomerates compared to the agglomerates of Example III.B.1. This suggests that the faster drainage rate of the agglomerates formed by staged addition of bridging liquid is due to more uniform agglomerates rather than larger agglomerates.

III.C Pipeline Agglomeration

[0592] ***Agglomeration within a Pipeline.*** The agglomeration process may occur within a pipeline. The oil sand slurry from the slurry system is fed into a pipeline where additional bitumen extraction may occur. The slurry flows within the pipeline, and at one or more point along the pipeline, an aqueous bridging liquid can be added to the pipeline to assist in the agglomeration of the solids within the pipeline. Alternatively or additionally, aqueous bridging liquid may be added to the oil sand slurry prior to the pipeline. Some form of agitation is also used to assist agglomeration. The agitation may be provided by turbulent flow within the pipeline. The rate of agglomeration may be controlled by a balance between velocity within the pipeline (i.e. flow turbulence), fines content of the slurry, aqueous bridging liquid addition, and residence time within the pipeline. The agglomerated slurry from the pipeline, comprising of agglomerates and bitumen extract, is sent to the solid-liquid separation system to produce a bitumen extract stream and an agglomerated solids stream.

[0593] ***Pipeline Zones for Pipeline Agglomeration.*** Nominally, the pipeline may comprise two zones, an extraction zone and an agglomeration zone. The agglomeration zone may comprise a nucleation zone and an agglomeration growth zone. The function of the extraction zone is to dissolve the bitumen from the oil sand into the solvent. In some embodiments the solvent is an extraction liquor. Unlike certain prior processes, where the solvent is first exposed to the bituminous feed within the process, in most of the embodiments described herein, bitumen may be extracted from the oil sand prior to the agglomeration step in order to prevent (or limit) the agglomeration process from hampering the dissolution of bitumen into the solvent. Thus, it is desirable to prevent or limit the agglomeration of particles within the extraction zone. Dissolution or extraction may be partially or fully complete before entering the agglomeration in the pipeline. The process need not be performed in a pipeline.

[0594] The function of the agglomeration zone is to agglomerate the solids to the amount commensurate with achieving economically viable solid-liquid separation. Micro-agglomerates may be generally preferred because they allow for good solid-liquid separation without entrapping a significant amount of the bitumen extract within the agglomerates. The extraction of the bitumen prior to the agglomeration process may have the effect of reducing the required residence time in the agglomeration zone, when compared to certain other proposed processes which require extraction of bitumen and agglomeration to occur simultaneously. The reduced residence time of the agglomeration zone allows for agglomerates of smaller particle size distribution to form.

[0595] The agglomeration zone may comprise a nucleation zone, a bridging liquid dispersion/nucleation zone, an agglomerate growth zone, and a comminution zone. The agglomeration process is initiated within the nucleation zone. The amount of bridging liquid added within the nucleation zone may be less or much less than the total amount of bridging liquid needed for desired agglomeration. The amount of bridging liquid added within the nucleation zone may be 5 to 35% of the total amount of bridging liquid added within the agglomeration zone. In another embodiment, the amount of bridging liquid added within the nucleation zone is 10 to 25% of the total amount of bridging liquid added within the agglomeration zone. Alternative embodiments exist where the amount of bridging liquid added within the nucleation zone may be 5 to 100% of the total amount of bridging liquid added within the agglomeration zone. The amount of bridging liquid added within the nucleation zone in some embodiments may also be 20 to 85% of the total amount of bridging liquid added within the agglomeration zone. The reduced amount of bridging liquid added within the nucleation zone may lower the rate of agglomerate growth and allow for rapid dispersion of the bridging liquid within the oil sand slurry. Following the nucleation zone, additional bridging liquid is added within the agglomeration growth zone in order to grow the agglomerates to the desired size and reduce the amount of fine solids dispersed within the bitumen extract. The bridging liquid may be added to the agglomerate growth zone at several points to assist uniform mixing of the bridging liquid within the slurry. A comminution zone may follow the agglomerate growth zone in order to comminute the undesirably large agglomerates that may form in the agglomerate growth zone. The comminution may be effected by, for example, increasing the velocity within the comminution zone or having internal structures within the comminution zone.

[0596] ***Velocity within Pipeline for Pipeline Agglomeration.*** The nature of slurry flow within a horizontal pipeline depends on the ratio of the average flow velocity of the slurry within the pipeline to the limiting settling velocity of the slurry. When the average flow velocity is sufficiently greater than the limiting settling velocity, the slurry flow within the pipeline is homogenous with no average concentration changes across the pipe. At any velocity below the limiting settling velocity, the slurry flow becomes heterogeneous with the concentration of the solids increasing towards the bottom of the pipe. For an average flow velocity that is heterogeneous but where the slurry velocity remains greater than about 40% of the limiting settling velocity, the solids that are deposited at the bottom of the pipe can flow by bouncing and rolling along the pipe. This type of flow is called saltation flow. The average flow velocity that is below that which is needed for saltation flow is usually avoided since pipeline plugging will occur as solids are continuously injected into the pipeline.

[0597] The limiting settling velocity for a slurry is best determined by conducting tests with the slurry flowing within a pipeline test rig. In the absence of such tests, the limiting settling velocity V_L can be estimated using the following equation proposed by R Durand:

$$V_L = F_L \sqrt{2gD \frac{\rho_s - \rho_l}{\rho_l}}$$

where, g is the acceleration due to gravity, D is the diameter of the pipeline, ρ_s is the density of the solids within the slurry, and ρ_l is the density of the liquid of the slurry. F_L is a parameter that is dependent upon the particle size distribution and the solids volume concentration within the slurry. For a slurry with mixed particle size, such as that expected for oil sand slurries as described herein, F_L has been measured to have values within the range of 0.5 to 1.5.

[0598] In the extraction zone, the average flow velocity within the pipeline can be that needed for saltation flow or greater. It is preferable that the slurry flow be homogenous or mildly heterogeneous. However, this is not necessary since the solvent will digest the oil sand lumps even under low agitation conditions. The average flow velocity within the extraction zone may be 1 to 6 m/sec. The average flow velocity within the extraction zone may be 2 to 4 m/sec. Alternative embodiments exist where the average flow velocity within the extraction zone may be 1 to 5 m/sec. In another embodiment, the average flow velocity within the extraction zone may be 2 to 3 m/sec.

[0599] In the agglomeration zone, it is desired that the slurry remains in the turbulent flow regime of slurry such that the solids are exposed to the high shear forces. The average flow velocity within the agglomeration zone may be greater than 2 m/sec. The average flow velocity within the agglomeration zone may be 2.5 to 6 m/sec. Practical considerations such as erosion of the pipeline, equipment capacity and excessive pressure change will limit the average flow velocity within all zones making up the agglomeration zone.

[0600] In some embodiments, in the agglomeration zone, it is desired that the slurry flow be a homogenous type slurry flow. The homogenous flow will allow for proper mixing of the bridging liquid. Additionally, this type of flow will ensure that most, if not all, of the solids remain in the turbulent flow regime of slurry such that they are consistently exposed to the high shear forces needed to prevent (or limit) excessive growth of the agglomerates and non-uniformity of agglomerate size. The average flow velocity within the agglomeration zone may be greater than 2 m/sec. In another embodiment, the average flow velocity within the agglomeration zone may be 3 to 6 m/sec.

[0601] In the agglomerate growth zone, the average flow velocity should not be too high a velocity so that the shear forces subject the agglomerates to severe attrition that prevents agglomerate growth. However, such severe attrition may be desired within the nucleation zone and in the comminution zone. In the nucleation zone, the severe attrition can be used to rapidly disperse the bridging liquid. In the comminution zone, the severe attrition can be used to reduce the size of the larger agglomerates. Erosion of the pipeline and excessive pressure drop will limit the average flow velocity within all zones making up the agglomeration zone.

[0602] ***Residence Time for Pipeline Agglomeration.*** An advantage of the pipeline agglomeration process described herein is the flexibility to have a long residence time for the extraction and agglomeration processes since the length of the pipeline can be readily increased to achieve the desired residence time. Increasing the residence time of the extraction process may result in an increase in both the bitumen recovery and the rate of solid-liquid separation. Figure 46 (as described further below) shows that the bitumen recovery and the initial liquid filtration rate increases as the extraction time increases for batch experiments conducted with the agglomeration time kept constant at 2 minutes. In contrast, as Figure 47 (as described further below) shows, the bitumen recovery reaches a maximum and then decreases as the agglomeration time increases for batch experiments conducted with the extraction time kept constant at 5 minutes. The decrease in recovery beyond the maximum recovery is most likely due to excessive agglomerate growth that led to entrapment of the bitumen extract within the agglomerates. However, this growth of agglomerates does result in an increase in the initial filtration rate as the agglomeration time increases.

[0603] The results plotted in Figure 46 and Figure 47 suggests that it is preferable for the residence time of the extraction zone to be greater or much greater than the residence time of the agglomeration zone. The residence time of the extraction zone may be greater than 5 minutes, or may be greater than 10 minutes, or may be greater than 15 minutes, or may greater than 30 minutes. The residence time of the agglomeration zone may be in the range of 30 seconds to 10 minutes. In one embodiment, the residence time of the agglomeration zone may be in the range of 1 to 5 minutes. The residence time of the nucleation zone within the agglomeration zone may be less than 30 seconds. For embodiments where the agglomeration zone comprises a comminution zone, the residence time within the agglomeration may be extended beyond 5 minutes to provide the required residence time for the comminution zone.

[0604] ***Geometry of Pipeline for Pipeline Agglomeration.*** It is desirable to have the pipeline diameter of the extraction zone to be constant and as large as possible commensurate with keeping the slurry flow above the saltation velocity. Exemplary pipeline diameters are in the range of 0.5 to 1.5 m. In some embodiments exemplary pipeline diameters are in the range of 0.1 to 1.5 m. These pipeline diameters are similar in size to those of the hydrotransport pipelines used in the WBE. Since the total pipeline length may comprise mostly the extraction zone, attempts should be made to minimize erosion within this portion of the pipeline.

[0605] For the agglomeration zone of the pipeline, it is desirable to have homogenous or close to homogenous type flow in order to ensure or promote uniform agglomerate formation and growth. In one embodiment, the homogenous slurry flow can be accomplished by reducing the pipeline diameter of the agglomeration zone (as seen in Figure 48A) in order to increase the average flow velocity of the slurry and reduce the limiting settling velocity. In Figure 48A, the slurry (48A-708a), the extraction zone (48A-750a), and the agglomeration zone (48A-754a) are shown. In one embodiment, the pipeline diameter in the agglomeration zone may be 0.25 to 1.5 m. In another embodiment the pipeline diameter in the agglomeration zone may be 0.1 to 1.5 m. In some embodiments, the homogenous slurry flow can be accomplished by incorporating a recycle loop with the agglomeration zone as shown in Figure 48B. In Figure 48B, the slurry (48B-708b), the extraction zone (48B-750b), and the agglomeration zone (48B-754b) are shown. The recycle loop (48B-755) may act to increase the average flow velocity within the agglomeration zone. In yet another embodiment, as shown in Figure 48C, the pipeline of the agglomeration zone (48C-754c) can be configured at angles to the horizontal. The configuration of the pipeline at angles will have the effect of reducing the limiting settling velocity of the slurry. By way of example, the pipeline may be angled 5° to 45° to horizontal. In an alternate configuration, the pipeline may be positioned vertically. A vertical positioning has the benefit of mitigating vertical segregation of particles in the pipeline.

[0606] The above described methods of promoting homogenous or near homogenous slurry flow may be employed separately or in combination in order to maximize effectiveness. Additionally, the pipeline of the agglomeration zone may comprise internal structures to promote homogenous slurry flow. Exemplary structures include intermittently spaced static mixers as shown in Figure 48D. In Figure 48D, the static mixers (48D-756) are shown within the agglomeration zone (48D-754d). It may be preferable that static mixers, or the like, be included in the pipeline in such a way that they can be readily replaced since such devices may be subject to high rates of erosion. Other potential internal structures will be readily known by those skilled in the art.

[0607] The present section provides a method of processing a bituminous feed. The bituminous feed is contacted with an extraction liquor to form a slurry. The slurry is then flowed through a pipeline. Before introduction into the pipeline and/or at one or more points along the pipeline, a bridging liquid is added to the slurry to assist agglomeration. Agitation is also used to assist agglomeration. The result is an agglomerated slurry comprising agglomerates and a low solids bitumen extract. The agglomerates are then separated from the low solids bitumen extract. Performing the agglomeration in a pipeline as opposed to in a conventional agitating vessel may provide certain advantages, such as improved sealing in order to contain the potentially flammable mixture of oil sands slurry from the atmosphere, production of smaller and more uniform agglomerates due to improved mixing of the bridging liquid into the oil sands slurry, and the flexibility to have a long residence time for the extraction and agglomeration processes since the length of the pipeline can be readily increased to achieve the desired residence time. Additionally, the plug flow nature of processing within the pipeline may allow for greater observation and control of the agglomeration process. Furthermore, the pipeline may have the added advantage of providing a means of transporting the oil sands slurry to other locations within the mine site and/or within the facility as the slurry is being processed within the pipeline.

[0608] In one aspect, the present section provides a method of processing a bituminous feed, the method comprising: a) contacting the bituminous feed with an extraction liquor to form a slurry, wherein the extraction liquor comprises a solvent; b) flowing the slurry through a pipeline and adding a bridging liquid to the slurry before and/or within the pipeline, and agitating solids within the slurry within the pipeline to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract; and c) separating the agglomerates from the low solids bitumen extract.

[0609] With reference to Figure 42, a bituminous feed may be contacted with an extraction liquor to form a slurry (42-102). The slurry may then be flowed through a pipeline and a bridging liquid may be added to the slurry and agitation may be provided to assist agglomeration (42-104). The result is an agglomerated slurry comprising agglomerates and a low solids bitumen extract. The agglomerates may then be separated from the low solids bitumen extract (42-106).

[0610] Figure 43 is a schematic of a disclosed embodiment with additional steps including downstream solvent recovery. The extraction liquor (43-202) is mixed with a bituminous feed (43-204) from oil sand in a slurry system (43-206) to form a slurry (43-208). The extraction liquor comprises a solvent and is used to extract bitumen from the bituminous feed. The slurry is fed into a pipeline (43-210). Extraction may begin when the extraction liquor (43-202) is contacted with the bituminous feed (43-204) and a portion of the extraction may occur in the pipeline (43-210). The slurry (43-208) is flowed in the pipeline (43-210), and at one or more points along the pipeline (43-210), a bridging liquid (43-212) is added to the pipeline to assist agglomeration of the slurry. Alternatively or additionally, bridging liquid may be added to the slurry prior to the pipeline. Some form of agitation is also used to assist agglomeration as described below. In one embodiment, the agitation is provided by turbulent flow in the pipeline.

[0611] The agglomerated slurry (43-214), comprising agglomerates and a low solids bitumen extract, is sent to a solid-liquid separator (43-216) to produce a low solids bitumen extract (43-218) and agglomerates (43-220).

[0612] The following additional steps may also be performed. The low solids bitumen extract is sent to a SRU (43-222) to recover solvent (43-224) leaving a bitumen product (43-226). The agglomerates (43-220) are sent to a TSRU (43-228) to recover solvent (43-230) leaving dry tailings (43-232).

[0613] In one embodiment, the bituminous feed is dry oil sand, which is contacted with extraction liquor that free of bridging liquid in a slurry system to produce a pumpable slurry. The slurry may be well mixed in order to dissolve the bitumen. In this embodiment, the bitumen is first extracted from the bituminous feed prior to agglomeration in order to prevent (or limit) the agglomeration process from hampering the dissolution of bitumen into the extraction liquor. In another embodiment, the bridging liquid may be directly mixed with the bituminous feed before or at the same time as the extraction liquor so that bitumen extraction and agglomeration occur simultaneously. In this embodiment, the bridging liquid is added before or at the same time as the extraction liquor in order to minimize the dispersion of fines, which may reduce the solids content of the bitumen extract after the agglomeration process.

[0614] In one embodiment, agglomerates may be produced that are sized on the order of 0.1-1.0 mm, or on the order of 0.1-0.5mm, or on the order of 0.1-0.3 mm. In one embodiment, at least 80 wt. % of the formed agglomerates are 0.1-1.0 mm, or 0.1-0.5mm, or 0.1 to 0.3 mm in size. The rate of agglomeration may be controlled by a balance between velocity within the pipeline (i.e. flow turbulence), fines content of the slurry, bridging liquid addition, and residence time within the pipeline.

[0615] Figure 44 illustrates an exemplary pipeline that is segmented into three zones. The slurry (44-308), comprising the bituminous feed and the extraction liquid, is fed into the pipeline (44-310). In the extraction zone (44-350), bitumen extraction, which began prior to delivering the slurry (44-308) to the pipeline (44-310), continues. The extraction zone (44-350) is designed to provide enough residence time and agitation to dissolve the bitumen. In the extraction zone (44-350), agglomeration does not occur, or is limited because bridging liquid is preferably not injected into the pipeline in the extraction zone of the pipeline.

[0616] At some point, bridging liquid (44-312a) is added to the pipeline (44-310). Adding a sufficient amount of bridging liquid (44-312a) assists agglomerate nucleation in the nucleation zone (44-352). The amount of bridging liquid added within the nucleation zone may be less or much less than the total amount of bridging liquid needed for desired agglomeration. In one embodiment, the amount of bridging liquid added within the nucleation zone is 5 to 35% of the total amount of bridging liquid added within the pipeline. In another embodiment, the amount of bridging liquid added within the nucleation zone is 10 to 25% of the total amount of bridging liquid added within the pipeline. The reduced amount of bridging liquid added within the nucleation zone may lower the rate of agglomerate growth and allow for rapid dispersion of the bridging liquid within the oil sand slurry.

[0617] At a later point, additional bridging liquid (44-312b) is added to the pipeline (44-310) to assist agglomerate growth, in the agglomerate growth zone (44-354), to a desired size for subsequent solid-liquid separation. In one embodiment, the bridging liquid (44-312b) is added to the agglomerate growth zone (44-354) at several points to assist uniform mixing of the bridging liquid with the slurry.

[0618] The three zones are not necessarily discrete zones. For instance, extraction may continue after the extraction zone, and nucleation may continue after the nucleation zone.

[0619] In another embodiment, (not shown in Figure 44) the agglomerate growth zone (44-354) may be followed by a comminution zone. The mixing energy within the comminution zone is increased significantly in order to comminute the undesirably large agglomerates that form in the agglomerate growth zone. Methods for increasing the mixing energy include, but are not limited to, increasing the slurry velocity within the comminution zone and/or having internal structures within the comminution zone of the pipeline.

[0620] ***Method of Bridging Liquid Addition.*** The bridging liquid may be added to within the pipeline as an emulsion where the hydrocarbon phase is the continuous phase. The emulsion may be formed in a device separate from the pipeline such as an emulsifier. The emulsion may be formed within the pipeline and/or within a device integrated with the pipeline. Exemplary devices to form the emulsion include a static mixer or jet pumps. In the case where the emulsifying device is integrated with the pipeline, the device may be said to form an emulsion because it may be capable of rapidly distributing the bridging liquid at a time scale much faster than agglomeration formation and/or growth. Additional discussion of bridging liquid addition by emulsion is provided above.

[0621] The bridging liquid may be added in stages within each agglomeration zone. Formed agglomerates may be separated from the slurry after each stage of bridging liquid addition. The bridging liquid may be added in regions of high shear along the pipeline. Exemplary location of high shear may be along pipe bends and downstream of pipe valves. Other locations include immediately upstream of the pumps, and/or immediately downstream of the pumps and/or within the pumps driving the flow within the pipeline. Exemplary pumps include jet pumps and centrifugal pumps. Additional discussion of staged addition bridging liquid to an agglomeration vessel is provided above.

[0622] ***Control Methods.*** The plug flow nature of processing the bituminous feed within the pipeline may allow for greater observation and control of the agglomeration process. Like Figure 44, Figure 45 illustrates a pipeline (45-410) in more detail divided into three zones, the extraction zone (45-450), the nucleation zone (45-452), and the agglomerate growth zone (45-454). The slurry (45-408), and bridging liquids (45-412a and 45-412b) are also shown. Measurement (45-456) of one or more of the properties of the slurry at a point within the pipeline (45-410) can be used to control (45-458) the operation downstream of the measurement location. One option is to adjust the amount of bridging liquid (45-412b) that is added. Another option is to adjust the velocity of the slurry in the pipeline. One possible measurement is agglomerate particle size distribution. This measurement can be accomplished by integrating an online particle size measurement device such as a Retsch Technology Camsizer. A slip stream can be taken from the slurry, filtered to remove liquid, and then measured to analyze particle size distribution. Another possible measurement is the filtration rate of the oil sand slurry. This measurement can be accomplished by integrating an online filtration device with the pipeline. A slip stream can be taken from the slurry and the rate of filtration of that slip stream can be measured. The filter medium should be similar to that which is used in the solid-liquid separator. Another possible measurement is the solids content of the bitumen extract. One method for accomplishing this measurement may be the measurement of the density of an unfiltered and micro-filtered bitumen extract. The difference in density of these two streams can be correlated with solid content. Yet another possible measurement is the power dissipation of the oil sand slurry at different points along the length of the pipeline. This measurement can be accomplished by measuring the static pressure along the length of the pipe.

[0623] ***Solvent Slurry Transport.*** In the mining of oil sand, the distance that mined oil sand must travel from the mine to the extraction plant and subsequently to a disposal site necessitates significant energy expenditure and cost. The processing of bituminous feed by conducting solvent extraction with solid agglomeration in a pipeline, as described herein, has the advantage of providing a means of transporting the oil sand as a slurry to other locations within the mine site while the slurry is being processed within the pipeline. A similar benefit is realized within the hydrotransport lines of WBE facilities. In the case of WBE facilities, it is generally more cost effective and less energy intensive to transport oil sand by pipeline than by dry solid transport methods such as trucks and/or conveyors. Similar cost and energy saving may be realized in the case of solvent slurry transport.

[0624] Figure 49 illustrates a mine facilities layout where slurry systems (49-802a, 49-802b, and 49-802c) are located close to the mine face to receive oil sand (49-804a, 49-804b, and 49-804c) by trucks and/or conveyors. Pipelines (49-806a, 49-806b, and 49-806c) are then used to conduct the solvent extraction with solids agglomeration process while transporting the slurry to a central facility (49-808) where the remaining processes of solvent extraction, as outlined in Figure 43, may occur. As illustrated in Figure 49, optional equipment (49-810) such as a drum, a clarifier, and an inclined plate separator may also be used. The central facility may include a solid-liquid separator (49-812) (such as a belt or pan filter), a tailings solvent recover unit (49-814), and a clean solvent storage (49-816), the operations of which are described above. The bitumen product (49-818) may be pipelined to a plant. The coarse solids (49-820) may be sent to a pit. The location of central facilities may be dictated by various factors such as the footprint of the facilities, tailings disposal requirements, and other considerations.

[0625] The solvent used for washing the agglomerates may be solvent recovered from the low solids bitumen extract, as described with reference to Figures 46 to 48. A second solvent may alternatively or additionally be used as described in Canadian Patent Application Serial No. 2,724,806 (Adeyinka *et al.*) for additional bitumen extraction downstream of the pipeline.

[0626] ***Potential Advantages of Pipeline Agglomeration.*** There may be advantages of embodiments described in this section, for instance as compared to SESA. Solids nucleation and extraction in the pipeline is expected to improve bitumen recovery due to full bitumen dissolution in the pipeline as well as to increase control of the agglomeration process. It is expected that embodiments will improve the distribution of bridging liquid within the slurry in order to produce a narrower particle size distribution for the agglomerates. Agglomerates that are more uniform in size may have higher drainage rates for solid-liquid separation methods such as filtration and screening. It is also expected that embodiments will improve the sealing required to contain the potentially flammable mixture of oil sand slurry from the atmosphere. Additionally, since the length of a pipeline can be readily extended, the residence time needed for agglomeration within the pipeline can be increased at a lower cost as compared to what would be needed for other agglomeration vessels. Additionally, the pipeline has the added advantage of providing a means of transporting the oil sand slurry to other locations within the mine site as the slurry is being processed within the pipeline.

[0627] Rotating type vessels, such as the vessel described in U.S. Patent No. 4,719,008 (Sparks *et al.*), need to be large in order to process the high volumetric flow rates of oil sand. These large vessels have a low surface to volume ratio, which in turn increases the difficulty of uniformly mixing the bridging liquid within the slurry. In contrast, a pipeline generally has relatively a high surface to volume ratio. This characteristic of the pipeline agglomeration vessel may make it easier to inject the bridging liquid into the slurry in such a way to allow for uniform mixing of the bridging liquid.

[0628] In contrast to other agglomeration vessels, a pipeline may enable plug flow, or close to plug flow, behavior of the agglomeration process. For this reason, the pipeline may comprise different zones along the length of the pipe, each accomplishing a different result, as described above with reference to Figures 44 and 45. In general, the plug flow (or near plug flow) behavior of the agglomeration process within a pipeline may allow for greater flexibility in observing and controlling the agglomeration process itself. For example, measurement of one or more of the properties of the slurry at a point or multiple points within the pipeline can be used to control the operation downstream of the measurement location. Since the ore quality and chemistry of the oil sand will change on a frequent basis as different mine shelves are progressed, the recipe of the agglomeration process may need to change accordingly. Thus, having greater control of the agglomeration process, as described herein, will help the agglomeration outputs to remain within acceptable ranges regardless of feed changes.

[0629] Rotating type vessels, such as the vessel described in U.S. Patent No. 4,719,008 (Sparks *et al.*), must have moving seals that allow it to interface with other process equipment. Since a hydrocarbon solvent is a preferable solvent for the extraction of bitumen from the oil sand, the seals must be robust in order to contain the potentially flammable mixture of oil sand slurry from the atmosphere. Furthermore, the materials being processed, such as sand and brine, accelerate the corrosion and erosion of seals. Since the pipeline itself has no moving parts, sealing is expected to be a much easier task for said pipeline. However, the pumps used in the process may need to be specially designed.

[0630] Unlike certain prior process, where the extraction liquor is first exposed to the bituminous feed within the agglomerator, in most of the embodiments described herein bitumen is extracted from the oil sand prior to the agglomeration step. The decoupling of the extraction and agglomeration processes may yield certain advantages. For example, the experimental results plotted in Figures 46 and 47 suggest that the rate of bitumen recovery and solid-liquid separation can increase by extending the extraction residence time while keeping the agglomeration residence time low. Thus, it may be beneficial to have the extraction residence time be as much as 30 minutes or greater. A potential advantage of the pipeline agglomeration process described herein is that such long residence time in the extraction zone of the pipeline is economically feasible since the length of the pipeline can be readily increased to achieve the desired residence time.

[0631] In the mining of oil sand, the distance that mined oil sand must travel from the mine to the extraction plant and subsequently to a disposal site necessitates significant energy expenditure and cost. The processing of bituminous feed by conducting solvent extraction with solid agglomeration in a pipeline, as described herein, has the advantage of providing a means of transporting the oil sand as a slurry to other locations within the mine site while the slurry is being processed within the pipeline. It is believed the solvent slurry transport, described herein can provide a more cost effective and less energy intensive method to transport oil sand within the mine site rather than by the dry solid transport methods such as trucks and/or conveyors.

[0632] ***The effects of extraction residence time on the solvent extraction with solids agglomeration process.*** 350g of oil sand and 235.07g of extraction liquor were placed into the Parr reactor vessel. The solids and solvent were mixed at 1500 rpm for a given extraction residence time to homogenize the mixture and to extract the bitumen that was in the oil sand. The extraction times tested were 0.5, 1, 2, 5, 15, and 30 minutes. After the extraction time elapsed, 16.8g of water was quickly poured into the vessel through a sample port. The mixture was then mixed at 1500 rpm for an additional 2 minutes to agglomerate the solids.

[0633] After the agglomeration process, the impeller was turned off and the agglomerates were allowed to settle for over 1 minute. The supernatant (bitumen extract) was poured into a separate container and the wet solids were transferred to a Buchner funnel. The solids rested on a filter paper with a nominal pore size of 170 μm. The filter's effective area was approximately 8 cm^2. The solids bed height was 10.8 cm. A portion of the collected supernatant was poured on top of the solids until a liquid height of 1.9 cm formed above the solids surface. A light vacuum was then applied to the Buchner funnel and the initial drainage rate of the liquid was recorded.

[0634] The remaining supernatant was poured onto the solid bed and allowed to filter through. 211 mL of pure cyclohexane was then filtered through the solid bed in order to wash the agglomerates. The solid bed was then allowed to drain of liquid under a light vacuum for about 30 seconds. The bitumen content of the washed solids was then measured to determine the bitumen recovery of the solvent extraction process.

[0635] Figure 46 plots the bitumen recovery and the initial liquid filtration rate as a function of the extraction residence time. The figure shows that the bitumen recovery and the initial liquid filtration rate increases as the extraction time increases for batch experiments conducted with the agglomeration time kept constant at 2 minutes.

***III.D* Agglomeration using Jet Pumps**

[0636] As described above, a jet pump may be used in the SBE to condition the slurry. With reference to Figure 30, bituminous feed (30-412) may enter a hopper (30-414), which may feed a jet pump (30-418). A motive fluid (30-420), comprising a solvent for extracting bitumen, may be added to the jet pump (30-418) via a motive fluid pump (30-421). The motive fluid pump (30-421) may also supply hopper wash solvent (30-490) to the hopper (30-414) as an upper hopper wash solvent (30-492) or a lower hopper wash solvent (30-494) in respective upper and lower regions of the hopper. Both upper and lower wash solvents may provide flow assurance of solids in the hopper, addition of heat, and dissolution of bitumen. The lower wash solvent may also provide a disintegration action to mitigate any bridging and packing to ensure flow into the jet pump. In addition, the upper and lower wash solvents may be added in single or multiple locations or ports.

[0637] A conditioned slurry (30-422) may be discharged from the jet pump (30-418) and passed through a slurry boost pump (30-423) to a screen (30-425) to remove oversized particles (30-426), such as clay lumps, undigested ore, rocks, or other debris. The screened conditioned slurry (30-496) from the screen (30-425) may enter a pump box (30-427). A slurry (30-429) may progress from the pump box (30-427) to a slurry pump (30-474). A portion of the screened conditioned slurry (30-496) may be used for hopper wash service to support flow assurance in the hopper (30-414).

[0638] A portion of the conditioned slurry (30-422a) may be recirculated to the jet pump feed hopper (30-414) to increase the energy dissipated on the solids enhancing ablation of large lumps, thus reducing the amount of material that is rejected on the screen (30-425), and accelerating the dissolution of bitumen from the ore. In order to keep the density of the condition slurry (30-422) constant, since more liquid is returned into the hopper through the recirculated conditioned slurry (30-422a), the hopper wash (30-492) rate may be reduced.

[0639] Oversized particles (30-426) may be washed on the screen (30-425) by a wash fluid (30-431). The screen may comprise two or more screens with differently size openings. The two oversize streams may be combined, or treated separately. Optionally, the particles screened by the second screen may be sent to an agglomerator or filtration (such as by a pan filter). The wash fluid (30-431) may comprise a washing solvent and, optionally, bitumen and fine particles. The wash fluid may comprise a first solvent and/or a second solvent. The wash fluid may comprise an extraction liquor. The wash fluid may provide the primary method of adding a first and/or second solvent to the SBE process in order to control the solvent to bitumen ratio in the dissolution and/or agglomeration processes. This wash fluid (30-431) may also assist in moving conditioned slurry (30-422) through the screen (30-425), minimizing the necessary screen size. The wash fluid (30-431) may comprise an aqueous or non-aqueous solvent.

[0640] Washed oversized particles (30-426) from the screen (30-425) may be sent to a scrubbing device (30-433) using second wash fluid (30-435) jets to remove bitumen or bitumen coated particulates that may have adhered to the components such as rock or clay lumps. The second wash fluid (30-435) may be aqueous or non-aqueous. The second wash fluid (30-435) may be a first solvent, a second solvent, and/or a bitumen extraction liquor. It is preferable the second wash fluid is a first solvent and/or a second solvent that is substantially free of bitumen. The second wash fluid (30-435) may be aqueous or non-aqueous. Where the second wash fluid (30-435) is non-aqueous, it may comprise a non-aqueous solvent, and optionally bitumen and fine particles. Where the second wash fluid (30-435) comprises an aqueous fluid, the conditioned slurry may be used as the bridging liquid (30-481). When the second wash fluid (30-435) comprises a non-aqueous solvent, a recycle stream (30-451) may be used as part of combined slurry (30-453) or as hopper wash fluid (30-492). The second wash fluid may be sprayed at a pressure between 50 psi and 3500 psi.

[0641] Remaining oversized material (30-439) may be washed on a secondary screen (30-441) with clean solvent (also referred to as liquid wash) (30-443) to remove residual bitumen, and prepare the oversized particles for solvent removal.

[0642] If the high pressure liquid wash for the oversize materials is performed with a non-aqueous or hydrocarbon solvent, the liquid and liberated fines (30-437) may be drained from the scrubbing device, and co-mingled with the screened conditioned slurry in the pump box (30-427). Liquid and liberated fines may be sent back to the hopper (30-414) as hopper wash solvent, or as part of the motive fluid for the jet pump (30-418). The liquid and liberated fines may be sent immediately upstream of the oversize reject screen. Alternately, if the wash is performed with an aqueous solvent, the liquid stream (30-437) may be recycled as part of the bridging liquid for agglomeration.

[0643] Washed oversized particles (also referred to as a disposal stream) (30-445) may be sent for solvent removal (30-447) prior to disposal (30-498). Steam (30-449) may be added to the washed oversized particles (30-445) to evaporate the solvent.

[0644] Alternatively, the liquid wash (30-443) on the secondary screen (30-441) may be hot water. In this case, the heat of the water evaporates solvent, preparing the oversized material for direct disposal. Waste water from this step may be used as the bridging liquid for agglomeration as described herein.

[0645] Liquid recycle stream (30-451) may be co-mingled with slurry in the pump box (30-427), co-mingled with the higher density slurry (30-429) to form a combined slurry (30-453). The combined slurry (30-453) may be agglomerated as described herein. The combined slurry (30-453) may be used as motive fluid in the jet pump (30-418) if it is a dilute slurry and in all other cases, used as hopper wash solvent, or as other diluting, washing, or mixing service in the process. If the liquid wash (30-443) is water, liquid recycle stream (3-451) may be used in whole or in part as the bridging liquid (30-481).

[0646] The combined slurry (30-453) may be passed through a slurry pump (30-474). A bridging liquid (30-481) may be added to the combined slurry (30-453) to assist agglomeration. The bridging liquid (30-481) may be added to the combined slurry upstream of the slurry pump and/or downstream of the slurry pump. The bridging liquid may be added directly to the slurry pump (30-474). The bridging liquid may be added directly to the combined slurry as a high velocity jet to promote the distribution of the bridging liquid. In-line static mixers may be added into the pipeline to promote mixing the bridging liquid with the combined slurry.

[0647] The bridging liquid may be added to the combined slurry as an emulsion where the hydrocarbon phase is the continuous phase of the emulsion. The emulsion may be formed separately from the slurry pump and pipeline. The emulsion forming device may be a static mixer or a high energy stirred tank. The emulsion may be formed within the pipeline by using a static mixer and/or by injecting the bridging liquid into the pipeline as a high velocity jet. A second static mixer (30-482) may be used to further increase bridging liquid dispersion of the combined slurry (30-453) to accelerate agglomeration, followed by filtration in a filter, for instance a pan filter (30-483), to produce dry tailings (30-485), a lean extract (30-486), and a rich extract (30-487). The slurry pump may be a jet pump. The presence of a jet pump may eliminate or reduce the need for a static mixer for agglomeration, due to the high shear and energy therein.

[0648] A purpose of the jet pump and hopper wash solvent is to reduce the volume and cost of other systems required for ablation and dissolution. In the event that additional dissolution is required, a heated dissolution solvent (30-497) can be added into the pipeline prior to agglomeration. Due to the relatively higher pressure in the pipeline, the heated dissolution solvent can be added at a temperature above its atmospheric boiling point. This heated dissolution solvent, heat, and additional retention time may complete the dissolution to a desired extent. This heated dissolution solvent may be added in or prior to or post the pump box, i.e. before the agglomerator, as described above, and in or after the discharge from the jet pump. The dissolution solvent may comprise bitumen and a lighter hydrocarbon. The heated dissolution solvent may be added at a temperature of 30 °C to 120 °C.

[0649] In order to mitigate recycling solids to obtain appropriate slurry density for a downstream filter system, a section of the pipeline containing agglomerated slurry may have a screen section, arranged in a pipe-in-pipe fashion. The screen size may be chosen to retain agglomerated solids, such as normally 100 to 200 microns. Liquid may be removed from the agglomerated slurry while still under pressure, and be measured and controlled to provide the agglomerated slurry in a higher solids concentration to the filter system. This hot, pressurized rich extract may be recycled to the prior steps as hopper wash or motive fluid for the jet pump.

A potential benefit of the higher density to the filter system is a reduction in filter system requirements. Other separation devices such as cyclones may be used.

[0650] With reference to Figure 31, bituminous feed (31-512) may enter a hopper (31-514), which may feed a jet pump (31-518). A motive fluid (31-520), comprising a solvent for extracting bitumen, may be added to the jet pump (31-518) via a motive fluid pump (31-521). The motive fluid pump (31-521) may also supply hopper wash solvent (31-590) to the hopper (31-514) as an upper hopper wash solvent (31-592) or a lower hopper wash solvent (31-594). The hopper wash may alternatively be supplied in a different composition and temperature than the motive fluid.

[0651] A conditioned slurry (31-522) may be discharged from the jet pump (31-518) and pass through a slurry boost pump (31-523) to a screen (31-525) to remove oversized particles (31-526), such as clay lumps, undigested ore, rocks, or other debris.

[0652] The screened conditioned slurry (31-596) from the screen (31-525) screen may enter a second hopper (31-527) for solid-liquid separation. A higher density slurry (31-529) may progress from the second hopper (31-527) to a second jet pump (31-560) toward agglomeration. A supernatant stream may also progress from the second hopper. The second hopper may be described as a solid-liquid separator since a primary function of the second hopper is to provide a fluid substantially free of solids which can be used as a motive fluid for a jet pump. The second hopper may also preferably provide a higher density slurry that is substantially dense such that when the higher density slurry is diluted with a motive fluid, the resulting slurry is as dense or denser the screened conditioned slurry.

[0653] The screen used to remove oversized particles may be a screen with an open vapor space above and/or below the screen. The screened condition slurry may discharge into the second hopper with a vapor space at a reduced speed so as to minimize gas entrainment into the hopper. The screened conditioned slurry falling velocity is reduced by adding baffles and/or shelves in the vapor space of the hopper to blunt the slurry's momentum. The baffles and/or shelves may be added to slow gravity feed the screened conditioned slurry to the hopper. Baffles may be added within the slurry phase of the pump box or hopper to minimize plugging and allow for time for gas disengagement. The size of the second hopper may be designed to provide sufficient residence time to allow entrained gas to separate from the slurry. It is preferable that the second hopper is designed with a sufficient liquid residence time such as to minimize the amount non-condensable gas from the vapor space that is present in either the higher density slurry and the supernatant stream of the second hopper.

[0654] Oversized particles (31-526) may be washed on the screen (31-525) by a wash fluid (31-531). The wash fluid (31-531) may be clean, or include a portion of bitumen and other materials, such as fine particles. This wash fluid (31-531) may also assist in moving conditioned slurry (31-522) through the screen (31-525), minimizing the screen size. The wash fluid (31-531) may comprise an aqueous or non-aqueous solvent. In a case where the screen (31-525) is a rotating trommel, heavy chains or other devices may be used to assist breaking up soft oversized particles.

[0655] Washed oversized particles (31-526) from the screen (31-525) may be sent to a scrubbing device (31-533) using high-pressure liquid solvent (31-535) jets to remove bitumen or bitumen coated particulates that may have adhered to the non-ablatable components such as rock. An example of such a device is the Hydro-Clean™ (WS Tyler, Mentor, Ohio, US). Liquid and liberated fines (31-537) may be drained from the scrubbing device and added to the second hopper (31-527).

[0656] Remaining oversized material (31-539) may be washed on a second screen (31-541) with new solvent (31-543) to remove residual bitumen, and prepare the oversized particles for solvent removal.

[0657] Washed oversized particles (31-545) may be sent for solvent removal (31-547) and disposal (31-598). Steam (31-549) may be added to the washed oversized particles (31-545) to evaporate the solvent. Solvent based liquid (31-551) may be combined into the second hopper (31-527).

[0658] Alternatively, the liquid wash (31-543) on the second screen (31-541) may be hot water. In this case, the heat of the water evaporates solvent, preparing the oversized material for direct disposal. Waste water from this step may be used as the bridging liquid for agglomeration as described herein. Water based liquid (31-551) may be added to the pipeline as bridging liquid (31-581) or as bridging liquid (31-570) to the jet pump motive fluid (31-566).

[0659] Supernatant (31-566) may be passed through a motive fluid pump (31-568), combined with bridging liquid (31-570), and fed as motive fluid to the second jet pump (31-560). The bridging liquid may be added to the supernatant stream upstream of the motive fluid pump. Alternatively, the bridging liquid may be added to the motive fluid downstream of the motive fluid pump. It may be preferable to form an emulsion with the bridging liquid and all or a portion of the supernatant stream. It may be preferable to form an emulsion with the bridging liquid and all or a portion of the motive fluid. The emulsion may be formed in a separate equipment, such as a stirred tank or any other commonly known emulsion forming device. Alternatively, the emulsion may be formed inline using a static mixer and/or by introducing the bridging liquid into the pipeline containing the supernatant or motive fluid as a high velocity jet. In the case where the emulsifying device is integrated with the pipeline, the device may be said to form an emulsion because it may be capable of rapidly distributing the bridging liquid at a time scale much faster than agglomeration formation and/or growth.

[0660] The bridging liquid may be added directly into the jet pump. The intense mixing of the second jet pump may effectively disperse the bridging liquid with the solids in the slurry (31-529). A second jet pump discharge (31-572), which may comprise about 20 to 60 wt. % solids, based on the weight of the discharge, may be passed to a second slurry pump (31-574). Additional bridging liquid (31-581) may be added to assist agglomeration. A static mixer (31-582) may be used for increased water dispersion to aid agglomeration, followed by filtration in a filter, for instance a pan filter (31-583), to produce dry tailings (31-585), a lean extract (31-586), and a rich extract (31-587). In this configuration as well, the presence of jet pump may eliminate or reduce the need for a static mixer for agglomeration, due to the high shear and energy therein.

[0661] Supernatant (31-576) may be passed through a motive fluid recycle pump (31-578), heated (31-580), and recycled as motive fluid (31-520) for the first jet pump (31-518), or as hopper wash solvent (31-590).

[0662] The second jet pump (31-560) may be used to increase the bitumen dissolution and recovery in bituminous feeds containing a significant amount of aqueous liquid such that no additional bridging liquid is required to agglomerate the solids. Under these conditions, the second jet pump (31-560) and the first jet pump (31-518) can be made to operate in a similar fashion. The first jet pump (31-518) may receive the bituminous feed containing the significant amount of aqueous liquid. The first jet pump (31-518) may be made to operate in a high ablation mode, as described above in section ***II.D*** , in order to maximize the breakup of the solids and maximize the dispersion (or emulsification) of the aqueous liquid. The conditioned slurry (31-522) may flow in a dissolution pipeline in which bitumen dissolution and solids agglomeration occur simultaneously. Furthermore, large lumps of the bituminous feed may breakup in the dissolution pipeline due to bitumen dissolution and shearing action within the pipeline. The agglomerated slurry from the dissolution pipeline may be directed to the screen (31-525) and then the screened conditioned slurry (31-596) is directed to the second hopper (31-527). The higher density slurry is then directed to the second jet pump and the supernatant stream (31-566) is directed to the motive fluid pump (31-568) to produce a motive fluid (31-570) that is directed to the second jet pump (31-560). No additional bridging liquid is added to the supernatant stream (31-566), the motive fluid (31-570), or within the second jet pump (31-560). The second jet pump (31-560) may be made to operate in a high ablation mode, as previously described, in order to break up the agglomerates formed in the dissolution pipeline. The second jet pump discharge (31-572) may flow in an agglomeration pipeline, which follows the second jet pump (31-560) in which additional bitumen dissolution and solids agglomeration occur simultaneously. Solvent may be added in the agglomeration pipeline to further dilute the slurry. The operation of the first jet pump (31-518) and second jet pump (31-560) in this fashion for a bituminous feed containing a significant amount of aqueous liquid may have the advantage of reducing the chance of bitumen occlusion within the formed agglomerates. The breakup of the formed agglomerates within the second jet pump allows for the release of bitumen entrained within agglomerates formed in the dissolution pipeline.

[0663] Wet crushing or sizing may be used in the hoppers (28-214, 29-314, 30-414, or 31-514) or to crush oversized particles (30-426 or 31-526). The addition of fluid to the bituminous feed can assist in the throughput through the sizing devices, reduce buildup of ore, and reduce frictional wear on grinding surfaces. Positioning the secondary screen (31-541) after the primary screen (31-525) may reduce the throughput of the combined slurry (30-453) which may reduce capital and/or operating expenses.

III.E Agglomeration Control

[0664] The present section provides a method of processing a bituminous feed. The bituminous feed is contacted with an extraction liquor to form a slurry. A bridging liquid is added to the slurry, and solids are agitated within the slurry to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract. In order to control agglomeration, the slurry is analyzed and the processing method is adjusted accordingly.

[0665] With reference to Figure 50, a bituminous feed may be contacted with an extraction liquor to form a slurry (50-102). A bridging liquid may be added to the slurry and solids may be agitated within the slurry to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract (50-104). At least one property of the agglomerated slurry, the agglomerates, or the low solids bitumen extract may be measured (50-106). The at least one measured property may be compared to a target range. Where the at least one measured property that is measured does not fall within the target range, at least one parameter of the method may be adjusted, for controlling the agglomeration (50-108).

[0666] Figure 37 is a schematic of a method of processing a bituminous feed with additional steps including downstream solvent recovery. Feedback control is not illustrated in Figure 37. The extraction liquor (37-202) is mixed with a bituminous feed (37-204) from oil sand in a slurry system (37-206) to form a slurry (37-208). The extraction liquor comprises a solvent and is used to extract bitumen from the bituminous feed. The slurry is fed into an agglomerator (37-210). Extraction may begin when the extraction liquor (37-202) is contacted with the bituminous feed (37-204) and a portion of the extraction may occur in the agglomerator (37-210). A bridging liquid (37-212) is added to the agglomerator to assist agglomeration of the slurry. Agitation of the slurry is also used to assist agglomeration.

[0667] The agglomerated slurry (37-214), comprising agglomerates and a low solids bitumen extract, is sent to a solid-liquid separator (37-216) to produce a low solids bitumen extract (37-218) and agglomerates (37-220).

[0668] The following additional steps may also be performed. The low solids bitumen extract is sent to a SRU (37-222) to recover solvent (37-224) leaving a bitumen product

(37-226). The agglomerates (37-220) are sent to a TSRU (37-228) to recover solvent (37-230) leaving dry tailings (37-232).

[0669] In one embodiment, the bituminous feed is dry oil sand, which is contacted with extraction liquor that free of bridging liquid in a slurry system to produce a pumpable slurry. The slurry may be well mixed in order to dissolve the bitumen. In this embodiment, the bitumen is first extracted from the bituminous feed prior to agglomeration in order to prevent (or limit) the agglomeration process from hampering the dissolution of bitumen into the extraction liquor. In another embodiment, the bridging liquid may be directly mixed with the bituminous feed before or at the same time as the extraction liquor so that bitumen extraction and agglomeration occur simultaneously. In this embodiment, the bridging liquid is added before or at the same time as the extraction liquor in order to minimize the dispersion of fines, which may reduce the solids content of the bitumen extract after the agglomeration process.

[0670] In one embodiment, the formed agglomerates are sized on the order of 0.1-1.0 mm, or on the order of 0.1-0.5mm, or on the order of 0.1-0.3 mm. In one embodiment, at least 80 wt. % of the formed agglomerates are 0.1-1.0 mm, or 0.1-0.5mm, or 0.1 to 0.3 mm in size. The rate of agglomeration may be controlled by a balance between intensity of agitation within the agglomeration vessel, shear within the vessel which can be adjusted by for example changing the shape or size of the vessel, fines content of the slurry, bridging liquid addition, and residence time of the agglomeration process.

[0671] The agglomeration of the fines within the slurry plays an important role in the recovery of bitumen from the oil sand. Little or no agglomeration of the fines hampers solid-liquid separation since fine particles interfere with the filtration process and/or increase the solids content of the low solids bitumen extract. However, excess agglomeration of solids results in entrapment of bitumen extract within the large agglomerates. Thus, it is desirable to control the agglomeration process with a view to achieving the desired agglomerates, such as agglomerates of a desired size, density, composition, other parameter, or a combination thereof.

[0672] The level of agglomeration will be affected by many factors among the most consequential are the composition of the bituminous feed (for instance as a result of ore quality), the amount of bridging liquid added, the method by which the bridging liquid is added, the residence time of the extraction and agglomeration processes, the type and intensity of agitation, the shear environment, the amount of any additional solids that are added, and the surface chemistry of the fines.

[0673] Because the ore quality, a measure of the ore chemistry and physical characteristics, may change on a very frequent basis as different mine shelves are progressed, the recipe for agglomeration may vary resulting in varying agglomeration. Thus, it is desirable to use a process that can be adjusted to account for feed variation and/or the resultant agglomeration outputs.

[0674] According to one embodiment, the bituminous feed and/or at least one of the agglomeration outputs (the agglomerates and the low solids bitumen extract) are analyzed as agglomeration proceeds. This information is then used to adjust the process, for instance by increasing or decreasing added solids content, adjusting the amount of bridging liquid added, adjusting the residence time of the extraction and/or agglomeration processes, adjusting intensity of agitation, or adjusting the shear environment to seek more desired output(s). These parameters may be adjusted individually or in combination in order to maximize the effective response of the control system.

[0675] Figure 51 illustrates one embodiment, where the following steps are performed:

1. Measure (A) properties of the slurry (51-302) comprised of bituminous feed and extraction liquor. In another embodiment, the bituminous feed may be measured prior to contact with the extraction liquor.
2. Combine the slurry (51-302) with a bridging liquid (51-304) and add to an agglomerator (51-306).
3. Measure (B) properties of one or more outputs (51-308) (i.e. the agglomerates and the low solids bitumen extract) of the agglomeration process. The measurement may be performed continuously.
4. Use the measurements in a controls system (51-310) to adjust a parameter of the process. One option is to adjust the amount of bridging liquid (51-304) that is added to the slurry. Another option is to adjust the composition of the bridging liquid added to the slurry. Another option is to adjust the methods and locations of the bridging liquid addition in the

process. Another option is to adjust the solid content of the slurry. Another option is to adjust the intensity of agitation of the slurry. Another option is to adjust the residence time of the extraction process. Another option is to adjust the residence time of the agglomeration process. Yet another option is to adjust the shear environment of the agglomeration by changing for example the size or shape of the vessel.

[0676] Measurable properties of a bituminous feed which could be used include but are not limited to: (i) fines content, (ii) moisture content, (iii) level of insoluble organics, (iv) quantity of bitumen present, (v) clays content, (vi) clay chemistry, (vii) particle size distribution, (viii) density, (ix) electrical properties such as conductivity. Water in the bituminous feed may also be measured. Standard tests are available for all of these measurements; for example methylene blue testing is a well-known method that can be used to quantify the quantity of clays in the oil sand ore.

[0677] Measurable properties of the outputs of the solvent extraction with solids agglomeration process include but are not limited to: (i) particle size distribution of output solids, (ii) filtration rate of slurry, (iii) fines content of the low solids bitumen extract, (iv) bitumen content of low solids bitumen extract, and (v) viscosity (rheology) of the slurry. The values of these properties are strongly impacted by the solvent extraction process and thus can be used in the control system described herein. Other measurable properties include: (vi) hydrocarbon content of the output solids, (vii) moisture content of agglomerates, (viii) attrition and/or strength of the agglomerated solids, (ix) electrical properties, and (x) yield strength of the slurry.

[0678] The at least one parameter may comprise recycling at least a portion of the agglomerated slurry back to the bituminous feed or slurry before or after adding the extraction liquor, and before or after adding the bridging liquid.

[0679] ***Particle Size Distribution Property.*** The particle size distribution of the output solids can be measured by integrating an on-line particle size measurement device such as a Retsch Technology Camizer. A slip stream can be taken from the slurry, filtered to remove liquid, and then measured to analyze particle size distribution. The particle size distribution of output agglomerates may have a measured D50 of between 100 microns and 300 microns, or the agglomerates might have a measured D50 of between 300 and 1000 microns, or the agglomerates might have a measured D50 of between 1000 and 2000 microns. It is preferable that the measured D50 be between 100 and 300 microns because such a particle size distribution would insure good solid-liquid separation rate while reducing the entrapment of bitumen extract within the pores of the agglomerates.

[0680] ***Filtration Rate Property.*** The filtration rate of the slurry can be measured by integrating an on-line filtration device with the pipeline. A slip stream can be taken from the slurry and the rate of filtration can be measured, or alternatively the filtration rate may be directly measured if a filtration process is included in the processing of the slurry in the solid-liquid separator. In the case of a slip stream filtration, the filter medium should be similar in material and pore size to that which is used in the solid-liquid separator. Exemplary filtration device include, but are not limited to, lab scale chamber presses and diaphragm filter presses. The filtration rate of the slurry is preferably in the range of 0.2 to 1 mL/cm^2sec. Higher filtration rates may be suitable; however, care should be taken to ensure that such filtration rates are not due to excessive channeling.

[0681] ***Fines Content Property.*** The fines content of the low solids bitumen extract may be measured using several methods that are well known in the art. However, a method that quickly measures the solid content is preferable. Such a method may involve taking a slip stream of the slurry and filtering it to produce a low solids bitumen extract or directly sampling the low solids bitumen extract from the solid-liquid separator. The density of the bitumen extract and a micro-filtered bitumen extract is then measured. The bitumen extract can be filtered through a micro-filter with a nominal pore size of 0.45 microns. Suitable density measuring devices include vibration type liquid density meters. The difference in density of the bitumen extract and micro-filtered bitumen extract can be correlated with solid content, S by using following equation:

$$S = \frac{\dfrac{1}{\rho_T} - \dfrac{1}{\rho_E}}{\dfrac{1}{\rho_S} - \dfrac{1}{\rho_E}}$$

where ρ_T is the measured density of the low solids bitumen extract and ρ_E is the measured density of the micro-filtered bitumen extract. ρ_s is the solid density that may be obtained by experimental calibration or approximated to have a value between 2.3 to 2.6 g/cm^3. The solid content of the low solids bitumen extract is preferably less than 2 wt. %, or preferably less than 1 wt. %, or even more preferably less than 0.5 wt. %.

[0682] Still another method of measuring the fines content may be an optical method, such as to dilute a low solids bitumen extract stream with excess solvent and then measure the turbidity of bitumen extract and micro-filtered bitumen extract. The difference in turbidity may be calibrated with fines content of the low solids bitumen extract.

[0683] ***Bitumen Content Property.*** During the extraction process as bitumen from the oil sand dissolves into the extraction liquor, the density of the low solids bitumen extract increases. The bitumen content of the low solids bitumen extract can be estimated by measuring the density of the low solids bitumen extract. A slip stream can be taken from the slurry and filtered to produce the low solids bitumen extract or the low solids bitumen extract can be sampled from the output of the solid-liquid separator. The low solids bitumen extract can be filtered through a micro-filter with a nominal pore size of 0.45 microns to obtain a solid-free bitumen extract. The density of the solid-free bitumen extract can be measured using an on-line density meter. The density of the bitumen extract can then be used to approximate the bitumen content of the solid-free bitumen extract. Figure 55 is a calibration curve relating bitumen content of a bitumen extract comprised of bitumen and solvent to the measured density of the bitumen extract. The measurement can also be used to determine the degree of bitumen extraction from the oil sand at different points along the extraction and agglomeration processes.

[0684] ***Viscosity Property.*** The particle size distribution of the oil sand slurry has a strong impact on the viscosity of the slurry. Slurries with a high fines content is expected to have a high viscosity. The slurry viscosity is expected to decrease as the average particle size of the slurry increases. Additionally, since a hydrocarbon phase is the continuous fluid in the slurry, water chemistry will have much less of an impact on the viscosity/rheology behavior of the slurry compared to the impact water chemistry has on the viscosity/rheology of WBE slurries. This fact makes correlation of particle size distribution with rheology much simpler for the oil sand slurries described herein. Thus, in one embodiment, measurement of the viscosity of the slurry can be used to estimate the amount of fines in the oil sand slurry and therefore used to control, for example, the amount of bridging added to the slurry. This measurement can be obtained in a simple viscometer or in a rheometer. Other related tests can also be used, such as a flow rate test and pressure drop measurements.

[0685] In another embodiment, measurement of the rheology of the slurry can be used to determine the progression of the agglomeration process. For example, after the bridging liquid is added to the slurry and agitated, a rapid increase in the viscosity of the slurry may indicate excessive agglomerate growth that has led to the trapping of a significant amount of bitumen extract within the agglomerates. Conditions that lead to such behavior should be limited or avoided since they can lead to poor bitumen recovery. The control system described herein can be used to change process parameters, such as the amount of bridging liquid addition, when the viscosity of the slurry is measured to rapidly increase. In another example, the viscosity or rheometer measurement can be used to track the growth of agglomerates. In cases when the formed agglomerates are compact, the growth of agglomerates may be accompanied by a gradual reduction in slurry viscosity or dynamic shear strength. Thus, the change in slurry viscosity may correlate well with agglomerate growth.

[0686] The viscosity of the oil sand slurry may be measured with any suitable instrument that is well known in the art. For example, an automatic on-line viscometer, which takes a slip stream from the slurry and measures the viscosity, can be used. An in-line viscometer, such as a vibrating-type viscometer, can be used to provide instant viscosity measurements within the process slurry. In another example, the torque is measured in the agitation process, and rheological measurements could be determined in-situ. That is, if a mixing vessel is used for the agglomerator, the torque applied to the vessel can be measured as an indicator of rheological properties such as viscosity.

[0687] Various other properties of the bituminous feed, or the outputs could be alternatively or additionally measured.

[0688] In another embodiment, the following steps may be performed:

1. Drill ore cores in advance of mining trucks to determine the quality of the ore.

2. As shovels proceed through a seam, obtain further data to characterize the ore. Send the ore to the extraction process, characterized as low, medium, or high fines content, or along another rating system.

3. Combine the oil sand with an extraction liquor and a bridging liquid in an agglomerator. The extraction liquor comprises a solvent used to dissolve bitumen. The bridging liquid is used to assist agglomeration. The bridging liquid may be water or a sludge from a WBE. Suitable sludge steams include, but are not limited to, WBE streams such as middling from primary separation, secondary and tertiary separation tailings, froth treatment tailings, mature fine tailings from tailings ponds, or a new stream resulting from passing any of these streams through a thickener, hydrocyclone, or other processes. For example, middlings passed through a cyclone might generate an overflow stream and an underflow stream. Either stream could be used in this process as bridging liquid. The amount of bridging liquid that is added will affect the extent of agglomeration. Agitation is also used to assist agglomeration.

4. Adjust one or more process parameters based on one or more output properties. One process parameter is the amount of bridging liquid that is added to the slurry. Another process parameter is the solid content of the bridging liquid added to the slurry. Another process parameter is the methods and locations of the bridging liquid addition in the process. Another process parameter is the solid content of the slurry. Another process parameter is the intensity of agitation of the slurry. Another process parameter is the shear environment of the agglomerator. Another process parameter is the residence time of the extraction process. Yet another option process parameter is the residence time of the agglomeration process. Potential output properties include particle size distribution of the produced agglomerates, filtration rate of the slurry, solids content of the low solids bitumen extract, bitumen content of low solids bitumen extract, and the viscosity of the slurry. The adjustments to the process parameters may be made based on the real time measurements of physical properties of the output(s) of the agglomeration process, which result in a feedback. In one embodiment, the feedback loop is a negative feedback, since the desired outputs of the agglomeration process may be set to one or more given target ranges and the input parameters may be adjusted to maintain the output parameters in the target range(s) regardless of type of ore feed and process upsets. The

expression "target range" as used herein may include a range such as between X and Y, but also may include a range such as at least Z, or a range such as less than W.

[0689] In one embodiment, the characterization of fines content comprises a methylene blue test. In another embodiment, the characterization of fines comprises a particle size distribution analysis. In another embodiment, the characterization of fines comprises viscosity/rheology tests of oil sand slurry. In another embodiment, the ore (or bituminous feed) is characterized by bitumen content rather than, or in addition to, fines content. In another embodiment, the ore (or bituminous feed) is characterized by spectroscopy, photoluminescence, fluorescence, or other photoactive technology. In another embodiment, the ore (or bituminous feed) is characterized by water chemistry and/or quantity. In yet another embodiment, the output solids are characterized by particle size distribution using sieves, laser diffraction, optical analysis, or other size quantification technique. In another embodiment, the hydrocarbon content of the output stream is measured by a bomb calorimeter, gas chromatography, photo activity such as phosphorescence or other photon technique, particle sniffer, or other technology. In another embodiment, the moisture content is measured by any type of technique suitable to measure water content, including but not limited to a bomb calorimeter, Karl Fischer Titration, Deen Stark analysis, electrical conductivity, relative humidity, or any other technique. In one embodiment, the analysis is performed in conjunction with batch analysis at intervals. In another embodiment, a slip stream is sampled for analysis. In another embodiment, on-line analysis provides continuous information.

[0690] In another embodiment, the bridging liquid is adjusted based on a measured property. The following steps may be performed, with reference to Figure 52:

1. Adding the slurry (52-402) comprised of bituminous feed and extraction liquor to an agglomerator (52-404).
2. Providing two different streams of bridging liquid (52-406 and 52-408) to the agglomerator (52-404) to form an agglomerated slurry (52-410).
3. Based on information on the quality of the oil sand ore (or bituminous feed) or the quality of one or more output streams (i.e. the low solids bitumen extract or the agglomerates) or both, adjusting (using a control point (52-412)) one or both of the flow rates of bridging liquid.

[0691] In one embodiment, the first bridging liquid comprises water and the second bridging liquid comprises sludge produced from the aqueous extraction of bitumen from oil sand.

[0692] In another embodiment, as shown in Figure 53, first and second bridging liquids are mixed before they are introduced into the agglomerator. The slurry comprised of bituminous feed and extraction liquor (together 53-502) is added to an agglomerator (53-504). The first bridging liquid (53-506) and second bridging liquid (53-508) are mixed to form a mixed bridging liquid (53-514) and added to the agglomerator (53-504) to form an agglomerated slurry (53-510). Based on information on the quality of the oil sand ore (or bituminous feed) or the quality of one or more output streams (i.e. the low solids bitumen extract or the agglomerates) or both, one or both of the flow rates of bridging liquids (53-506 and 53-508) are adjusted (using a control point (53-512)). In yet another embodiment, the first and second bridging liquids are mixed in the agglomerator.

[0693] In another embodiment, as shown in Figure 54, the properties of the agglomeration process are adjusted through the recycling of agglomerator output upstream of the agglomeration process. For example, the agglomerated slurry could be recycled through the process to affect the residence time of the agglomeration process. The agglomerated solids could also be recycled through the process to increase the solids content of the feed slurry. Additionally, the agglomerated solids could be recycled through the process to provide seed particles within the bridging liquid for the agglomeration process. First, properties of the bituminous feed and extraction liquor (54-602) are measured (A). In another embodiment, the bituminous feed may be measured prior to contact with the extraction liquor. The bridging liquid (54-604) is added to the agglomerator (54-606) to produce outputs (54-608) (i.e. the agglomerates and the low solids bitumen extract) of the agglomeration process. One or more properties of the outputs are measured (B). The measurements may be performed continuously. The measurements (A and B) are used in a control system (54-610) to adjust a parameter of the process, for instance the amount and/or composition of an input. For instance, a portion of the agglomerated solids (54-611) could be recycled back into the process to adjust effective residence time and/or increase solids content.

[0694] In another embodiment, the at least one property further comprises at least one property of the slurry prior to agglomeration.

[0695] The preferred temperature of the slurry is in the range of 20-60 °C. An elevated slurry temperature is desired in order to increase the bitumen dissolution rate and reduce the viscosity of the slurry to promote more effective sand digestion and agglomerate formation. Temperatures above 60 °C are generally avoided due to the complications resulting from high vapor pressures.

[0696] ***Residence Time.*** The residence time of the extraction and agglomeration processes has a strong impact on the bitumen extract and agglomerated solids. Batch experiments within a mixing vessel were conducted to test the effects of residence time. Figure 5 (as described further below) shows that the bitumen recovery and the initial liquid filtration rate increases as the extraction time increases for batch experiments conducted with the agglomeration time kept constant at 2 minutes. Thus, increasing the residence time of the extraction process may result in an increase in both the bitumen recovery and the rate of solid-liquid separation. In contrast, as Figure 46 (as described further below) shows, the bitumen recovery reaches a maximum and then decreases as the agglomeration time increases for batch experiments conducted with the extraction time kept constant at 5 minutes. The decrease in recovery beyond the maximum recovery is most likely due to excessive agglomerate growth that leads to entrapment of the bitumen extract within the agglomerates. However, this growth of agglomerates does result in an increase in the initial filtration rate as the agglomeration time increases.

[0697] The results plotted in Figure 46 and Figure 47 demonstrate the impact that residence time of the extraction and agglomeration processes have on the bitumen extract and agglomerated solids.

[0698] As shown in Figure 56, the recycle loops, (56-1020) and (56-1022) can be used in the control system described herein to adjust the effective residence time within the slurry system (56-1005) and agglomerator (56-1006). First, properties of the bituminous feed and extraction liquor (56-1002) are measured (A). In another embodiment, the bituminous feed may be measured prior to contact with the extraction liquor. The bridging liquid (56-1004) is added to the slurry system (56-1005) and the slurry is passed to the agglomerator (56-1006) to produce outputs (56-1008) (i.e. the agglomerates and the low solids bitumen extract) of the agglomeration process. One or more properties of the outputs (56-1008) are measured (B). The measurements may be performed continuously. The measurements (A and B) are used in a control system (56-1010) to adjust a parameter of the process, for instance the amount and/or composition of an input. For instance, a portion of the agglomerated solids (56-1022) or a portion of the slurry prior to agglomeration (56-1020) could be recycled back into the process to adjust effective residence time and/or increase solids content.

[0699] The results plotted in Figure 46 and Figure 47 also suggest that it is preferable for the residence time of the extraction process be greater or much greater than the residence time of the agglomeration process. The extraction process may occur in the slurry system and the agglomeration process may occur in the agglomerator. The residence time of the extraction process may be greater than 5 minutes, or may be greater than 10 minutes, or may be greater than 15 minutes, or may greater than 30 minutes. Depending on the desired level of agglomeration, the residence time of the agglomeration process may be in the range of 15 seconds to 10 minutes. In order to maximize bitumen recovery, the residence time of the agglomeration process may be in the range of 1 to 5 minutes.

[0700] The solvent used for washing the agglomerates may be solvent recovered from the low solids bitumen extract, as described with reference to Figures 37 and 43. A second solvent may alternatively or additionally be used as described in Canadian Patent Application Serial No. 2,724,806 (Adeyinka *et al.*) for additional bitumen extraction downstream of the agglomerator.

III.F Relocatable Components

[0701] Systems and processes are described in this section which involve relocatable components that can effect early solids content reduction of oil sands. By decreasing solids content of extracted oil sands prior to transporting over long distances, efficiencies and cost savings can be realized. As a mine face recedes, relocatable system components can be moved as well, to remain in close proximity to the receding mine face. This advantageously permits reductions in solid content in a location proximal to the mine face. Early solids content reduction can result in a more cost effective handling of materials.

[0702] Advantageously, certain embodiments of modular and relocatable systems for extraction and processing of bitumen from oil sands may include smaller, more portable equipment than fixed-location equipment. The flexibility of a relocatable system may permit some solids content reduction to be conducted prior to transportation of an oil sands at a location that can be moved to maintain a nearly constant proximity to the mine face, thereby reducing transportation costs. In a system that produces dry tailings, there is the additional advantage of reducing or eliminating tailings ponds and the concomitant cost of transporting tailings thereto.

[0703] A relocatable system for processing oil sands is described herein. The system comprises a relocatable slurry system, relocatable to a near mine face location, for receiving oil sands from the mine and for mixing the oil sands therein with a solvent to form a slurry; and a relocatable pipeline in fluid communication with the relocatable slurry system, for receiving the slurry from the relocatable slurry system and transporting the slurry while agglomerating solids within the slurry through turbulent flow through the pipeline, for delivery of an agglomerated slurry to downstream solvent extraction components.

[0704] A process is described in the section for forming an agglomerated slurry from oil sands. The process comprises receiving oil sands in a relocatable slurry system located at a near mine face location; mixing oil sands with a first solvent within the relocatable slurry system to form an initial slurry; and pumping the slurry through a relocatable pipeline, with subsequent injection of water or high fines streams from a WBE process, to downstream solvent extraction, wherein turbulent flow through the pipeline causes agglomeration of solids within the initial slurry, forming an agglomerated slurry.

[0705] Certain components described herein may be rendered relocatable, such as a mix box for a slurry system, which can be rendered relocatable to a mine face of a continually receding mine.

[0706] By the term "relocatable" as applied to a system component or to a, it is meant that the system component, or one or more components of a system can be moved to another location. Frequent, occasional, or infrequent movement of a system or of a component is encompassed in the term relocatable. System components that are considered portable, mobile or movable would fall within the meaning of the term "relocatable". Components which are not fixed in a particular location, and which would not require onerous or complete disassembly and re-assembly to be relocated would be considered relocatable components. In order to be relocated, a system component may be disassembleable, may include wheels that are optionally detachable, may employ a track system for movement, or may involve some other means of movement, whether permanently or temporarily attached to a single component, or multiple components. A system having one or more components that are relocatable, and other components that are fixed in place, is considered to be a relocatable system for the purposes of the technology described herein.

[0707] The relocatable system described in this section comprises a relocatable slurry system, which is relocatable to a location near to a mine face or a "near mine face location". As the mine face recedes in the course of obtaining oil sand ore, the system can be moved as well to minimize movement or transport of oil sand from ore. When the slurry system is near to a mine face, this need not mean directly adjacent, but is understood to mean that intervening mining components may be disposed between the mine face and the relocatable slurry system, as needed for mining purposes.

[0708] A relocatable crushing unit can be used to crush the oil sand ore, which can be moved as needed to follow the receding mine face, located in-pit. The crushing unit can be moved so as to remain a nearly constant distance from either the mine face or the relocatable slurry system, or can be relocated more or less often than the relocatable slurry system. The crushing unit is used to reduce the size of ore mined, so that the oil sand received by the relocatable slurry system is of an appropriate size for slurrying. The transport of the crushed ore between the relocatable crushing unit and the relocatable slurry system can be done, for example by conveyors, or in any acceptable manner. The relocatable crushing unit is used to reduce the size of oil sand ore to sizes capable of being transported, for example by one or more conveyors, to the relocatable slurry system.

[0709] An optional relocatable solids content reducing unit may be incorporated into the system for reducing the solids content of the oil sand prior to entry into the relocatable slurry system. The solids content reducing unit may, for example, comprise a de-sanding unit, and may employ water-based techniques or other techniques such as involving gravity, to reduce the solids content, and in particular sand, prior to slurrying. The location of the solids content reducing unit may be in close proximity to the mine face, near the crushing unit. Crushed ore received from the crushing unit can be provided to the solids content reducing unit. The relocation of the solids content reducing unit may be conducted with similar frequency to the relocation of the relocatable slurry system, or more or less frequently, as desired. Advantageously, by removing solids from the crushed ore prior to mixing with solvent, less solvent can be used in forming a slurry, and a reduced amount of energy would thus be required to move a lower volume of slurry through the relocatable pipeline. By using a solids content reducing unit to reduce the sand content of the crushed ore, the slurry so formed is rendered more transportable.

[0710] Downstream components of the relocatable system described herein may be any components used in a SBE. For example, a solid-liquid separator for separating agglomerates from the agglomerated slurry, and a TSRU.

[0711] In the case where a secondary solid-liquid separator is employed, a gravity separator, cyclone, screen or filter may be used. Examples of gravity separators include, but are not limited to spiral classifiers, extractors, settling vessels, and/or gravity separators which may employ a wash step such as a countercurrent wash step with progressively cleaner solvent.

[0712] A relocatable system for processing oil sand may comprise: a relocatable slurry system, relocatable to a near mine face location, for receiving oil sands from the mine and for mixing the oil sands therein with a solvent to form a slurry; and a relocatable pipeline in fluid communication with the relocatable slurry system, for receiving the slurry from the relocatable slurry system and transporting the slurry while agglomerating solids within the slurry through turbulent flow through the pipeline, for delivery of an agglomerated slurry to downstream solvent extraction components. The system may additional comprise a relocatable crushing unit, relocatable to a location between the mine face and the relocatable slurry system, for receiving and crushing oil sands ore and for providing oil sand to the relocatable slurry system. The conveyor may be used to convey crushed oil sand ore from the relocatable crushing unit to the relocatable slurry system. The system may additionally comprise a relocatable conveyor system or a relocatable stacker to back-fill dry tailings in-pit.

[0713] A process for forming an agglomerated slurry from oil sands may comprise: receiving oil sands in a relocatable slurry system located at a near mine face location; mixing oil sands with a first solvent within the relocatable slurry system to form an initial slurry; and pumping the slurry through a relocatable pipeline, with subsequent injection of water or high fines streams from a WBE process, to downstream solvent extraction, wherein turbulent flow through the pipeline causes agglomeration of solids within the initial slurry, forming an agglomerated slurry. The process may additionally comprise crushing oil sands ore in a relocatable crushing unit located between the mine face and the relocatable slurry system, and conveying crushed ore to the relocatable slurry system.

[0714] Figure 57 depicts a schematic representation of an exemplary system (57-800) with modular relocatable components. An optional relocatable crushing unit (57-802), is relocatable within a mine so as to be located near the mine face as the mine face recedes. The crushing unit, when used, is employed to crush oil sand for delivery to a relocatable slurry system (57-804). The relocatable slurry system is located adjacent the mine, and is capable of regularly moving to remain proximal to the mine face. The relocatable slurry system (57-804) receives a mixture of recycle solvent with bitumen entrained therein from a recycle source, for mixing with the oil sand. The relocatable slurry system (57-804) is in fluid communication with a relocatable pipeline (57-806) through which the slurry travels. Controlled amount of water or a controlled amount of a WBE stream is added to the pipeline in order to permit the fines or the oil sand ore to agglomerate. Mixing due to turbulent flow in the pipeline distributes water and fines to allow for a uniform agglomeration process. Thus, an agglomerated slurry evolves from the pipeline (57-806) and is directed to downstream solvent extraction components, which are optionally considered as components of the system. As an example of a downstream solvent extraction component is a separator unit (57-808), which can separate a low solids bitumen product from solvent and coarse solids or agglomerates. A primary solid-liquid separator, such as a filter that employs counter current washing with progressively cleaner solvent, may be employed, for example. A gravity separator may also be a component of the separator unit (57-808). The gravity separator may be used in the depicted separator unit (57-808) for receiving a low solids bitumen extract coming from the primary solid-liquid separator and a second solvent. A SRU is employed for recovering solvent from high grade bitumen extract arising from the gravity separator. Bitumen and solvent may thus be separated. Agglomerated solids arising from the separator unit (57-808) is directed to a TSRU where residual solvent remaining on the solids is recovered. The dry coarse solids may then be re-directed back to the pit (57-810) for storage therein. In this way, solids extracted using solvent extraction are not directed to a tailings pond, and the need for a tailings pond is reduced or eliminated.

[0715] A relocatable system that employs solvent extraction near a mine face and directs solids to dry disposal in a pit is described herein. Such a system derives a feed, such as crushed oil sand, from a relocatable mining system within a mine pit. The relocatable mining system comprises a shovel together with relocatable crushers and relocatable conveyors. The shovel recovers oil sand from the mine for delivery to the relocatable crushers and conveyors. The relocatable conveyors then transfer the crushed oil sand to a relocatable slurry system where recycle solvent, loaded with bitumen, is mixed with the crushed oil sand, in the presence of a controlled amount of water. Within the slurry, the solvent contacts the crushed oil sand, permitting extraction of bitumen therefrom. The solvent slurry system can be rendered relocatable so that as the relocatable mining system progresses within the mine, and the mine face recedes, the slurry system may be similarly moved. The relocatable slurry system may take the form of a rotary mixer or a mix box of a size and configuration appropriate to permit initial mixing of the crushed oil sand.

[0716] In an exemplary embodiment of the system, the solvent slurry system is located ex-pit but close to the mine face.

[0717] The slurry produced in the slurry system may be transferred via a pipeline or other appropriate conveyor onto a filter. The solvent in which bitumen is entrained may be recycled from the filter via a return pipeline or conduit to the slurry system near the mine face. The filter may optionally incorporate a drying stage for solvent recovery and re-use. Alternatively, a drained filter cake with about 4 wt. % residual solvent may be passed into a TSRU to reduce solvent content to an environmentally acceptable value before directing the dried filter cake to a dry storage area, such as for back-fill in a spent mine.

[0718] In another embodiment, the slurry produced in a slurry system with solvent and controlled amounts of water is first subjected to agglomeration of fines before solid-liquid separation via a very low shear conduit. Agglomeration can be conducted by rotation, agitation, or using the turbulence caused when the slurry is transported through a pipeline.

[0719] To provide flexibility for mine planning, tailings disposal, and land reclamation, the relocatable slurry system feeds into a flexible and/or relocatable pipeline that directs the slurry to further processing. The equipment downstream of the pipeline may optionally be located close to the dry, agglomerated tailings disposal area.

[0720] Bitumen product formed in the system described herein may be sent via pipeline to a remote location for further processing or storage. Dry tailings produced as a result of the system described herein may be backfilled in-pit. An exemplary type of backfilling system may include relocatable conveyor systems and stackers.

[0721] Relocatable modular extraction systems can process large volumes of oil sand, while requiring less transportation of solids than would be employed with a fixed location system.

[0722] Figure 58 illustrates a relocatable system (58-900) that employs relocatable and modular components to conduct solvent extraction near a mine face, and later directs solids to dry disposal in a pit. A feed (58-902), such as crushed oil sand is conveyed into a relocatable solvent slurry system (58-904) that can be relocated to a location near to the mine face as the mine face recedes. The solvent, which may be a mixture (58-906) of recycle solvent with bitumen entrained therein, can be derived from downstream processes. Solvent and oil sand can be combined in the relocatable solvent slurry system (58-904) with a controlled amount of water to extract bitumen from oil sand. The slurry may then be transported from the slurry system (58-904) via a flexible and relocatable pipeline (58-908), in which pipeline agglomeration occurs. The turbulent movement of the slurry through the pipeline causes agglomeration of fines entrained within the slurry. The pipeline (58-908) may deliver slurry to additional optional equipment (58-910), which may include solvent extraction system components (58-910), as described herein. Such optional equipment may include a drum or clarifier. An exemplary separation unit (58-912) may be a consolidated separation unit or may comprise individual system components such as a solid-liquid separator (58-914). The solid-liquid separator (58-914) may take the form of a filter that washes agglomerates using countercurrent washing with progressively cleaner solvent, together with a TSRU (58-916). A bitumen product derived from the separation unit (58-912) may be directed via pipeline (58-918) to a plant for further processing. Coarse solids (58-920) derived from the separation unit (58-912) having had nearly all of the solvent removed therefrom, can be redirected to the pit (58-920) for storage. Solvent recovered from the TSRU (58-916) can be stored in clean solvent storage (58-922) for subsequent use as needed in the system.

[0723] Figure 59 depicts a further embodiment of a relocatable system wherein relocatable system components of a solvent extraction system are integrated with a water-based relocatable process for solids content reduction. Units can be located close to the mine face so that a slurry system and/or a TSRU may be re-located regularly as a mine face recedes. It can be said that the relocatable units of the system can "chase" the mine face, and thus can continually realize efficiencies. In this way, extracted sand need not be transported to distant downstream locations for ultimate disposal, but can instead be processed near the mine pit from which the oil sand are derived. An extract that is processed to have a lower solids content than mined oil sand is then transported to downstream locations.

[0724] Figure 59 illustrates a bitumen extraction system (59-1000) for extracting bitumen from oil sand, which system has relocatable components for solids content reduction near a mine face. A WBE system having relocatable components (59-1012) is integrated with solvent extraction system components to arrive at an integrated system with efficiencies introduced by negating transport of large volumes of solids. The system (59-1000) incorporates a feed (59-1002) which may comprise crushed oil sand, and delivers this feed into a relocatable slurry system (59-1004) which may be a water-based mild communition slurry system that can be relocated readily to be a constant or near constant distance to a mine face. The slurry system (59-1004) combines crushed oil sand with water to begin the WBE. It is known hat bitumen can be extracted from the oil sand in the presence of a sufficient amount of water and mechanical agitation. The slurry formed in a WBE system within the slurry system (59-1004) may be delivered to a relocatable countercurrent decantation unit (59-1006), where the slurry is separated into a solids rich stream and an aqueous stream. The aqueous stream is directed to a relocatable floatation unit (59-1008) where a bitumen froth stream is formed as the overflow.

The solids rich stream from the decantation unit (59-1006) along with crushed oil sand feed (59-1016) are directed to a solvent slurry system (59-1014). The solvent slurry system (59-1014) combines the two streams with solvent, to begin a solvent extraction process. The solvent used may be recycle solvent (59-1032) containing bitumen entrained therein. The slurry formed in the solvent slurry system (59-1014) may then be transported to additional equipment (59-1018), which may comprise a drum and clarifier, to process oil sand using agglomeration and subsequent separation may be included in this system. Solid-liquid separation within a consolidated unit (59-1020) may then be conducted to remove solvent from agglomerated fines. Optionally, within the consolidated unit (59-1020) there may be a solid-liquid separator (59-1022), such as a filter that incorporates countercurrent washing with progressively cleaner solvent, and a TSRU (59-1024) to withdraw solvent from the solids for recycling. Froth that may have been recovered from the relocatable components (59-1012), as well as diluted bitumen from the solid-liquid separator (59-1022), may be directed to a fixed location plant (59-1026) for further processing. Coarse solids (59-1028) derived from TSRU (59-1024) with a low water and solvent content may be directed back to the pit (59-1010) for disposal without need of a tailings pond. Solvent recovered from TSRU (59-1024) can be directed to clean solvent storage (59-1030) for later re-use. Recycle solvent (59-1032) derived from a filter, which contains a mixture of recycle solvent and bitumen entrained therein, can be re-used in the solvent extraction conducted within the solvent slurry system (59-1014).

[0725] Figure 60 illustrates an embodiment of a system described herein. A system (60-1600) is described in which a bituminous feed (60-1601) is mixed with a solvent and optionally water in a mix box (60-1605), and a pumpable initial slurry is formed. The initial slurry is pumped by pump (60-1607) into a pipeline (60-1609) to agglomerate solids through mixing. The pipeline (60-1609) may be one that is stationary but can be readily extended or shortened in length depending on the positioning of the mix box. A water containing stream may optionally be injected at any location along the pipeline to promote agglomeration of the fines therein. The pipeline may have a retention time of from 2 to 30 minutes, for example 5 minutes, and may be of an appropriate length to permit such retention time, for example, less than about 3 km of pipeline, such as less than about 1.7 km of pipeline may provide a retention time of about 5 minutes at an appropriate flow rate. In this example, the pipeline may be stationary. The agglomerated slurry arising from the pipeline (60-1609) may be pumped via a booster pump (60-1617) into a deep cone settler or clarifier (60-1614). The overflow (60-1616) of the deep cone settler may be sent to a SRU (60-1626) so as to remove bitumen from solvent, thereby forming a bitumen product. Underflow of the settler is pumped via pump (60-1619) to a filter (60-1621) where countercurrent washing is used to remove bitumen from agglomerates with washing along the length of the filter involving progressively cleaner solvent. The filter cake from the filter is then conveyed by a conveyor-dryer, such as a steam conveyor-dryer (60-1623), which serves as a TSRU. Steam may serve as the heating and/or stripping fluid for the conveyor-dryer. Solvent recovered in this conveyor-dryer may have bitumen light ends entrained therein, and may be used as is, or sent to a SRU (60-1626), to remove bitumen light ends entrained therein. The dried agglomerates arising from the conveyor-dryer may be conveyed via conveyors (60-1627) to a location for storage of dry tailings (60-1629).

[0726] Figure 61 illustrates a further embodiment of a system described herein. A system (61-1700) is described in which a bituminous feed (61-1701) is mixed with a solvent (61-1703) and optionally water in a relocatable mobile mix box (61-1705), and a pumpable initial slurry is formed. The initial slurry is pumped by pump (61-1707), which is also relocatable, into a relocatable movable pipeline (61-1709) to agglomerate solids through mixing. A water containing stream may optionally be injected at any location along the pipeline (61-1709) to promote agglomeration of the fines therein. The pipeline may have a retention time of from 2 to 30 minutes, for example 5 minutes, and may be of an appropriate length to permit such retention time, for example, less than about 3 km of pipeline, such as less than about 1.7 km of pipeline may provide a retention time of about 5 minutes at an appropriate flow rate. In this example, the nature of the pipeline being movable and relocatable permits the feed and mix box to be relocated when necessary to an area of an oil sand mine where ore is derived. In this way, the remaining components of the system, downstream of the pipeline, may be stationed in an area removed from the mining operation. The agglomerated slurry (61-1712) arising from the pipeline (61-1709) may be pumped via a booster pump (61-1717) into a length of stationary pipeline (61-1710), and into deep cone settler or clarifier (61-1714). The overflow (61-1716) of the deep cone settler or clarifier (61-1714) may be sent to a SRU (61-1726) so as to remove bitumen from solvent, thereby forming a bitumen product. Underflow of the deep cone settler or clarifier, is pumped via pump (61-1719) to a filter (61-1721) where countercurrent washing is used to remove bitumen from agglomerates with washing along the length of the filter involving progressively cleaner solvent. The filter cake from the filter is then conveyed by a steam conveyor (61-1723), which may be a conveyor-dryer, and which serves as a TSRU to recover solvent. Steam may serve as the heating and/or stripping fluid for the conveyor. Solvent recovered in the steam conveyor (61-1723) may have bitumen light ends entrained therein, and may be used as is, or sent to a SRU (61-1726), to remove bitumen light ends entrained therein. The dried agglomerates arising from the steam conveyor (61-1723) may be conveyed via conveyors (61-1727) to a location for storage of dry tailings (61-1729).

[0727] Figure 62 illustrates another embodiment of the system described herein. A system (62-1800) is described in which a bituminous feed (62-1801) is mixed with a solvent (62-1803) and optionally water in a relocatable mobile mix box (62-1805), and a pumpable initial slurry is formed. The initial slurry is pumped by pump (62-1807), which is also relocatable, into a relocatable movable pipeline (62-1809) to agglomerate solids through mixing. A water containing stream may optionally be injected at any location along the pipeline (62-1809) to promote agglomeration of the fines therein. The relocatable movable pipeline may have a retention time of from 2 to 30 minutes, for example 5 minutes, and may be of an appropriate length to permit such retention time, for example, less than about 3 km of pipeline. For example, about 1.7 km of pipeline may provide a retention time of about 5 minutes at an appropriate flow rate. In this example, the nature of the pipeline being movable and relocatable permits the feed and mix box to be relocated when necessary to an area of an oil sand mine where ore is derived. In this way, the remaining components of the system, downstream of the relocatable movable pipeline, may be stationed in an area removed from the mining operation. The agglomerated slurry (62-1812) arising from the pipeline (62-1809) may be pumped via a booster pump (62-1817) into a length of stationary pipeline (62-1810), and into a separator unit which may include one or more counterflow cyclones (62-1816). Countercurrent washing within multi-stage counterflow cyclones, such as 3 stage counterflow cyclones depicted in Figure 62, can be used to remove bitumen from agglomerates with progressively cleaner solvent washes. The overflow of the separator unit may be sent to a SRU (62-1826) so as to remove bitumen from solvent, thereby forming a bitumen product. Underflow of the separator unit, comprising washed and dried agglomerates, can be conveyed by conveyor (62-1820) to further processing, as described previously.

Example III.E.1

[0728] Approximately 500 g of low grade oil sand (comprising 22 wt. % fines) was mixed with 300 g cyclohexane as a first solvent (loaded with bitumen up to 40 wt. %) using an impeller in a mixing vessel at 30 °C. Sand grains greater than 1 mm were removed by screening. The remaining slurry was passed into an agglomerator where 30 ml of water was added. Agglomerates of sizes ranging from 0.1 mm to 1 cm were formed. The agglomerated slurry was allowed to settle for 30 minutes and a first supernatant was collected for water and solids content analysis. Solids content determined by ashing ranged between 5,000 – 20,000 ppm on a dry bitumen basis for this first supernatant while water content by Karl Fischer analysis was generally less than 1000 ppm. Portions of the first supernatant were mixed with normal pentane as a second solvent above the critical solvent to bitumen ratio to effect precipitation of asphaltene at 30 °C. After settling for 30 minutes, a second supernatant was collected and analyzed for solids and water content. The sediment from the settling test comprised predominantly of asphaltenes and less than 20 wt. % solids and was treated as the lower grade bitumen extract. Solids and water contents of the second supernatant were determined to be less than 400 ppm and 200 ppm on a dry bitumen basis, respectively. The second supernatant was a dry, clean and partially de-asphalted bitumen product suitable for transportation via a common carrier pipeline and processing in a remote refinery.

Example III.E.2

[0729] In another experiment similar to the one described in Example **III.E.1**, a mixture of 30% cyclohexane and 70% heptane, by volume, was used in agglomeration as the first solvent. For the first supernatant, solids content determined by ashing range between 5,000 – 10,000 ppm on a dry bitumen basis while water content by Karl Fischer analysis was generally less than 1,000 ppm. Portions of the first supernatant were mixed with normal pentane as a second solvent above the critical solvent to bitumen ratio to effect precipitation of asphaltene at room temperature. The solids and water content of the resulting second supernatant was determined to be less than 400 ppm and 200 ppm on a dry bitumen basis after 30 minutes of settling.

Example III.E.3

[0730] In another experiment similar to the one described in Example **III.E.1**, normal heptane loaded with 40 % bitumen was used as extraction solvent (the first solvent). Solids content of the first supernatant was determined to be less than 400 ppm on a dry bitumen basis after 30 minutes of settling. Water content was less than 200 ppm. The resulting product, having less than 400 ppm of filterable solids was a high grade bitumen product.

III.F Bridging Liquid Control

[0731] A goal of agglomeration in SBE processes is to capture fines. Insufficient fines capture can be a detriment to downstream operations, potentially causing a low filtration rate or even plugging of a downstream unit. Large particles in the agglomeration operation may result in excessive bitumen occlusion and hence affect the recovery.

[0732] With reference to Figure 63, a method of processing a bituminous feed may comprise: a) contacting (63-102) the bituminous feed with a solvent to form a slurry; b) adding (63-104) a bridging liquid to the slurry and flowing the slurry to agitate solids within the slurry to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract; c) measuring (63-106) a characteristic of the slurry at one or more points along the slurry flow; d) adjusting (63-108) the bridging liquid addition to the slurry based on the characteristic; and e) separating (63-110) the agglomerates from the low solids bitumen extract.

[0733] As shown in Figure 43, an extraction liquor (43-202) comprising solvent is mixed with a bituminous feed (43-204) from oil sand in a slurry system (43-206) to form a slurry (43-208). The slurry is fed into a pipeline (43-210). Extraction may begin when the solvent is contacted with the bituminous feed (43-204) and a portion of the extraction may occur in the pipeline (43-210). The slurry (43-208) is flowed in the pipeline (43-210), and at one or more points along the pipeline (43-210), a bridging liquid (43-212) is added to the pipeline to assist agglomeration of the slurry. Alternatively or additionally, bridging liquid may be added to the slurry prior to the pipeline. Some form of agitation is also used to assist agglomeration, as described below. Agitation may be provided by turbulent flow in the pipeline.

[0734] The agglomerated slurry (43-214), comprising agglomerates and a low solids bitumen extract, is sent to a solid-liquid separator (43-216) to produce a low solids bitumen extract (43-218) and agglomerates (43-220).

[0735] The low solids bitumen extract is sent to a SRU (43-222) to recover solvent (43-224) leaving a bitumen product (43-226). The agglomerates (43-220) are sent to a TSRU (43-228) to recover solvent (43-230) leaving dry tailings (43-232). Generally, dry tailings do not have a substantial amount of free draining liquid.

[0736] The bituminous feed may be oil sand, which is contacted with solvent that is free of bridging liquid in a slurry system to produce a pumpable slurry. The slurry may be well mixed in order to dissolve the bitumen. The bitumen may be first extracted from the bituminous feed prior to agglomeration in order to prevent (or limit) the agglomeration process from hampering the dissolution of bitumen into the solvent. A portion of the bridging liquid may be directly mixed with the bituminous feed before or at the same time as the solvent so that bitumen extraction and agglomeration occur simultaneously. The bridging liquid may be added before or at the same time as the solvent in order to minimize the dispersion of fines, which may reduce the solids content of the bitumen extract after the agglomeration process.

[0737] The formed agglomerates may be sized on the order of 0.1-1.0 mm, or on the order of 0.1-0.5, or on the order of 0.1-0.3 mm. At least 80 wt. % of the formed agglomerates may be 0.1-1.0 mm, or 0.1-0.5, or 0.1-0.3 mm in size. The rate of agglomeration may be controlled by a balance between velocity within the pipeline (i.e. flow turbulence), fines content of the slurry, bridging liquid addition, and residence time within the pipeline.

[0738] Figure 44 illustrates an exemplary pipeline that is segmented into three zones. The slurry (44-308), comprising the bituminous feed and the solvent, is fed into the pipeline (44-310). In the extraction zone (44-350), bitumen extraction, which began prior to delivering the slurry (44-308) to the pipeline (44-310), continues. The extraction zone (44-350) is designed to provide enough residence time and agitation to dissolve the bitumen. In the extraction zone (44-350), agglomeration generally does not occur, or is limited, because bridging liquid is preferably not injected into the pipeline in the extraction zone of the pipeline. However, where the process detects that the bituminous feed includes a large amount of connate water and that agglomerated particles already exist, little to no bridging liquid may be added and agglomeration will indeed occur in the extraction zone.

[0739] At some point, bridging liquid (44-312a) is added to the pipeline (44-310). Adding a sufficient amount of bridging liquid (44-312a) assists agglomerate nucleation in the nucleation zone (44-352). The amount of bridging liquid added within the nucleation zone may be less than or equal to or much less than the total amount of bridging liquid needed for desired agglomeration. The amount of bridging liquid added within the nucleation zone may be 5 to 100% of the total amount of bridging liquid added within the pipeline. The amount of bridging liquid added within the nucleation zone may be 20 to 85% of the total amount of bridging liquid added within the pipeline.

[0740] At a later point, additional bridging liquid (44-312b) may be added to the pipeline (44-310) to assist agglomerate growth, in the agglomerate growth zone (44-354), to a desired size for subsequent solid-liquid separation. The bridging liquid (44-312b) may be added to the agglomerate growth zone (44-354) at several points to assist uniform mixing of the bridging liquid with the slurry.

[0741] The three zones are not necessarily discrete zones. For instance, extraction may continue after the extraction zone, and nucleation may continue after the nucleation zone.

[0742] The agglomerate growth zone (44-354) may be followed by a comminution zone. The mixing energy within the comminution zone is increased significantly in order to comminute the undesirably large agglomerates that form in the agglomerate growth zone. Methods for increasing the mixing energy include, but are not limited to, increasing the slurry velocity within the comminution zone and/or having internal structures within the comminution zone of the pipeline.

[0743] Like Figure 44, Figure 45 illustrates a pipeline (45-410) in more detail divided into three zones, the extraction zone (45-450), the nucleation zone (45-452), and the agglomerate growth zone (45-454). The slurry (45-408), and bridging liquids (45-412a and 45-412b) are also shown. Measurement (45-456) of one or more characteristic of the slurry at one or more points along the pipeline (45-410) can be used to control (45-458) the operation upstream or downstream of the measurement location(s). The measurement (45-456) may be made at one or more points along the pipeline in any or all of the zones. The control (45-458) may be control of bridging liquid addition.

[0744] The characteristic may be a pressure differential measured in the slurry flow, density of the slurry, or particle size distribution of the slurry. Each of these characteristics will now be described individually although two or more of characteristics may be used together. The characteristic may be a solids characteristic, that is, a characteristic of the solids profile of the slurry or an analog therefor.

[0745] ***Pressure Differential.*** Slurry pipeline pressure differential is a function of particle size, particle distribution, concentration and flow velocity as seen in Figure 5, from Kaushal *et al.*, *International Journal of Multiphase Flow* 31 (2005) 809–823.

[0746] Among these variables, the particle size itself is a function of the bridging liquid content of the solids in the slurry. The permeability measured downstream via a filtration unit operation is also a function of the particle size and is sensitive to the bridging liquid content as seen in Figure 65, which depicts variation in permeability as a function of bridging liquid content added for agglomeration based on data from one liter stirred tank experiments. The term permeability in this context refers to the ability of fluids to flow through a partially permeable structure, such as a bed of particles (such as sand, charcoal, or beads), a filter, a membrane, which typically preferentially restricts solid particles in a solid/liquid fluid that are larger than a certain size from passing through the permeable structure. The measured permeability is an indication of the size of particles as well as the particle size distribution of the particles forming the bed.

[0747] Experiments were performed in which 350 grams (g) of solids was mixed with solvent to create a slurry in a stirred tank. The impeller in the stirred tank was rotated at 1500 rotations per minute (rpm). The amount of fines in the solids was varied in a range of 10 wt. %-25 wt. % of the total mass (i.e. 350g). The overall solids concentration of the slurry was 30 wt. %-60 wt. % in different tests. A known amount of water (as bridging liquid) was added for the agglomeration step and provided a residence time in the tank, varying in the range of 15 seconds-2 minutes. The amount of water added was also a variable, as depicted in Figure 65. The slurry was then transferred to a filtration unit, where a vacuum was drawn and subsequently, the permeability was measured. This experiment was repeated multiple times with increasing amount of bridging liquid addition in each case. The trends from the experimentation are shown in Figure 65, depicting increase in permeability as a function of bridging liquid content added in the agglomeration step in each experiment.

[0748] In a pipeline, measured pressure differential can be used as a characteristic and is a non-intrusive/in-situ property that can be measured across a pump or straight pipe section. The pressure differential can be used as an indication of the bridging liquid content in the solid particles that are present in the slurry. The pressure differential may be measured across multiple points in a pipe section.

[0749] There are at least two approaches for implementation of this concept. The first, relatively simplistic approach, is to use the pressure differential data directly. It has been observed in experimental work in 6 inch and 4 inch pipelines that the pipeline pressure differential varies depending on bridging liquid content of the slurry, as seen in Figure 66. In these experiments, solids and solvent were mixed in a tank and then passed through a pipeline with a diameter of 6 inches. The solids content of the slurry in these cases varied in the range of 30 wt. %-60 wt. %. The flow was maintained above a pre-calculated minimum settling velocity in this pipeline (at least above 2.8m/s in these cases) and a known amount of bridging liquid was added. A similar protocol was followed in experiments corresponding to a 4 inch pipeline. In particular, Figure 66 shows variation in pump pressure rise and straight section pressure differential as a function of bridging liquid content (and residence time). Also, permeability follows a similar trend, which is favorable to the present concept.

[0750] The second approach, which requires data processing, is based on Fast Fourier Transforms (FFTs) of pressure differential data, for instance from agglomeration in a pipeline of a given diameter. A distinct sensitivity to bridging liquid content was observed, as shown in Figure 64. As an example, Fast Fourier Transforms (FFTs) were performed on the pressure differential data collected on slurries with different bridging liquid content and hence, different particle sizes. Figure 64 is a graph of slurry pipeline pressure differential versus solids content of the slurry. Figure 64 depicts the shift in the processed curves depending on the bridging liquid content. This sensitivity can be leveraged to understand the bridging liquid content or particle size distribution in the slurry. In particular, Figure 67 shows results of FFT on pressure measurements depicting shift in peaks based on bridging liquid content with a 6 inch pipeline and 60 wt. % solids content of the slurry.

[0751] Figures 68A, 68B, and 68C illustrate theoretical predictions from a model depicting pressure differential as a function of particle size for various pipe dimensions and fines concentration. Solid lines are 25 wt. % fines and dotted lines are 10 wt. % fines. Black lines are 30 wt. % slurry and grey lines are 50 wt. % slurry. Figures 68A, 68B, and 68C show the sensitivity of pressure differential to particle size distribution, and slurry density is shown in the theoretical calculations made using the model.

[0752] For implementation, one needs to decouple the sensitivity to bridging liquid content from that of slurry density. One way is to generate a set of preliminary data that can be used to create a baseline. Once this is generated, an algorithm can be programmed and that can predict the required bridging liquid to be added in the system to optimize the process. The residence time for agglomeration is typically short (on the order of about 1-5 minutes) and hence programing this may be the easiest and most timely manner to respond to the conditions in the pipeline.

[0753] Therefore, the method may further comprise data processing the characteristic of the slurry prior to adjusting the bridging liquid addition. The data processing may be performed on measured pressure differential information, measured density, or measured particle size distribution.

[0754] ***Slurry Density.*** The density may be a local density, or a density profile. Solids and solvent were mixed in a tank and then passed through a pipeline with a diameter of 6 inches. The flow was maintained above a pre-calculated settling velocity in this pipeline (equal to or above 2.8 m/s) and a known amount of bridging liquid was added. The solids concentration was varied in the range of 30-45% by weight. A similar protocol was followed in experiments corresponding to a 4 inch pipeline. In these experiments in 6 inch and 4 inch pipelines, Gamma-Ray scan measurements were made on a slurry before and after water addition. Figure 69 shows Gamma-Ray scans measured in a 6 inch pipeline experiment. The x-axis is the slurry density and y-axis depicts the height in pipeline, with a y/D (height/diameter) of 1 being the top of the pipeline and 0 being bottom of the pipeline (radial location) at common superficial liquid or slurry velocity. In this data, a clear shift in recording was observed as a function of a) change in solids content of the slurry and b) water addition (i.e. particle size distribution in the slurry). When there is a larger amount of solids in the system, the overall slurry density changes. Also, when the bridging liquid is added to the system, the particles combine, and as observed in Figure 69, there is a highly visible change in the local density across the diameter of pipe due to settling of the larger particles. Based on observation of the 60 wt. %, 8% water injected data of Figure 69, the system could also be operated at a higher velocity to prevent or limit bed formation in the system.

[0755] A traversing Gamma-Ray densitometer provides a measurement of the in-situ density of the slurry in the loop. The densitometer provides a measurement of the change in density (solids concentration) with vertical position in the pipe and by averaging this density profile it also provides a measure of the density of the material over the cross-section through a slice of the pipe which is equivalent to the in-situ density of the slurry in the loop. Alternately multiple fixed position densitometers could provide an equivalent density profile. The traversing Gamma-Ray densitometer consists of a source, a housing for the source, shutter and a collimator to provide a narrow slit of gamma radiation to a scintillation radiation detector. Radiation measurements were collected on a data acquisition system. The entire system was mounted to a solid steel frame attached to a hydraulic jack which was used to raise and lower the traversing unit. The vertical position of the unit can be measured to within 0.01 mm with digital calipers. Measurements were performed at y/D intervals of 0.05. The solids concentration of the slurry in the loop at specific heights can be calculated from the measured radiation intensity based on the Beer-Lambert law. The absorption coefficients for fluid and the solids were taken from a database and measured prior to the tests for the solvents used in the study. All concentration measurements were corrected for background radiation. The following equation below shows the Beer-Lambert law for a two phase mixture in pipe flow.

$$\frac{N}{N_0} = \exp\left[-(\mu_w x_w + \mu_f x(1-C) + \mu_s x C)\right]$$

N = measured intensity (Hz or counts/s)

N_0 = unattenuated intensity (Hz or counts/s)

μ = radiation absorption coefficients for pipe wall (w), fluid (f) and solids (s)

X_w = length of beam through the pipe wall (cm)

X = path length of beam through the pipe interior (cm)

C = volumetric chord averaged, solids concentration (volume %).

[0756] ***Particle size measurement.*** The characteristic may comprise a particle size distribution of the slurry. Information about the particle size in the slurry can be gathered via non-intrusive instrumentation that can be mounted on the pipeline. These can be directly looking at the pipeline itself or at a slip stream withdrawn from the pipeline for characterization. The particle size distribution of the slurry may be measured by an optical method or by a laser method. A few examples include a Focused Beam Reflectance Measurement (FBRM), Particle View Microscopy (PVM), and CYCLONEtrac™. Figure 70 shows FBRM data from a 6 inch pipeline depicting shift in chord length depending on particle size distribution. In this case, the FBRM was mounted on the pipeline at a 45 degree angle. It is positioned such that the laser is looking at the slurry in the direction of flow. The device is connected to a data acquisition system and measurements were recorded in the software installed on the computer. Prior to installation in the pipeline, a calibration was performed with the FBRM device on samples to ensure the device performs as expected. The particle size distribution may be measured across multiple points in a pipe or in one or multiple withdrawn slip streams. The characteristic may also be a particle size analog.

IV. Solid-Liquid Separation

[0757] ***Optional Primary Solid-Liquid Separator.*** Following agglomeration, agglomerates may be subjected to settling for primary separation of solids from liquid using a gravity separator, for example by using deep cone settling. Purge gas may be used to maintain a low oxygen environment. Overflow from such a settler can be further cleaned and the solvent removed. Underflow, including agglomerates, which settle out can be sent on to further cleaning through washing steps which may involve, for example, belt filtration and/or counter current washing with progressively cleaner solvent (with less and less bitumen entrained within the solvent) so as to recover bitumen from agglomerates. Other exemplary gravity separators include a spiral classifier and a rake classifier.

[0758] The primary solid-liquid separator may act to reduce the load on the secondary solid-liquid separator. It may also act as a surge bin between the agglomerator and secondary solid-liquid separator so as to smooth out any operating fluctuations in the output of the agglomerator and thus improving the operation of the secondary solid-liquid separator. Furthermore, where a filtration unit is used as the secondary solid-liquid separator, the primary solid-liquid separator may provide a more suitable feed to said secondary solid-liquid separator by increasing the solids concentration of the agglomerated slurry.

[0759] ***Solid-Liquid Separator.*** The agglomerated slurry may be separated into a low solids bitumen extract and agglomerates in a solid-liquid separator. The solid-liquid separator may comprise any suitable unit capable of separating solids from liquids, so as to remove agglomerates. Exemplary types of units include a gravity separator, a clarifier, a cyclone, a screen, a pan filter, a belt filter or a combination thereof.

[0760] The system may contain a solid-liquid separator but may alternatively contain more than one. When more than one solid-liquid separation step is employed at this stage of the process, it may be said that both steps are conducted within one solid-liquid separator, or if such steps are dissimilar, or not proximal to each other, it may be said that a primary solid-liquid separator is employed together with a secondary solid-liquid separator. When a primary and secondary unit are both employed, generally, the primary unit separates agglomerates, while the secondary unit involves washing agglomerates.

[0761] Non-limiting methods of solid-liquid separation of an agglomerated slurry are described in Canadian Patent No. 2,724,806 (Adeyinka *et al.*), issued February 24, 2015.

[0762] ***Secondary Stage of Solid-Liquid Separation to wash Agglomerates.*** As a component of the solid-liquid separator, a secondary stage of separation may be introduced for counter currently washing the agglomerates separated from the agglomerated slurry. The initial separation of agglomerates may be said to occur in a primary solid-liquid separator, while the secondary stage may occur within the primary unit, or may be conducted completely separately in a secondary solid-liquid separator. By "counter currently washing", it is meant that a progressively cleaner solvent is used to wash bitumen from the agglomerates. Solvent involved in the final wash of agglomerates may be re-used for one or more upstream washes of agglomerates, so that the more bitumen entrained on the agglomerates, the less clean will be the solvent used to wash agglomerates at that stage. The result being that the cleanest wash of agglomerates is conducted using the cleanest solvent.

[0763] A secondary solid-liquid separator for counter currently washing agglomerates may be included in the system or may be included as a component of a system described herein. The secondary solid-liquid separator may be separate or incorporated within the primary solid-liquid separator. The secondary solid-liquid separator may be a gravity separator, a cyclone, a screen or filter, or a combination thereof. Further, a secondary SRU for recovering solvent arising from the solid-liquid separator can be included. The secondary SRU may be conventional fractionation tower or a distillation unit.

[0764] The temperature for counter currently washing the agglomerates may be selected to be higher than the temperature at which the first solvent is combined with the bituminous feed. Further, the temperature selected for counter currently washing the agglomerates may be higher than the temperature at which solids are agglomerated.

[0765] When conducted in the process, the secondary stage for counter currently washing the agglomerates may comprise a gravity separator, a cyclone, a screen, a filter, or a combination thereof.

[0766] The solvent used for washing the agglomerates may be solvent recovered from the low solids bitumen extract, as described with reference to Figure 37 and 43. The solvent used for washing the agglomerates may be solvent recovered from the low solids bitumen extract, as described in Canadian Patent Application Serial No. 2,724,806 (Adeyinka *et al.*). A second solvent may alternatively or additionally be used as described in Canadian Patent Application Serial No. 2,724,806 (Adeyinka *et al.*) for additional bitumen extraction downstream of the agglomerator.

[0767] ***Filtration Unit.*** Following agglomeration, either directly or indirectly after a settling step in a primary solid-liquid separator, agglomerates can be drained and washed in a low oxygen, gas-tight filtration unit, such as a vacuum belt or pan filter. Agglomerates are conveyed on one or more filters and washed in a counter-current manner with progressively cleaner solvent. For example, four separate washing stages with progressively cleaner solvent may be employed as agglomerates progress along the belt. The final filter cake, which should be relatively free of bitumen may go on to further solvent removal steps before discarding as agglomerates with a low water content, and a residual hydrocarbon content that meets or exceeds environmental requirements.

[0768] In counter-current washing, solvent having bitumen entrained therein for the earlier stages washing can be obtained from later stages of the system. The drained solvent from the later stages of the counter-current washing, having entrained more bitumen therein from the washing step, can thus be used in earlier stages of the counter current washing. This action allows for washing stages to occur with progressively cleaner solvent, which results in a more efficient use of solvent.

[0769] ***Separation of Fine Solids Stream and Coarse Solids Stream.*** The processes described herein may involve separation of a fine solids stream from a coarse solids stream from the initial slurry after it is mixed in a slurry system. This aspect of the process may be said to occur within a fine/coarse solids separator. An exemplary separator system may include a cyclone, a screen, a filter or a combination of these. The size of the solids separated, which may determine whether they are forwarded to the fine solids stream versus the coarse solids stream can be variable, depending on the nature of the bituminous feed. Whether a bituminous feed contains primarily small particles and fines, or is coarser in nature may be taken into consideration for determining what size of particles are considered as fine solids and directed toward agglomeration. Notably, embodiments of the process described herein do not require separation of coarse and fine solids from the initial slurry. In such instances, both coarse and fine solids will be present in the agglomerator. When separation of coarse and fine solids is desired, a typical minimum size to determine whether a solid is directed to the coarse solids stream would be about 140 microns. Fines entrainment in the coarse stream is unavoidable during this separation. The amount of fines entrained in the coarse solids stream is preferably less than 10 wt. %, for example, less than 5 wt. %.

[0770] ***Fine/Coarse Solids Separator.*** A coarse solids stream derived from the fine/coarse solids separator may be derived from the system. When the fine/coarse solids separator is present, the coarse solids stream may be directed for combination with the agglomerated slurry arising from the agglomerator prior to entry of the slurry into the solid-liquid separator.

[0771] The feed stream entering the agglomerator unit is pre-conditioned to separate out coarse particles before entry into the agglomerator unit. Thus, the stream entering the agglomerator is predominantly comprised of finely divided particles or a "fine solids stream". The slurry fraction containing predominantly coarse particles or the "coarse solids stream" may by-pass the agglomerator unit and can then be combined with the agglomerated slurry before the solid-liquid separation stage in which low solids bitumen is extracted from the agglomerated slurry.

[0772] A fine solids stream is processed separately from the coarse solids stream, in part because coarse solids are readily removed and need not be subjected to the processing within the agglomerator. The separator permits separation of a fine solids stream as a top stream that can be removed, while the coarse solids stream is a bottom stream flowing from the separator.

[0773] The coarse solids fraction derived from the separator may be combined with the effluent arising from the agglomerator, as the coarse solids together with the agglomerates will be removed in a later solid-liquid separation step. This would permit recovery of bituminous components that were removed in the coarse solids stream.

[0774] ***Re-combining Coarse Solids with Agglomerated Slurry.*** It is optional in the process to utilize the coarse solids stream derived from the fine/coarse solids separator by re-combining it with the agglomerated slurry prior to separating the low solids bitumen extract from the agglomerated slurry. Alternatively, the coarse solids stream may be processed separately, or added back into the slurry system for iterative processing.

IV.A Solid-Liquid Separation by Fluidizing

[0775] The present section provides a system and a process for separating bitumen extracts from solids.

[0776] A system for separating a bitumen extract from solids may comprise (a) a separator unit configured to receive an oil sands slurry and to separate the solids in the oil sands slurry from the bitumen extract in the oil sands slurry to produce a bitumen extract stream and a solids stream; (b) an accumulator configured to receive the solids stream and configured to remove additional bitumen extract from the solids stream to produce a concentrated solids stream; and (c) a fluidizing unit configured to discharge the concentrated solids stream by mixing the concentrated solids stream with a washing fluid to form a low bitumen oil sands slurry.

[0777] A process for separating a bitumen extract from solids within an oil sands solvent extraction process may comprise (a) receiving an oil sands slurry, wherein the oil sands slurry comprises the bitumen extract and the solids; (b) producing a bitumen extract stream including the bitumen extract and a solids stream including the solids by separating the solids from the bitumen extract; (c) producing a concentrated solids stream by removing additional bitumen extract from the solids stream; and (d) forming a low bitumen oil sands slurry by fluidizing the concentrated solids stream by mixing the concentrated solids stream with a washing fluid.

[0778] Figures 71 to 76 display systems and processes for separating a bitumen extract from solids.

[0779] The system may be a solid-liquid separation system (71-100) (Figure 71). The solid-liquid separation system (71-100) and process (76-600) (Figure 76) may be for separating a bitumen extract (71-110) from solids (71-112). The solid-liquid separation system (71-100) and process may include a bituminous feed (71-102). The bituminous feed (71-102) may be mixed with an extraction liquor (71-104) in an extractor (71-106) to form an oil sand slurry (71-108). Complete or partial bitumen dissolution into the extraction liquor (71-104) occurs in the extractor (71-106). The extractor (71-106) may comprise at least one of a slurry system (not shown), an extraction vessel (not shown), and an agglomerator vessel (not shown).

[0780] The extraction liquor (71-104) may comprise a solvent used to extract bitumen from the bituminous feed (71-102). The extraction liquor (71-104) may comprise a hydrocarbon solvent capable of dissolving the bitumen in the bituminous feed (71-102). The extraction liquor (71-104) may be a solution of a hydrocarbon solvent(s) and bitumen, where the bitumen content of the extraction liquor (71-104) may range between 10 and 70 wt. %, or 10 and 50 wt. %. The bitumen content of the extraction liquor may include any number within or bounded by the preceding ranges. Dissolved bitumen may be within the extraction liquor to increase the volume of the extraction liquor without an increase in the required inventory of hydrocarbon solvent(s). In cases where non-aromatic hydrocarbon solvents are used as the extraction liquor (71-104), the dissolved bitumen within the extraction liquor (71-104) may increase the solubility of the extraction liquor towards dissolving additional bitumen in the bituminous feed (71-102).

[0781] The extraction liquor (71-104) entering the extractor (71-106) may be recycled to the extractor (71-106) from a downstream step. For instance, as described in the present disclosure, solvent recovered in a SRU, may be used to wash agglomerates, and the resulting stream may be used as the extraction liquor (71-104). As a result, the extraction liquor (71-104) may comprise residual bitumen and residual solid fines. The residual bitumen may increases the volume of the extraction liquor. The residual bitumen may increase the solubility of the extraction liquor for additional bitumen dissolution.

[0782] The solid-liquid separation system (71-100) and process (76-600) may include a separator unit (71-114). The separator unit (71-114) may be configured to receive the oil sand slurry (71-108), (76-602). The separator unit (71-114) may be in fluid communication with the extractor (71-106). The separator unit (71-114) may receive the oil sand slurry (71-108) after it exits the extractor (71-106).

[0783] The oil sand slurry (71-108) may be a mixture of the extraction liquor (71-104) and the bituminous feed (71-102). The oil sand slurry may include additional additives besides the extraction liquor (71-104) and the bituminous feed (71-102). The bitumen entrained within the bituminous feed (71-102) may be given an opportunity to become partially or fully extracted into the solvent phase of the extraction liquor (71-104) prior to further processing and solid-liquid separation within the system and process.

[0784] The extraction liquor (71-104) may be added in two distinct stages to the oil sand slurry (71-108). When the extraction liquor (71-104) is added in two distinct stages, the extraction liquor (71-104) may comprise a first extraction liquor and a second extraction liquor. In the first stage, the first extraction liquor may be used to dissolve bitumen within the bituminous feed (71-102). In the second stage, the second extraction liquor may be used to dilute bitumen extract within the oil sand slurry (71-108) to improve solid liquid separation within the system and process. The oil sand slurry (71-108) may be formed within a slurry system that may be at least one of a mix box, a pump, and a cyclonic device.

[0785] The oil sand slurry (71-108) may have a solid content in the range of 5 to 65 wt. %, 20 to 65 wt. %, or 40 to 65 wt. %. The solid content of the resulting oil sand slurry may be any number bounded or included within any of the aforementioned ranges. In the case of a solvent extraction with solids agglomeration process, a higher solids content oil sand slurry (for instance in an upper half of the aforementioned ranges) may be desired to increase the compaction forces that may help in the agglomeration process. A lower solids content oil sand slurry (for instance in a lower half of the aforementioned ranges) may be desired to reduce the energy needed in the oil sand solvent extraction processes for mixing the oil sand slurry. A lower solids content oil sand slurry (for instance in a lower half of the aforementioned ranges) may be desired for solid-liquid separation. The oil sand slurry may have a higher solids content slurry (for instance in an upper half of the aforementioned ranges) for the extraction and agglomeration processes and then may be diluted to a lower solids content slurry (for instance in a lower half of the aforementioned ranges) prior to solid-liquid separation. The diluting fluid may be a portion of the bitumen extract stream from the solid-liquid separation system and process.

[0786] The temperature of the oil sand slurry (71-108) may be in the range of 20-80 °C, inclusively. The temperature of the oil sand slurry (71-108) may be any temperature included within or bounded by the preceding range. An elevated oil sand slurry temperature (for instance 60-80 °C, inclusively) may be desired to increase the bitumen dissolution rate and reduce the viscosity of the slurry to promote more effective sand digestion and agglomerate formation. An elevated slurry temperature may be desired to improve the solid-liquid separation process. An elevated oil sand slurry temperature may result in a reduced slurry viscosity, which in turn, may improve solid-liquid separation. Temperatures above 80 °C are generally avoided due to the complications resulting from high vapor pressures. However, one potential advantage of the process described herein is the ability to operate at higher pressures than conventional solid-liquid separation systems, such as filters.

[0787] The separator unit (71-114) may be configured to separate solids in the oil sand slurry (71-108) from bitumen extract in the oil sand slurry (71-108), (76-604). The separator unit (71-114) may separate the solids from the bitumen extract because the separator unit (71-114) may include solid-liquid separation devices capable of separating solids from liquids so as to separate the solids from the bitumen extract. The separator unit (71-114) may be of the type that it is capable of being incorporated into a single enclosed vessel. Applicable separator units (71-114) include, but are not limited to one or more of at least one of a solid-liquid separator, at least one of a hydrocyclone, at least one of a gravity settler, and at least one of a centrifuge. The separator unit (71-114) may contain a single solid-liquid separator. The separator unit (71-114) may contain more than one solid-liquid separator. When more than one solid-liquid separator and/or separation steps are conducted, it may be said that both steps are conducted within one separator unit (71-114). The separator unit (71-114) produces at least two streams when it separates the solids from the bitumen extract: the bitumen extract stream (71-110) and the solids stream (71-112). The bitumen extract stream (71-110) may have a solids content of less than 15 wt. % solids. For example, the bitumen extract stream (71-110) may have a solids content of less than 5 wt. % solids. The solids content of the bitumen extract stream (71-110) may be any number within the aforementioned ranges.

[0788] If the separator unit (71-114) is a hydrocyclone, the hydrocyclone may comprise hydrocyclones arranged in a configuration suitable to separate the solids stream (71-112) from the bitumen extract stream (71-110). For example, the hydrocyclone may comprise hydrocyclones arranged in parallel to maximize the available throughput through the hydrocyclone unit while maintaining the desired amount of solid-liquid separation. The hydrocyclone may have the advantage of being a compact and a high throughput system that can be readily incorporated into a sealed vessel. The hydrocyclone may not generally have moving parts, thereby reducing the required maintenance of the hydrocyclone.

[0789] If the separator unit (71-114) is the gravity settler, the gravity settler may be a clarifier. The gravity settler may comprise a feed distribution unit that is designed to prevent or mitigate feed solids from contaminating the bitumen extract stream. Suitable feed distribution units are known in the art for instance as described in U.S. Patent Publication 2014/0091049 and International Patent Publication WO 2012/051536. The gravity settler may comprise internals to assist in the settling of solids. Additives and/or solvent may be added prior and/or within the gravity settler to increase the settling rate of solids. Suitable additives may be, but are not limited to, surfactants, flocculants, and coagulants. The solvent may be a paraffinic solvent that is added to precipitates asphaltenes. The solvent may increase the settling rate of solids.

[0790] The system (71-100) and process (76-600) may include an accumulator (71-118). The accumulator (71-118) may be configured to receive the solids stream (71-112). The accumulator (71-118) may receive the solids from the separator unit (71-114) after the solids stream (71-112) exits the separator unit (71-114). The accumulator (71-118) may be in fluid communication with the separator unit (71-114). The separator unit (71-114) may discharge the solids stream (71-112) directly into the accumulator (71-118).

[0791] The accumulator (71-118) may be one of a vertically oriented vessel and a horizontally oriented vessel, with respect to inlet flow directions. A horizontal orientation may provide superior fines removal since the solids settling velocity and superficial fluid velocity are perpendicular rather than countercurrent as in a vertical orientation. A vertical orientation may provide superior solids compaction, which, when combined with a fluidization unit, may reduce the amount of washing fluid required to hydraulically transport the solids and thus increase wash efficiency.

[0792] The accumulator (71-118) may be configured to remove additional bitumen extract (71-119) from the solids stream (71-112) to produce a concentrated solids stream (71-116), (76-606). The accumulator (71-118) may comprise a settling zone (not shown) and a compaction zone (not shown). Within the settling zone, the solids within the solids stream settle. The solids may settle by gravity. The settling zone of the accumulator may be designed such that the solids undergo hindered settling. The settling zone may extend from the separation unit (71-114). In the case where a gravity settler is used as the separator unit (71-114), the settling zone may be an extension of the gravity settler. The compaction zone may compact the solids within the solids stream (71-112). The compaction zone may compact the solids within the solids stream (71-112) to, for example, a solids content of greater than 65 weight (wt.) % such that the concentrated solids stream (71-116) has a solids content of greater than 65 wt. %. The compaction may occur simply by the weight of the solids stream (71-112). The compaction squeezes out fluid (bitumen/solvent mixture) and thus reduces the amount of bitumen entrained in the concentrated solids stream (71-116). Additional bitumen extract from the settling and compaction zones of the accumulator (71-118) may be discharged in one or more discharge ports (not shown) located in upper regions of the accumulator.

[0793] When the solids within the solids stream (71-112) compact, additional bitumen extract (71-119) may be separated out from the solids stream (71-112) such that the solids stream (71-112) separates into the additional bitumen extract (71-119) and the concentrated solids stream (71-116). The additional bitumen extract (71-119) may percolate as the solids stream (71-112) is compacted. After the additional bitumen extract (71-119) percolates upwards, the additional bitumen extract (71-119) may exit the accumulator (71-118). The additional bitumen extract (71-119) may be removed from an upper region of the accumulator (71-118). A screen (not shown) or filter (not shown) may be placed near outlet ports (not shown) of the accumulator (71-118) to prevent or mitigate at least some of the solids stream (71-112) from exiting the accumulator (71-118) when the additional bitumen extract (71-119) exits the accumulator (71-118). The additional bitumen extract (71-119) may pass through the screen or filter before being removed from the accumulator (71-118). The screen or filter may be constructed, such as but not limited to the size of the openings of the screen or filter, to prevent or mitigate at least some of the solids stream (71-112) from exiting the accumulator (71-118) when the additional bitumen extract (71-119) exits the accumulator (71-118).

[0794] The accumulator (71-118) may comprise internal structures, such as baffles, to assist in the movement of solids within the accumulator. In the case of a single vessel system, the accumulator may be located directly below the separator unit (71-114) in order to directly receive the solid stream (71-112) from the separator unit (71-114). The accumulator (71-118) may comprise the majority of the size of the single vessel in order to provide the required bed height and residence time for the desired compaction of the solids.

[0795] After exiting the accumulator (71-118), the additional bitumen extract (71-119) may be combined with the bitumen extract stream (71-110). The additional bitumen extract (71-119) may be combined with the bitumen extract stream (71-110) because the accumulator

(71-118) may be in fluid communication with a line connecting the separator unit (71-114) to a SRU (71-134).

[0796] The system (71-100) and process (76-600) may include a fluidizing unit (71-122). The fluidizing unit (71-122) may receive the concentrated solids stream (71-116) from the accumulator (71-118) when the concentrated solids stream (71-116) exits the accumulator (71-118). The fluidizing unit (71-122) may receive the concentrated solids stream (71-116) because the accumulator (71-118) may be in fluid communication with the fluidizing unit (71-122). The fluidizing unit (71-122) may be one of directly below a compaction zone of the accumulator (71-118) and within the compaction zone of the accumulator (71-118). The compaction zone is illustrated in Figures 72 and 73.

[0797] The fluidizing unit (71-122) may be configured to discharge the concentrated solids stream (71-116). The fluidizing unit (71-122) may be used to discharge the concentrated solids stream (71-116) from the accumulator (71-118) in a controlled fashion. The fluidizing unit (71-122) may direct a washing fluid (71-120) at a pressure to the concentrated solids stream (71-116). The pressure may be about 8-10 psi above an operating pressure of the accumulator (71-118) and may be achieved using a pump. The fluidizing unit (71-122) and the washing fluid (71-120) may act to fluidize the concentrated solids stream (71-116) to produce a low bitumen extract slurry (71-124) that is discharged from the fluidizing unit (71-122). The fluidizing unit (71-122) may be sufficiently isolated from the settling zone of the accumulator (71-118) so as to prevent or mitigate mixing of the washing fluid (71-120) with the additional bitumen extract stream (71-119) that flows out of the accumulator (71-118). The low bitumen extract slurry (71-124) may be discharged with less than 20 wt. % of the bitumen that was dissolved within the oil sand slurry (71-108). The bitumen amount within the low bitumen extract slurry (71-124) may be any number bounded by or within the aforementioned range.

[0798] The washing fluid (71-120) may have a lower dissolved bitumen concentration than the bitumen extract stream (71-119). For example, the washing fluid (71-120) may be a solvent that is used to dilute the bitumen concentration within the concentrated solids stream (71-116). The washing fluid (71-120) may be a hydrocarbon liquid with a dissolved bitumen concentration lower than a dissolved bitumen concentration of the oil sand slurry (71-108). The washing fluid (71-120) may have the characteristics of the solvent as described in the present disclosure. The washing fluid (71-120) may displace and/or further extract/dissolve bitumen out of agglomerates. A low boiling point (as described herein with reference to the solvent) of the washing fluid allows a lower energy consumption and/or substantial dissolving of asphaltenes.

[0799] In general, for better reliability, the fewer the moving parts in the fluidizing unit (71-122) the better. Suitable fluidizing units include, but are not limited to, one of an eductor, ejector, jet pump, Tore® from Merpro Process Systems (National Oilwell Varco, Houston, Texas, USA), and gRay® from FLSmidth gMAX Systems (Houston, Texas, USA). The fluidizing unit (71-122) may use the washing fluid as a motive fluid to fluidize solids and create a vortex to evacuate solids. In particular, the washing fluid may be introduced tangentially under pressure into a chamber of the fluidizing unit via a supply duct creating a vortex in the chamber. The vortex may fluidize the solids and force the solids out of the chamber via a discharge duct. An end of the supply duct may be closed when the fluidizing unit is not in use. The fluidizing unit (71-122) may be directly incorporated below the compaction zone of the accumulator (71-118). In this way, the accumulator (71-118) and the fluidizing unit (71-122) may be within a single vessel. The operational parameters of the fluidizing unit (71-122) may be adjusted to control a density of low bitumen extract slurry (71-124).

[0800] The (71-100) and process (76-600) may include a TSRU (71-128). The TSRU (71-128) may receive the low bitumen extract slurry (71-124) from the fluidizing unit (71-122). The TSRU (71-128) may be in fluid communication with the fluidizing unit (71-122). The TSRU (71-128) may separate solvent (71-126) from a low bitumen oil sand slurry (71-130) within the low bitumen extract slurry (71-124) to output solvent (71-126) and a low bitumen oil sand slurry (71-130), (76-608). The low bitumen oil sand slurry (71-130) may be considered a tailings stream from which one may choose to recover no further bitumen.

[0801] The system (71-100) and process (76-600) may include a SRU (71-134). The SRU (71-134) may be in fluid communication with the accumulator (71-118). The SRU (71-134) may be in fluid communication with the separator unit (71-114). The SRU (71-134) may receive the bitumen extract (71-110) and the additional bitumen extract (71-119). The SRU

(71-134) may separate out solvent in the bitumen extract (71-110) and the additional bitumen extract (71-119) from bitumen product (71-136) in the bitumen extract (71-110) and the additional bitumen extract (71-119). The SRU (71-134) may output solvent (71-132) and bitumen product (71-136) after the separation.

[0802] The system may be referred to as an oil sand solvent extraction process. The system may be combined with aspects of other oil sand solvent extraction processes, including but not limited to, those described herein.

[0803] The use of the pipeline for the solvent extraction with solids agglomeration process described herein may allow for an overall solvent extraction facility with an improved integration of the pipeline if used with the solid-liquid separation system (71-100) described in this section.

[0804] The agglomeration of the solids may improve the system (71-100) or process (76-600) described in the present section. For example, the agglomeration of the solids stream (71-112) may reduce the amount of solids remaining in the bitumen extract stream (71-110) downstream of the separator unit (71-114). The larger particle sizes resulting from the agglomeration of the solids may allow for a higher rate of solid-liquid separation in the separator unit (71-114) than without agglomeration of the solids stream (71-112). The aqueous bridging liquid within the agglomerates may displace the additional bitumen extract (71-119) during compaction within the accumulator (71-118). The displacement may allow the concentrated solids stream (71-116) to have less bitumen extract trapped within the concentrated solids stream (71-116), compared to a case where no aqueous bridging liquid is used. The aqueous bridging liquid may lubricate the concentrated solids stream (71-116) to lower the amount of fluid pressure needed by the fluidizing unit (71-122) to discharge the concentrated solids stream (71-116) from the accumulator (71-118).

[0805] The separator unit (71-114), the accumulator (71-118), and the fluidizing unit (71-122) may be disposed within, or form part of, a single vessel. The separator unit (71-114), the accumulator (71-118) and the fluidizing unit (71-122) may be isolated from a surrounding environment. The separator unit (71-114), the accumulator (71-118), and the fluidizing unit (71-122) may be referred to as a single solid-liquid separation step that produces a low solids bitumen extract stream and a low bitumen oil sand slurry. The system (71-100) and process (76-600) may employ a single solid-liquid separation step or may employ more than one solid-liquid separation steps. When more than one solid-liquid separation steps is employed, all of the steps may be conducted within one solid-liquid separation system. If the steps are dissimilar, or not proximal to each other, it may be said that a primary solid-liquid separation system is employed together with additional solid-liquid separation systems. For example, when primary and secondary separation systems are both employed, the primary separation system may separate a solid stream from the bitumen extract stream, while the secondary solid-liquid separation system may wash the solids to remove residual bitumen within, using a fluidizing unit (71-122).

[0806] As a component of the solid-liquid separation system, secondary separation steps may be introduced for counter-currently washing the solids separated from the oil sand slurry. The initial separation of the solids may be said to occur in a primary solid-liquid separation system, while the secondary steps may occur within the primary separation system, or may be conducted separately in a secondary solid-liquid separation system. The secondary solid-liquid separation system may be the same or different from the solid-liquid separation system described in the present disclosure. By “counter-currently washing”, it is meant that a progressively cleaner solvent may be used to wash bitumen from the solids. Solvent involved in the final wash of solids may be re-used for one or more upstream washes of solids, so that the more bitumen entrained with the solids, the less clean the solvent will be that is used to wash the solids at that stage. In this way, the cleanest wash of solids is conducted using the cleanest solvent. An example of counter-current washing is described with reference to Figure 74.

[0807] The additional solid-liquid separation steps for counter-currently washing solids may be included within the primary solid-liquid separation system. The additional solid-liquid separation steps may use a combination of separator units, accumulators, and fluidizing units similar to the primary solid-liquid step. The additional solid-liquid steps may be separate from the primary solid-liquid separation system. The additional solid-liquid separation systems may be the same or different from the primary separation system. Different solid-liquid separation systems include at least one of gravity separators, cyclone, screens, and filters.

[0808] The solvent used for washing the solids may be solvent recovered from the low solids bitumen extract. A second solvent may alternatively or additionally be used for additional bitumen extraction downstream of an oil sand solvent extraction process.

[0809] Figures 72 to 75 illustrate particular system configurations by way of example.

[0810] Figure 72 is a schematic of a single vessel solid-liquid separation system with hydrocyclones as the separator unit. An oil sand slurry (72-202) is introduced into a series of hydrocyclones (72-204) arranged in parallel. Bitumen extract stream (72-206) is removed from the top of the hydrocyclones (72-204). Solids (72-208) settle in a settling zone (72-210) of the accumulator (72-210 and 72-218). The settling zone (72-210) comprises baffles (72-214). The additional bitumen extract stream (72-212) exits through a screen (72-216) and is combined with the bitumen extract stream (72-206). The solids (72-208) compact in a compaction zone (72-218) of the accumulator (72-210 and 72-218). A washing fluid (72-220) is introduced into a fluidizing unit (72-222) to produce a low bitumen oil sand slurry (72-224).

[0811] Figure 73 is a schematic of a single vessel solid-liquid separation system with a gravity separator as the separator unit. An oil sand slurry (73-302) is introduced into a gravity separator (73-304b). Bitumen extract stream (73-306) is removed from the gravity separator (73-304b). The gravity separator (73-304b) comprises a baffle (73-314b). Solids (73-308) settle in a settling zone (73-310) of the accumulator (73-310 and 73-318). The solids (73-308) compact in a compaction zone (73-318) of the accumulator (73-310 and 73-318). A washing fluid (73-320) is introduced into a fluidizing unit (73-322) to produce a low bitumen oil sand slurry (73-324).

[0812] Figure 74 is a schematic of a multi-stage solid-liquid separation system with wash stages and four solid-liquid separation systems in series, namely, a first solid-liquid separation system (74-426a), a second solid-liquid separation system (74-426b), a third solid-liquid separation system (7-426c), and a fourth solid liquid separation system (74-426d). The first, second, and third solid-liquid separation systems (74-426a, 74-426b, and 74-426c) include first, second, and third, fluidizing units (74-422a, 74-422b, and 74-422c), respectively. An oil sand slurry (74-402) is introduced into the first solid-liquid separation system (74-426a). A washing fluid (74-420) is introduced into a third fluidizing unit (74-422c) of the third solid-liquid separation system (74-426c). First and second bitumen extract steams (74-406a and 74-406b) are removed from the first and second solid-liquid separation systems (74-426a and 74-426b), respectively. Third and fourth bitumen extract stream (74-406c and 74-406d) are recycled to the first and second solid-liquid separation systems (74-426a and 74-426b), respectively, as washing fluid. Solid streams (74-428a, 74-428b, and 74-428c) are directed downstream from the first to the fourth solid-liquid separation systems (74-426a and 74-426d). A low bitumen oil sand slurry (74-424) is removed from the fourth solid-liquid separation system (74-426d). In this way, a progressively cleaner solvent is used to wash bitumen from progressively cleaner solids. Therefore, the washing fluid may comprise a downstream bitumen extract stream from a downstream process to counter-currently wash the solids.

[0813] Figure 75 is a schematic of a system for processing a bituminous feed comprising a slurry system, pipeline agglomeration, solid-liquid separation, and SRUs. A bituminous feed (75-502) is combined with a solvent (75-504) in a mix-box (75-506) producing an oil sand slurry (75-508). The oil sand slurry (75-508) is transported in a pipeline (75-510) having an extraction zone (75-512) and an agglomeration zone (75-514). The entry of the agglomeration zone is defined by the location where at least a portion of an aqueous bridging liquid is first injected. The agglomerated slurry (75-516) exits the pipeline (75-510) and is introduced into a series of solid-liquid separation systems (75-530) as previously described with respect to Figure 74. The second bitumen extract stream (75-516b) is added to the oil sand slurry (75-508) transported in the pipeline (75-510). Solvent (75-534), recovered from the first bitumen extract stream (75-516a) in a SRU (75-536) to make a bitumen product stream (75-538), is recycled for use as solvent (75-504) and washing fluid (75-532). A low bitumen slurry (75-540) is removed from the fourth solid-liquid separation system (75-542). Solvent is removed from the low bitumen slurry (75-540) in a TSRU (75-544) to produce dry solids (75-546).

[0814] The performance of the single vessel solid-liquid separation system at least partially depends on the highest achievable solids content of the fluidizing unit discharge. The higher the solids content, the less the bitumen is entrained in the low bitumen oil sand slurry. The solids content of the fluidizing unit discharge is at least partially controlled by a combination of the degree of compaction of the solids and the fluidization effectiveness of the fluidizing unit. It may be desirable to size the accumulator to provide a sufficient bed height to achieve a desired compaction of the solids. By increasing the efficiency of the fluidizing unit, one can reduce the amount of washing fluid required to hydraulically transport the solids. The performance or overall wash efficiency of the multi-stage solid-liquid separation system depends on the performance of each solid-liquid separation system and the number of solid-liquid separation systems.

[0815] As described above, the separator unit, accumulator, and the fluidizing unit may be within, or form part of, a single vessel. A single vessel system may have advantages over other systems, such as a multi-vessel system. The compact nature of the single vessel system may allow for effective sealing of the system from the environment, the ability to handle much higher pressures and/or higher temperatures, and effective heat insulation to limit heat loss than that of other systems. The fluidizing unit may provide high shear mixing, which may result in improved dispersion and/or mass transfer to scrub bitumen off the solids. The single vessel system may be made to have few or no moving parts and therefore may provide improved operability and/or easier maintenance than other solid-liquid separation systems. The single vessel system may have a lower energy consumption compared to energy-intensive solid-liquid separation systems such as vacuum filters. The single vessel system may be more readily scaled to a size suitable to handle the large solid flow rates found in oil sand processing.

[0816] The separator unit, accumulator, and the fluidizing unit system described herein may be followed by a filter for further solid-liquid separation. More preferably, the separator unit, accumulator, and fluidizing unit system may be followed by a filter which uses heated gas to evaporate solvent from the solids and produce solvent dry tailings suitable for disposal to the environment. It is preferred that the heated gas is a condensable gas such as solvent vapor or steam. Further description of the condensable gas is provided below in the discussion of the filter.

IV.B Solid-Liquid Separation by Filtering

[0817] The present section provides methods of filtering an oil sand slurry.

[0818] A method of filtering an oil sand slurry from a solvent based extraction process may include depositing the oil sand slurry onto a filter of a sealed vacuum filter system; utilizing a vacuum to separate a rich bitumen filtrate from the oil sand slurry to form a filter cake on the filter; washing at least a portion of the filter cake with a washing fluid, the washing fluid being the same or different from the solvent; and drying the filter cake with condensable vapor.

[0819] By way of background, slurries in certain industries are sometimes filtered using vacuum filtration. For instance, Figure 77 illustrates a horizontal vacuum belt filter (HVF) manufactured by Komline-Sanderson Engineering Corporation (Peapack, NJ). The vacuum belt filter is top fed and can perform filtration, washing, and drying in one machine. Slurry is fed continuously and forms a filter cake, which can then be washed as it is progressively indexed through discrete zones. The process of the HVF is continuous. The filter cloth moves forward through cake formation, cake washing, dewatering or drying, and cake discharge. Using this HVF, a filtration method may comprise the following steps:

[0820] Feed slurry (77-102) is deposited continuously onto a cloth (77-104) acting as a filter media on a moving belt filter.

[0821] A vacuum applied using a liquid ring vacuum pump or other means (77-106) draws liquid through the cloth (77-104) which retains solids to form a filter cake (77-108).

[0822] The filter cake (77-108) can be washed with a cake wash liquor (77-110) in multiple stages to remove impurities or to extract more product. Additional drying of the cake (77-108) follows washing.

[0823] The vacuum pulls air (or gas) through the filter cake (77-108) and continues to remove liquid and moisture as the cloth (77-104) moves forward.

[0824] Finally, the cake (77-108) is discharged from the end of the belt to a conveyor or chute to the next process step.

[0825] The filtrate (77-112) and air (or gas) pulled through the cloth (77-104) flow through a control valve and into the filtrate receiver (77-114).

[0826] Liquid filtrate (77-116) is separated from the vapor stream (77-118) in each filtrate receiver (77-114).

[0827] The liquid filtrate (77-116) is then pumped to the next step in the process using a filtrate pump (77-120).

[0828] Most vacuum filtration systems are not sealed and use ambient air to displace fluid in the filter cake. Some systems (such as described in U.S. Patents Nos. 3,744,543 and 3,672,067) have an atmospheric steam hood to direct steam to the filter cake. In such systems, a filter cake is dried on a rotary drum or a disc type vacuum filter provided with a steam dome or hood. During at least a portion of the drying cycle, steam is passed through the filter cake and condensation of the steam within the filter cake releases heat to lower the viscosity of the water in the filter cake. The steam performs several functions: heating the filter cake and interstitial fluid for viscosity reduction to allow faster drainage, as well as providing a dryer final filter cake. Steam consumption is reduced by limiting the quantity of live steam breaking through the filter cake to the vacuum side. Additional drying is accomplished by moving air through the filter cake prior to discharge.

[0829] Because most vacuum filtration systems are open to the atmosphere, and use air as the displacing agent, a vacuum is created using blowers, compressors, and vacuum pumps. For a large scale production such as oil sand mining applications, both machinery size and the power that would be required to generate the necessary vacuum would be very large.

[0830] Figures 78 to 81 show methods and systems according to the present disclosure. The methods and systems may include a sealed vacuum filter system for removing solids from an oil sand slurry (78-202) comprising bitumen, solvent, and solids. The oil sand slurry may come from a solvent based extraction process.

[0831] To extract bitumen from oil sand using a solvent based extraction process, a solvent based extraction process solvent may be combined with a bituminous feed. The solvent and bituminous feed may be combined in any suitable mechanism. For example, the solvent based extraction process solvent and bituminous feed may be combined in an extractor to form an oil sand slurry. Complete or partial bitumen dissolution into the solvent based extraction process solvent may occur in the extractor. The extractor may comprise at least one of a slurry system and an extraction vessel.

[0832] The solvent based extraction process may be adjusted to render the ratio of the solvent to bitumen in the oil sand slurry (78-202) at a level that avoids or limits precipitation of asphaltenes during the solvent based extraction process. Some amount of asphaltene precipitation may be unavoidable, but by adjusting the amount of solvent based extraction process solvent flowing into a system, with respect to the expected amount of bitumen in the bituminous feed, when taken together with the amount of bitumen that may be entrained in the solvent based extraction process solvent used, can permit the control of a ratio of solvent to bitumen in the extractor. When the solvent based extraction process solvent is assessed for a target ratio of solvent to bitumen during downstream agglomeration, the precipitation of asphaltenes may be minimized or avoided beyond an unavoidable amount; costs of the oil sand solvent based extraction process may be decreased due to reduced total solvent usage when having a target ratio.

[0833] The oil sand slurry (78-202) may have a solid content in the range of 5 to 70 wt. %, 20 to 70 wt. %, or 40 to 70 wt. % based upon total weight of the slurry. The oil sand slurry (78-202) may have a solid content of greater than 70 wt. %. The solid content within the oil sand slurry may be any number within or bounded by the preceding ranges.

[0834] The temperature of the oil sand slurry (78-202) may be in the range of 20-80 °C, inclusively. An elevated oil sand slurry temperature may be desired to increase the bitumen dissolution rate and reduce the viscosity of the slurry to promote more effective sand digestion and agglomerate formation. An elevated slurry temperature may be any temperature within or bounded by the range of 60-80 °C or 30-50 °C, inclusive. An elevated slurry temperature may be desired to improve the solid-liquid separation process. An elevated oil sand slurry temperature may result in a reduced slurry viscosity, which in turn, may improve solid-liquid separation. Temperatures above 80 °C may be avoided due to the complications resulting from high vapor pressures of low boiling point solvents.

[0835] As described below with reference to Figure 79, the oil sand slurry (78-202) may be agglomerated prior to introduction into a sealed vacuum filter system.

[0836] Using a low boiling point solvent instead of water for a solvent based extraction process may require, for safety reasons, that the oil sand slurry comprising the solvent be sealed in an inert environment. The low boiling point solvent may interchangeably be referred to as a volatile solvent. To avoid a flammable situation, at least some oxygen may be removed from the inert environment. To avoid a flammable situation, at least some solvent vapor may be contained and not let out to the atmosphere. To contain solvent vapor, a vacuum filter system may be placed into a containment vessel. In unsealed vacuum filter systems, mechanical power may be used to reduce pressure through fans, blowers, or vacuum pumps. A unique aspect of integrating a sealed filter system into a solvent based extraction process is the use of solvent vapor in the drying step rather than air or other non-condensable gas such as nitrogen or carbon dioxide. The solvent may have a boiling point of 30 to 90 °C.

[0837] Choosing a low boiling point solvent may permit a low or near atmospheric pressure environment above a filter cake, which may enable low cost pressure containment. The filter cake may be part of a sealed vacuum filter system. Choosing a low boiling point solvent may provide the ability to change how a vacuum beneath the filter is created. Since the sealed vacuum filter system is sealed, with the gas space full of solvent vapor, creating and maintaining a vacuum requires less vacuum power than an unsealed vacuum filter system. Since the sealed vacuum filter system is sealed, with the gas space full of condensable vapor, creating and maintaining a vacuum requires less vacuum power than if an inert gas is present in gas-space above the filter cake. A vacuum generating device, such as a small vacuum pump, may be used to remove non-condensable gases from a sealed vacuum filter system, to establish a vacuum. The vacuum may be maintained by a combination of condensing vapor and removing non-condensable gases from the sealed vacuum filter system. The vacuum may create a pressure difference across the filter cake, thereby transporting a rich bitumen filtrate (described below) and a lean bitumen filtrate (described below) through a filter (described below).

[0838] A method of filtering an oil sand slurry from a solvent based extraction process may include depositing the oil sand slurry onto a filter of a sealed vacuum filter system; utilizing a vacuum to separate a rich bitumen filtrate from the oil sand slurry to form a filter cake on the filter; washing at least a portion of the filter cake with a washing fluid, the washing fluid being the same or different from the solvent; and drying the filter cake with a solvent vapor. A condensable vapor may be a solvent vapor, a steam or a combination thereof.

[0839] With reference to Figures 78 and 80, the methods and systems may include depositing the oil sand slurry (78-202) onto a filter (78-204), (80-402). The filter (78-204) may be part of the sealed vacuum filter system. The filter (78-204) may include a filter media. The filter (78-204) may be any suitable filter. For example, the filter (78-204) may be a moving filter. The filter (78-204) may be a belt filter. The filter (78-204) may be a rotary pan filter. The filter (78-204) may a vibrating screen, a stationary screen or a spiral classifier.

[0840] The methods and systems may comprise utilizing a vacuum to separate a rich bitumen filtrate (78-206) from the oil sand slurry (78-202) to form a filter cake on the filter (78-204), (80-404). The rich bitumen filtrate (78-206) may be separated from the oil sand slurry (78-202) by going through the filter (78-204) into a liquid receiver (78-208).

[0841] The method and system may comprise washing at least a portion of the filter cake with a washing fluid (78-211), (80-406). The filter cake may be washed in a washing stage (78-210). The washing fluid (78-211) may be a clean solvent (78-211). The clean solvent (78-211) may be the same solvent or a different solvent from the solvent within the oil sand slurry. After removing residual liquid from the filter cake, the washing fluid (78-225) that has passed through the filter cake may be composed of both bitumen and solvent.

[0842] The method and system may comprise removing residual bitumen loaded washing fluid (78-225) from the washing stage (78-210). The method and system may comprise removing the residual bitumen loaded washing fluid (78-225) to a wash receiver (78-227).

[0843] The method and system may comprise separating a lean bitumen filtrate (78-214) from the oil sand slurry (78-202) to form additional filter cake on the filter (78-204). The additional filter cake may be referred to interchangeably as filter cake. The lean bitumen filtrate (78-214) may be separated from the oil sand slurry (78-202) by going through the filter (78-204) into a liquid receiver (78-216).

[0844] The rich bitumen filtrate (78-206) and the lean bitumen filtrate (78-214) may comprise bitumen extracted from the oil sand slurry (78-202). The rich bitumen filtrate (78-206) may have a same or a similar solvent composition as liquid in the oil sand slurry (78-202). The rich bitumen filtrate (78-206) may have up to two orders of magnitude lower solids content than the oil sand slurry (78-202). The lean bitumen filtrate (78-214) may comprise a higher percentage of solvent than the oil sand slurry (78-202). The rich bitumen filtrate (78-206) may have a higher bitumen content than the lean bitumen filtrate (78-214).

[0845] The method and system may comprise forming a bitumen product by removing the solvent from the rich bitumen filtrate and/or the lean bitumen filtrate. The solvent may be removed from the rich bitumen filtrate and/or the lean bitumen filtrate using a SRU. The SRU may be any suitable SRU. For example, the SRU may be a fractionation tower or a distillation unit.

[0846] The method and system may comprise washing the additional filter cake with the residual bitumen loaded wash fluid (78-259). The residual bitumen loaded wash fluid (78-259) may be the same fluid as the residual bitumen loaded wash fluid (78-225), but it may be accessed from a collection point. The residual bitumen loaded wash fluid (78-259) may be from a wash receiver (78-227). The residual bitumen loaded wash fluid (78-259) may wash the additional filter cake in additional washing stages (78-212) in a counter current manner. The methods and systems may comprise drying the filter cake with a condensable vapor (78-219). The drying may include supplying the condensable vapor at a pressure greater than a pressure of the sealed vacuum system. The filter cake may be dried in a drying stage (78-218), (80-408). During the drying stage (78-218), solids that remain on the filter (78-204) may be dried using condensable vapor (78-219) to displace additional liquid and further dry the filter cake (78-221). The condensable vapor (78-219) may be supplied at a positive pressure above the filter cake (78-221). Supplying the condensable vapor (78-219) at a positive pressure above the filter cake (78-221) may assist filtrate flow. A potential benefit of using condensable vapor to displace remaining liquid or as the drying media is the possibility of condensing the vapor onto the filter cake. Further drying the filter cake may provide higher wash efficiency and/or a higher temperature cake to a filter cake desolventizer stage. The condensable vapor may condense on the filter cake when it interacts with the filter cake to perform additional filter cake washing and/or to heat the filter cake.

[0847] The condensable vapor (78-219) may stem from various sources, such as from a solvent source (78-230). The solvent source (78-230) may be from bitumen product cleaning (not shown), a SRU (78-238) that separates bitumen (78-240) from a bitumen and solvent feed (78-242), or a stand-alone solvent vapor generator (not shown). Solvent vapor from the SRU (78-238) of vapor generator may be present in a superheated form, at much higher temperatures than the filter cake. For instance, the filter cake may be at approximately 40 °C while the condensable vapor from the bitumen-solvent SRU could be approximately 185 °C if emanating from a flash drum, or have an approximate temperature of 85 °C if the condensable vapor is from a stripping column. These temperatures are supplied as examples only, and would vary with different solvents and SRU designs. The level of superheat may be adjusted to change the quantity of condensable vapor condensed on the filter cake. It may be preferable to have the temperature of the condensable vapor be greater than 50 °C higher than the normal boiling point of the solvent saturated in the agglomerates in order to sufficiently dry said agglomerates of the solvent. The condensable vapor may be at a temperature to sufficiently heat the filter cake such that the vapor pressure of the solvent saturating the filter cake is greater than 100 kPa, or greater than 200 kPa, or greater than 300 kPa above the operating pressure of the operating pressure of the desolventizing process. The rate and amount of solvent removal from agglomerates may vary with the vapor pressure of the saturating solvent. As the condensable vapor provides heat into the agglomerate structure, a higher solvent vapor pressure may be advantageous to allow solvent to migrate to the external surface of the agglomerate where it can be easily removed. As an example for the situation where washed agglomerates are exposed to a 100 kPaa operating pressure; heating the agglomerates to 100 °C would cause a vapor pressure of about 173 kPaa for cyclohexane, giving a net driving force of 73 kPa to move solvent from the interior of the agglomerate to the exterior. Lower boiling point solvents, such as cyclopentane, exhibit higher vapor pressures at the same temperature. It has also been found that the azeotropic vapor pressure for a water-solvent mixture could be higher than for a pure solvent. Accordingly, the temperature of the condensable vapor may be selected to provide the necessary solvent vapor pressure to promote drying of the agglomerates. Table 1 provides the vapor pressure of several saturating solvent mixtures at 100 °C.

Table 1

	cC5 100 wt%	cC6 100 wt%	cC5:cC6 50/50 wt%	cC5_H2O azeotrope	cC6_H2O azeotrope	cC5_cC6_H2O 50/50 HC wt% azeotrope
P_{vap} @ 100°C (kPaa)	418	173	304	524	277	409
P_{vap} @ 100 °C - Patm (kPa)	318	73	204	424	177	309

[0848] The condensable vapor may be a different composition from the solvent in the oil sand slurry. The condensable vapor may be a different composition from the solvent in the washing fluid. The condensable vapor may comprise steam. Steam may be introduced in a steam hood, or in combination with the condensable vapor to increase the overall vapor temperature. The condensable vapor accessed from the SRU steam stripping column may contain steam (water vapor). The condensable vapor comprising solvent vapor and steam results in a superheated steam vapor due to the resulting change in partial pressure. The amount of steam condensation on the filter cake may be modified by adjusting the composition of the steam/solvent vapor mixture. Steam may be supplied in series after the solvent vapor. Steam alone may be considered a condensable vapor. Steam may help to dry the filter cake. The steam may dry the filter cake to form a filter cake having a solvent content of less than 1000 ppmw.

[0849] The methods and systems may comprise establishing a vacuum with a vacuum generating device. The methods and systems may comprise maintaining the vacuum by a combination of condensing the condensable vapor and removing non-condensable gases from the sealed vacuum filter system. The vacuum generating device may be any suitable device. For example, the vacuum generating device may comprise a vacuum pump (78-220), an ejector, a blower or a compressor.

[0850] The vacuum may create a pressure difference across the filter cake, thereby transporting the rich bitumen filtrate (78-206) and the lean bitumen filtrate (78-214) through the filter (78-204).

[0851] A condenser (78-226) may be used to maintain the vacuum by controlling the condensable vapor condensing temperature. For instance, a vapor space in the liquid receivers (78-208 and 78-216), wash receiver (78-227) and condensable vapor from the drying stage (78-218) may be connected via a vacuum line (78-223) ultimately to a condenser (78-226) which may set a vacuum level by controlling the condensable vapor condensing temperature. Valves (78-241, 78-243, and 78-245) connected to liquid and wash receivers (78-208, 78-216, and 78-227, respectively) allow for each receiver to operate at a different vacuum level. Condensable vapor in the vacuum line (78-223) and condensable vapor (78-247) from the drying stage (78-218) may be sent to a liquid knock out vessel (78-249) to knock out liquid

(78-251) and send condensable vapor (78-253) to the condenser (78-226) to produce a condensed vapor. The solvent in the vacuum line (78-223) and/or from the drying stage (78-218) may be the same solvent in the oil sand slurry. The liquid knock out vessel (78-249) collects liquid that may have condensed in the vacuum line (78-223) or is present in the solvent (78-247) from the drying stage. Vapor from the liquid knock out vessel (78-249) may be substantially liquid free, enhancing condenser performance (78-226).

[0852] Maintaining the vacuum by condensing the condensable vapor may comprise continuously removing non-condensable gases (78-224) from the sealed vacuum filter system. Non-condensable gases present after the condensing stage are removed by the vacuum generating device and sent to other process steps as described below.

[0853] The method and system may comprise controlling vacuum pressure of the vacuum. The vacuum pressure of the vacuum may be controlled by controlling a condensing temperature of the condensable vapor. The vacuum pressure of the vacuum may be controlled by changing a flow rate of a cooling medium or a temperature of the cooling medium introduced into the condenser (78-226). The condensing temperature of the condensable vapor (78-263) can be measured by a temperature sensing device (78-260). The temperature sensing device (78-260) may be used to control the flow rate of cold liquid (78-261) entering the condenser (78-226) by adjusting a flow control valve (78-262). The cold liquid (78-261) may exit the condenser (78-226) as warmed liquid (78-264). The temperature sensing device (78-260) may control a temperature of a cooling media that is used in the condenser (78-226).

[0854] The condensable vapor (78-263) condensed in the condenser (78-226) may enter a separator (78-228). The separator (78-228) may separate the solvent vapor (78-263) into a condensed vapor (78-244) and non-condensable gas (78-224). The condensed vapor (78-244) may exit the separator (78-228). The condensed vapor (78-244) may exit the separator (78-228) through a bottom of the separator (78-228). After exiting the separator (78-228), the condensed vapor (78-244) may travel to a recovered condensed vapor tank (78-234). The condensed vapor (78-244) that travels to the recovered condensed vapor tank (78-234) may be used as the washing fluid (78-211) in the washing stage (78-210). The condensed vapor (78-244) that travels to the recovered condensed vapor tank (78-234) may be used in dissolution or dilution

(78-213) upstream in oil sand processing for producing the oil sand slurry (78-202). The non-condensable gas (78-224) may exit the separator (78-228). The non-condensable gases (78-224) may be exit the separator (78-228) from a top of the separator (78-228). The vacuum generating device (78-220) may assist in helping remove the non-condensable gas (78-224) from the separator (78-228). The non-condensable gas (78-224) may travel to other process steps. For example, the non-condensable gas (78-224) may travel as an overhead system in the drying stage (78-218).

[0855] The methods and systems may comprise processing liquid (78-255, 78-257, 78-259, and 78-251) from the liquid receivers (78-208 and 78-216), wash receiver (78-227) and liquid knock out vessel (78-249), respectively, to, for example, recover bitumen and solvent. As dictated by the mass balance requirements of an incoming bituminous ore and desired solvent to bitumen ratio, certain quantities of lean extract (78-257) and rich extract (78-255) may be recycled to produce the slurry (78-202). Other amounts of rich extract (78-255) and lean extract (78-257) may be sent to the solvent feed (78-242) to produce bitumen and clean solvent for recycling. Wash liquid (78-259) may be sent to additional wash stages (78-212), or combined with the lean extract (78-257). Liquid (78-251) from the liquid knock out vessel (78-249) may be used as wash liquid (78-259). Liquid (78-251) from the liquid knock out vessel (78-249) may be used as wash liquid (78-259) or may be combined with the lean extract (78-257).

[0856] The methods and systems may include a sealed vacuum filter system integrated with a solvent based extraction process (Figures 79 and 81). The sealed vacuum system may have similar and/or analogous features to the description of Figure 78. Bituminous ore (79-300) from a mine may be conditioned for use (79-301), for instance, by crushing to an appropriate maximum size. An appropriate maximum size may be, for instance, 600 mm or 100 mm. Conditioned ore (79-311) may be sent to a surge bin or stockpile (79-302) and may then be fed into an inerting system (79-303). The inerting system (79-303) may act as a boundary between general purpose and electrically classified zones. The inerting system (79-303) may have two main purposes: to remove sufficient oxygen through a venting stream (79-325) to prevent flammable mixtures from occurring; and to admit ore into the extraction process while preventing solvent vapor from escaping to the atmosphere.

[0857] The methods and systems may comprise combining an inerted ore (also referred to herein as a bituminous feed) (79-312) with a solvent (79-313) to form an initial oil sand slurry (79-314). The bituminous feed (79-312) and the solvent (79-313) may be combined in an ablation/dissolution drum (79-304). The ablation/dissolution drum (79-304) may break down lumps and expose pore spaces to the solvent (79-313) to achieve greater dissolution of the bitumen contained in the bituminous feed (79-312). The initial oil sand slurry (79-314) may exit the ablation/dissolution drum (79-304) through a screen. The initial oil sand slurry (79-314) may be sent to a pump (79-306) and an agglomerator (79-307). Solvent wet particles that are deemed to be too large for further processing may be screened out from the ablation/dissolution drum (79-304) and may be sent to a wet reject crusher (79-305) and reprocessed through the ablation/dissolution drum (79-304) or may be washed on the screen, and sent directly to a reject drying (not shown).

[0858] The methods and systems may comprise adding a bridging liquid (not shown) to the initial oil sand slurry (79-314) and agglomerating the initial oil sand slurry (79-314) by agitating the solids within the initial oil sand slurry (79-314) to form the oil sand slurry. The bridging liquid may assist in agglomeration of solids with a mixing action in an agglomerator (79-307) to capture hydrophilic fines. Capturing the hydrophilic fines may assist separation of solids from bitumen and solvent. An agglomerated slurry (79-315) may exit the agglomerator (79-307).

[0859] Formed agglomerates within the agglomerated slurry (79-315) may be sized on the order of 0.1-1.0 mm, or on the order of 0.1-0.5 mm, or on the order of 0.1-0.3mm. At least 80 wt. % of the formed agglomerates may be 0.1-1.0 mm, or 0.1 to 0.5mm, or 0.1-0.3mm in size. The rate of agglomeration may be controlled by a balance between intensity of agitation within an agglomerator (79-307), shear within the agglomerator (79-307) which can be adjusted, for example, by changing the shape or size of the agglomerator (79-307), fines content of the slurry (79-314), bridging liquid addition, and/or residence time of the agglomeration process. The size of the agglomerates may be related to the particle size distribution of the conditioned bituminous feed (79-311) or the particle size distribution of the screened slurry (79-314). The agglomerated slurry may have a solids content of 20 to 70 wt. %.

[0860] The bridging liquid may be an aqueous liquid with affinity for the solids particles in the bituminous feed. The bridging liquid may be immiscible in the solvent. Exemplary bridging liquids may be water that accompanies the bituminous feed and/or recycled water from other aspects or steps of oil sand processing. The 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 and/ or any other acceptable aqueous solution capable of adhering to solid particles in such a way that permits fines to adhere to each other. The bridging liquid may be added to the slurry (79-314) in a concentration of less than 20 wt. % of the slurry (79-314), less than 10 wt. % of the slurry (79-315), between 1 wt. % and 20 wt. %, or between 1 wt. % and 10 wt. % based upon total weight of combined bridging liquid and slurry (79-314). The concentration of bridging liquid added may be any number within or bounded by the preceding ranges. The bridging liquid may comprise fine particles suspended therein. The fine particles may serve as seed particles for the agglomeration process. The bridging liquid may comprise less than 40 wt. % solid fines, or have a solids content of 20 to 70 wt. %, based upon total weight of bridging liquid.

[0861] Agglomerating the initial oil sand slurry by agitating the solids may include agitating by mixing, shaking, rolling, or another known suitable method. The agitation of the slurry (79-314) need only be severe enough and of sufficient duration to intimately contact the bridging liquid with solids in the slurry (79-314). Mixing may occur in a mixing type vessel. Rolling may occur in a rolling type vessel. 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 substantial amount of agitation is needed to keep the formed agglomerates in suspension. In rolling type vessels, the solids content of the slurry (79-314) may be greater than 40 wt. % so that compaction forces assist agglomerate formation. The agitation of the slurry (79-314) 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 the agglomerates. In the case of rolling type vessels the fill volume and rotation rate of the vessel can be adjusted in order to vary the compaction forces on the agglomerates.

[0862] The agglomeration process may occur within a pipeline. The initial oil sand slurry (79-314) may be fed into a pipeline where additional bitumen extraction may occur. The initial oil sand slurry (79-314) may flow within the pipeline, and at one or more point along the pipeline, the bridging liquid may be added to the pipeline to assist in the agglomeration of the solids within the pipeline. Alternatively or additionally, bridging liquid may be added to the initial oil sand slurry (79-314) prior to the pipeline. Some form of agitation is also used to assist agglomeration. The agitation may be provided by turbulent flow within the pipeline. The rate of agglomeration may be controlled by a balance between velocity within the pipeline (i.e. flow turbulence), fines content of the initial oil sand slurry (79-314), bridging liquid addition, and residence time within the pipeline. The agglomerated slurry from the pipeline, comprising of agglomerates and bitumen extract, may be sent to the solid-liquid separation system to produce a bitumen extract stream and an agglomerated solids stream.

[0863] Additional features of an agglomeration process that may be used are described herein.

[0864] The agglomerated slurry (79-315) may be sent to a sealed vacuum filter system (79-308) including a filter, for instance a moving filter, to filter the agglomerated slurry (79-315). The filter may be without limitation, a belt filter or a rotary pan filter. Other sealed solid-liquid separation devices such as vibrating screens, stationary screens, or spiral classifiers configured to have a vacuum applied on the liquid discharge may be used.

[0865] In the sealed vacuum filter system (79-308), described above with reference to Figure 78, solids settle, and the applied vacuum underneath the filter media provides enough of a driving force to remove the rich bitumen filtrate from the solids. Several stages of solids washing with a clean solvent may then be used to remove residual bitumen as the lean bitumen extract. While Figure 79 illustrates the rich and lean bitumen filtrates as one exit stream (79-322), they may remain segregated if desired.

[0866] A vapor condenser and non-condensable gas (NCG) removal system (79-320) (as described with reference to Figure 78) may initiate and sustain the required vacuum pressure to operate the sealed vacuum filter system (79-308). The condenser may be an indirect contact heat exchanger or a direct contact condenser. The condenser may be of an indirect contact design, such as a shell and tube heat exchanger, where the cooling media does not contact the vapor. The condenser may be of a direct contact design, where a fluid such as cold liquid solvent or water is sprayed into the vapor stream to condense the vapor. The cooling duty of the condenser may be integrated with the heating duty of on anther process of the SBE facility. For example, the condensable vapor condenser may use extraction liquor from the extraction liquor storage tanks as the cooling medium to condense the vapor. In this way, the extraction liquor may be heated prior to coming into contact with the bituminous feed.

[0867] The vacuum may be initially created by removing non-condensable gas such as nitrogen through vacuum generating device such as a blower, compressor, ejector or vacuum pump (not shown), which may be disposed of through a vent and flare system, or processed as part of a filter cake desolventizer overhead system (79-340). As the liquid of the condensable vapor and the condensable vapor break through the filter media, the condenser may continually remove heat from the vapor phase to cause liquid condensation. The liquid may have a much smaller volume than the condensable vapor, causing a vacuum to form that is closely aligned with the saturation pressure-temperature curve of the condensable vapor. Depending on process needs, the rich and lean filtrates may be operated at different pressures. The vapor space above the filter cake may be close to atmospheric in order to minimize the thickness of the containment vessel. A higher pressure may be supplied at the vapor space above the filter cake to allow for efficient design of a vent and flare system. In this alternative case, a driving force across the filter is from both the positive pressure, and from the vacuum underneath the filter cake, and may provide higher filtration rates than vacuum alone.

[0868] The vapor condenser and non-condensable gas (NCG) removal system (79-320) may remove condensable vapor (79-330) and non-condensable gas (79-331) (together 79-332) from the sealed vacuum filter system (79-308). The non-condensable gas (79-331) may be passed to the filter cake desolventizer overhead system (79-340).

[0869] The rich and lean bitumen filtrates (together 79-322) may be sent to tanks (not shown), for use as solvent in the dissolution step (79-304), or may be sent to a SRU (79-360) to recover the solvent (79-316), and prepare bitumen (79-317) for further processing. If additional mineral solids removal from the bitumen (79-317) is required or desired, the bitumen (79-317) may be sent to a product cleaning system (79-370). The product cleaning system may entail the use of paraffinic solvents to precipitate asphaltenes, such as described in Canadian Patent Application 2,651,155 ("Sury"). As described by Sury, a paraffinic solvent may be added to a bitumen-containing stream to precipitate and remove asphaltenes. Bitumen (79-318) meeting pipeline specifications may be produced and sent to tankage for shipping (79-390). Precipitated asphaltenes and associated minerals (79-319) may be sent to a solvent recovery step (79-380), after which asphaltenes and minerals (79-385) may be sent for disposal, for instance in a tailings pond, mixed with the dry tailings stream, or used for dust suppression purposes on dry tailings conveyors or deposits.

[0870] Washed filter cake (79-321) may be discharged from the sealed vacuum filter system (79-308) and sent to a filter cake desolventizer (79-310), also referred to as a drier. The washed cake may be of a lower solvent content due to the drying effect of passing condensable vapor through the cake compared to using a non-condensable gas. The filter cake desolventizer (79-310) may be any device suitable for the purpose of removing solvent from the washed filter cake (79-321), such as a directly or indirectly-heated rotary drum or fluidized beds. When the solvent (79-323) has been removed to a desired specification, dry tailings (79-324) may be purged of the condensable vapor in the pore space in a purging device (79-350), and discharged to tailings storage or mine backfill (79-355).

[0871] The filter cake may be mixed with water wet tailings produced from a WBE to form strengthened tailings for co-disposal. The filter cake may have a water content of less than 15 wt. % and the water wet tailings may have a water content of more than 25 wt. %. The strengthened tailings may have a shear strength of 5 kPa or greater.

[0872] In certain prior processes for filtering coarse particles using vacuum filters, a gas rate of 10-20 m^3/m^2-min (meter cubed per meter squared minute) is commonly used. About 25% (percent) of a total filtration area can be used for the drying stage. A single filter can have an area of 100 m^2 (meters squared) and can rotate at about 1 rpm (rotation per minute). For the present oil sand application, several filters of this size could be used, perhaps on the order of 10 units. Assuming a gas flow rate of 20 m^3/m^2-min, the gas flow rate would therefore be 20 m^3/m^2-min x 100 m^2 x 25% x 10 units = 5,000 m^3/minute. The solubility of nitrogen in cyclohexane (cyclohexane being one solvent example) is less than 1%. Therefore, assuming a combined nitrogen contamination and ingress leakage rate from connected equipment of 1%, the power requirement could be reduced by 2 orders of magnitude, handling only 50 m^3/min (meters cubed per minute) compared to using a vacuum pump or blower which would have to process the entire 5,000 m^3/min.

[0873] Figure 81 uses a step of flowing condensable vapor through a filter cake to reduce a solvent content of the filter cake. In particular, Figure 81 illustrates a method comprising: providing a bituminous feed (81-502); adding solvent to the bituminous feed to form an oil sand-solvent slurry (81-504); adding a bridging liquid to the oil sand-solvent slurry to form a mixture (81-506); agglomerating the mixture to form agglomerated solids (81-508); depositing the agglomerated solids onto a filter (81-510); separating a rich bitumen filtrate from the agglomerated solids to form a filter cake on the filter (81-512); and flowing a condensable vapor through the filter cake to reduce the solvent content in the filter cake (81-514).

[0874] A pressure difference across the filter cake may be generated by a creating a vacuum under the filter cake, supplying the condensable vapor at a positive pressure above the filter cake, or a combination thereof.

[0875] By flowing the condensable vapor through the filter cake to reduce the solvent content in the filter cake, as in Figure 78, solvent reduction can be achieved within the filter system and without the need for other desolventizers such as dryers, as described above.

[0876] The condensable vapor may be steam. Steam may be introduced at the last filtration step. The steam may be saturated or superheated and it may be at, or slightly above, atmospheric pressure in vacuum filtration or at higher pressure where pressure filtration is used. As condensable vapor contacts the cooler filter cake, it condenses to form a condensation front, releasing its latent heat, increasing the temperature of the filter cake to the boiling point of the water/solvent heteroazeotrope and evaporating remaining solvent. As the condensation front moves downwards, due to gravity, capillary force and the pressure difference between the top and the bottom of the filter cake, it gets replaced by condensable vapor and the temperature of the filter cake increases to the condensable vapor temperature. The temperature increase leads to the vaporization of the solvent. The vaporized solvent moves downwards with the condensable vapor front and condenses on the cold filter cake below where the solvent is removed from the filter as a liquid. When the condensation front exits from the bottom of the filter cake, condensable vapor flow can further reduce the solvent content of the solids through a stripping mechanism. The condensable vapor time can be used to control the level of desolventization.

[0877] In addition to the potential elimination of another desolventization step, during the filtration process of Figure 81, the vaporized solvent condenses upstream of the condensable vapor condensation front and moves downwards through the filter cake. The condensing solvent washes remaining bitumen from the solids in a similar fashion to the washing stage described above. Accordingly, the washing step may be reduced or eliminated, thus potentially increasing the capacity or throughput of a filter of a given size.

[0878] The effectiveness of condensable vapor filtration for removing solvent may improve when the permeability of the filter cake is high and uniform. Large permeability variability can possibly lead to condensable vapor maldistribution and incomplete desolventizing of the solids which may have to be reprocessed in order to meet residual solvent specifications before deposition back to the mine. A unique feature of solvent based processes using agglomeration is their controlled agglomeration step that enables effective solid-liquid separation. Agglomeration may be controlled by the amount of bridging liquid and mixing energy. Due to the controlled size distribution of the agglomerated solids, the permeability of the filter cake on the filter media may not vary significantly with different ore grade or fines content. Thanks to the relatively high and relatively uniform permeability, effective filtration may be achieved with relatively low driving forces exerted by vacuum. An agglomerated slurry may form a filter cake having an average permeability of about 20 to 300 Darcy, or above 20 Darcy, or above 40 Darcy, or above 80 Darcy, or above 160 Darcy. An agglomerated slurry may form a filter cake having variation of permeability of less than 30%, or less than 60%, or less than 120%, or less than 240%. Variation of permeability means the permeability difference between the most and least permeable area of filter cake. An agglomerated slurry may form a filter cake having a relative standard deviation of permeability less than 30%, or less than 60%, or less than 120%, or less than 240%. Relative standard deviation of permeability is defined as the ratio of the standard deviation of filter cake permeability to the mean (or average) cake permeability.

[0879] The condensable vapor filtration may involve various aspects of process control to meet solvent concentration specification of discharged cake (or dry tailings). For instance, Infrared (IR) temperature sensing may be used under the filter media using IR scans across the radius of a pan filter to detect off specifications conditions. Temperature scans may be used on a discharge auger, the discharged cake, and the heel left underneath the discharge augur on the pan to detect cold spots or temperature variations. The increase in cold spots and temperature variation can serve as early indicator of insufficient drying (desolventization), which may trigger increasing condensable vapor pressure or rate, raising the auger height or reducing filter throughput (by reducing rotation speed in a pan filter or belt speed in a belt filter while maintaining a constant cake height) to prevent off-spec operation. Permeability change measurements may be made from the flow rates of draining liquids during draining and washing stages. Steam pressure, steam rate, or filter throughput (by adjusting rotation speed in a pan filter or belt speed in a belt filter while maintaining a constant cake height), may be adjusted based on permeability change measurements. Load sensors may be used on the pan filter for upset condition sensing, for instance detection of slow drainage.

[0880] Simulations have shown that the desolventization process may progress with a sharp front. Due to the uni-directional force vectors (gravity, pressure drop all in the same direction), and similar viscosities between extract, solvent and water, there is an absence of fingering. Therefore, off-specification material may be concentrated at the bottom of the filter cake. A discharge auger may be raised to achieve a higher heel and a sharp demarcation line may allow small adjustments of heel height to meet solvent specifications.

[0881] When a hydrocarbon detector on a filter cake discharge bin detects a solvent content above a specification amount, indicating insufficient drying (desolventization), the mitigation response may be to increase steam pressure, or steam rate, to raise the auger height (i.e. leave a higher cake heel with concentrated solvent), or to reduce the filter throughput (by reduced rotating speed in a pan filter or belt speed in a belt filter) to allow more steam time.

[0882] Two or more steam hoods may be used with independent steam control to achieve solvent concentration specification.

[0883] Steam flow in excess of that required for the permeability of the filter cake may be detected by an increase in pressure in the vapor space of the vacuum filtration system.

[0884] Discharge bins may be arranged for gas purging (for instance using hot nitrogen) to further reduce residual solvent content.

[0885] A screed device may be used to ensure uniform filter cake height and distribution of the incoming slurry.

[0886] It may be beneficial to reduce the presence of non-condensable gas (NCG). This may be accomplished in a variety of ways, including but not limited to the following. A pump box may be configured to mitigate ingestion of non-condensable gas into the slurry, promote removal of NCG from the pore space, and further reduce the amount of dissolved NCG in the liquid mixture. A vapor stream purge may be used in a pump box or in a feed hopper (or any other suitable device) to remove any NCG from the slurry. A slight vacuum may be used in head space of the pump box (or the feed hopper or any other suitable device) to remove NCG.

[0887] Off-specification materials may be recycled to any suitable location upsteam of the filter. Off-specification materials may be recycled to a location prior to briding liquid addition, such as to initial oil sand slurry (79-314), or to a mixture of bridging liquid and oil sand-solvent slurry formed by step (81-506).

[0888] Off-specification materials may be diverted to a off-specfication handling process. Off-specification materials may be diverted to a secondary gas purging bin to remove solvent to a desired specification before discharged to tailings storage or mine backfill.

[0889] ***Recovery of Solvent Following Filtration.*** Following filtration, solvent still remaining in filter cake and from the rejects (separated before or after agglomeration) can be recovered within a TSRU. By imposing a slight vacuum, or using a gas flow current to remove solvent vapor, the remaining amount of solvent in the solids is encouraged to evaporate. A purge gas may be used to maintain a low oxygen environment, and a flow of vent gas can serve the dual purpose of carrying solvent vapor away for recovery. Exemplary TSRU include a rotary drum dryer, a tray dryer, or a fluidized bed dryer, employing external heating and/or internal steam stripping. The TSRU may employ separate equipment components. A "rejects

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

V. Product Cleaning & Bitumen Handling

V.A Water-Assisted Deasphalting Technologies for Streams Derived from SBE

[0890] It is desirable to provide processes through which residual fine solids and water can be removed from a stream derived from a SBE process, by a deasphalting process such as paraffinic froth treatment associated with a WBE process or a process similar to paraffinic froth treatment. In this way, advantages associated with paraffinic froth treatment, such as enhanced settling rates, higher product yields, and reduced operating temperatures, can be realized.

[0891] There is described herein a process for removing solids from oil sands, the process comprising: (a) forming an oil sands slurry by mixing the oil sands with a first solvent, wherein the amount of first solvent added is greater than 10 wt. % of the oil sands; (b) separating a majority of the solids from the oil sands slurry, forming a solids-rich stream and a bitumen-rich stream, wherein the bitumen-rich stream comprises residual solids; (c) emulsifying the bitumen-rich stream with a water-containing stream to form a hydrocarbon-external emulsion, wherein hydrocarbons form an external phase of the emulsion; (d) mixing the hydrocarbon-external emulsion with a deasphalting solvent in sufficient quantity to cause some asphaltene precipitation, wherein precipitated asphaltenes adhere to at least a portion of the residual solids and to water droplets; and (e) separating the precipitated asphaltenes from the hydrocarbon-external emulsion, thereby removing residual solids and water droplets adhering to the precipitated asphaltenes and forming a cleaned hydrocarbon product.

[0892] The solvents may be removed from the cleaned hydrocarbon product to form a fungible bitumen product, such as one comprising 300 wppm solids or less on a bitumen basis.

[0893] In one embodiment, the majority of the deasphalting solvent comprises C3-C6 components, on a weight basis. In certain embodiments, the first solvent and deasphalting solvent are the same.

[0894] The water-containing stream may be process water, bitumen froth, middlings, flotation tailings, froth treatment tailings, deasphalting unit tailings, or mixtures thereof.

[0895] The hydrocarbon-external emulsion formed in the process may comprise a hydrocarbon dominated phase as overflow and an underflow with water as the dominant fluid.

[0896] The first solvent may be removed from the bitumen-rich stream prior to emulsifying the bitumen-rich stream with the water-containing stream. Optionally, adding the deasphalting solvent to the bitumen-rich stream may occur prior to emulsifying the bitumen-rich stream with the water-containing stream. Advantageously, the deasphalting solvent can be added to the bitumen-rich stream in an amount that is not sufficient to precipitate asphaltenes.

[0897] The process may comprise removing the first solvent from the hydrocarbon-external emulsion prior to mixing the hydrocarbon-external emulsion with the deasphalting solvent.

[0898] Agglomeration of fines may be employed in order to separate a majority of the solids from the oil sands slurry.

[0899] The bitumen-rich stream may be one containing between 0.1 to about 2 wt. % solids on a bitumen basis.

[0900] Mixing the emulsion with the deasphalting solvent may occur in a deasphalting unit, for example, a paraffinic froth treatment unit of a WBE process. In certain embodiments, the water-containing stream may provide a sufficient amount of water to allow water to be the dominant fluid in a settling phase when the emulsion is deasphalted. Alternatively, the deasphalting unit may comprise primary separation and secondary separation. Deasphalting may occur within the deasphalting unit by mixing the deasphalting solvent with the hydrocarbon-external emulsion and directing the mixture into a primary settling vessel to produce a primary overflow and a primary underflow; introducing the primary overflow into a solvent recovery unit to produce the cleaned bitumen product and to recover the deasphalting solvent. Optionally, the primary underflow may be introduced into a secondary settling vessel with the deasphalting solvent from the solvent recovery unit, to recovery deasphalting solvent and a secondary underflow. Deasphalting solvent derived from the secondary settling vessel may be used as the deasphalting solvent for mixing with the hydrocarbon-external emulsion.

[0901] The process may additionally comprise adding water, additives, or a combination thereof, to the primary settling vessel. Further, the secondary underflow may be introduced into a tailings solvent recovery unit to produce tailings and to recover deasphalting solvent. The deasphalting solvent from the tailings solvent recovery unit may be recycled into the secondary settling vessel.

[0902] In embodiments of the process, the ratio of the deasphalting solvent to bitumen of the secondary settling vessel may be about 10:1 or greater, which minimizes bitumen lost in the secondary underflow. The deasphalting solvent may be a paraffinic solvent.

[0903] There is also described in this section a further process for removing solids from oil sands comprising bitumen and solids which involves mixing oil sands with a first solvent to form an oil sands slurry, wherein the amount of the first solvent added is greater than 10 wt. % of the oil sands. A majority of the solids are then separated from the oil sands slurry to form a solids-rich stream and an initial bitumen-rich stream, wherein the initial bitumen-rich stream comprises residual solids. The first solvent is then removed from the initial bitumen-rich stream to form a solvent depleted bitumen-rich stream; and at least a portion of the solvent-depleted bitumen-rich stream is directed to a paraffinic froth treatment process of a WBE process. A fungible bitumen product can then be derived from the paraffinic froth treatment process. Optionally, the process may comprise mixing oil sands with water, wherein the amount of water added is greater than 50 wt. % of the oil sands, and forming bitumen froth, wherein the bitumen froth comprises bitumen, solids and water; and directing the bitumen froth and a second solvent to paraffinic froth treatment.

[0904] The residual solids within the initial bitumen-rich stream may be less than 2 wt. % of the mass content of the initial bitumen-rich stream. Further, the second solvent may be a paraffinic solvent or a mixture thereof.

[0905] According to one embodiment, the paraffinic froth treatment process may occur within a first froth settling unit (FSU 1) and a second froth settling unit (FSU 2). The solvent-depleted bitumen-rich stream may be mixed with the bitumen froth before being directed to the FSU 1. The solvent-depleted bitumen-rich stream may be mixed with overflow of FSU 1. Optionally, the second solvent can be removed from the overflow of FSU 1 prior to mixing with the solvent-depleted bitumen-rich stream. Further, the solvent-depleted bitumen-rich stream can be mixed with the underflow of FSU 1. The solvent-depleted bitumen-rich stream can optionally be mixed with the overflow of FSU 2.

[0906] A fungible bitumen product so formed may have a solids content of less than 300 wppm on a bitumen basis.

[0907] A bridging liquid, such as for example water, may be added to the oil sands slurry to agglomerate fines within the oil sands slurry.

[0908] According to certain embodiments, the first solvent and the second solvent can be the same.

[0909] Solvent deasphalting assisted by the addition of water to the solvent extracted bitumen will allow for a deasphalting process similar to PFT, bringing about some of the advantages of the PFT process within solvent-based bitumen extraction process.

[0910] A process of deasphalting is now described in more detail through which residual fine solids and residual water droplets can be removed from a bitumen stream derived from a SBE, utilizing a water-assisted deasphalting technology.

[0911] A goal in the extraction of bitumen from a mining operation such as oil sand mining is ultimately to produce a fungible bitumen product that can be pipelined and sold to refineries located considerable distances from the mining operation. An exemplary fungible bitumen product is a product that has been partially deasphalted and has a solids content of 300 ppm or less on a bitumen basis. PFT of the WBE is the only technology in current use that produces a fungible bitumen product from water extracted bitumen.

[0912] A bitumen product meeting the fungible requirement of less than 300 ppm solids may be refined in a downstream process, such as hydroprocessing, without danger of dramatically fouling the downstream equipment. In some of the previously known SBEs, such as those discussed above within the background section, the resulting bitumen product may typically have a solids content of approximately 0.1 to 2 wt % on a bitumen basis. The water content of such a bitumen product is usually less than 1 wt %. Although the solids and water content of a product of a SBE is much less than that of bitumen froth produced in a conventional WBE, the residual fine solids and water content may still render the solvent extracted bitumen product unsuitable for marketing. Removing residual fine solids and water droplets from solvent extracted bitumen to achieve a fungible product is difficult using conventional solids separation methods such as gravity settling, centrifugation or filtering. A water-assisted deasphalting process, similar to what is used to produce a fungible bitumen product from WBE froth, is described herein for the final product cleaning of solvent extracted bitumen.

[0913] The water-assisted deasphalting step can be integrated with the SBE in the following manner. The bitumen extraction occurs in an extraction stage using a solvent that dissolves the bitumen from the oil sand, forming a SBE slurry. The slurry is then directed to a solids separation stage where most of the solids are removed from the diluted bitumen. In an exemplary embodiment, the resulting low solid content diluted bitumen is then sent to a SRU where the extraction solvent is separated from the bitumen. The resulting low solids bitumen, with some or all solvent removed, is then directed to the product cleaning unit, where it is mixed in a controlled fashion with a water-containing stream and optionally with a solvent. Examples of water-containing streams, which are not limiting but provided here by way of example, include process water and WBE streams such as bitumen froth, middlings, flotation tails, froth treatment tails, and mature fine tailings. The water-containing stream may be added in an amount no greater than that which keeps the hydrocarbon phase as the dominant phase by volume of the mixture. However, the water-containing stream may also added in a sufficient amount such that when the mixture is partially deasphalted and introduced into a gravity settling vessel, relatively large asphaltene flocs comprised of water, solids, and precipitated asphaltenes may form. Large asphaltene flocs are generally defined as flocs that are significantly greater in size than the asphaltene flocs that would form in the absence of added water. Specifically, the large asphaltene flocs have a hydraulic diameter in the range of 1000 to 10 μm, or more preferably in the range of 500 to100 μm. Additionally, the water-containing stream may be added in an amount no greater than that which keeps the hydrocarbon phase as the dominant phase by volume of the mixture. However, the water-containing stream may also be added in a sufficient amount such that a water-continuous phase is present at the bottom of the separation vessel such that the settling flocs transition between a hydrocarbon continuous phase to a water continuous phase. The water-continuous phase acts to separate interstitial hydrocarbon fluid among the settling flocs. In the water-assisted deasphalting process, the bitumen and water-containing stream mixture is well mixed so that a water-in-bitumen emulsion is formed, containing water droplets of about 100 microns or less in size. A mixture with these properties is similar to froth formed in a conventional WBE, and thus may be partially deasphalted in a system similar to or the same as existing PFT units. Thus, the known advantages of PFT units over conventional deasphalting units may be applied to the product cleaning of solvent extracted bitumen.

[0914] The process described herein may have an advantage over previously proposed deasphalting technologies for solvent extracted bitumen products. Formation of a water-in-bitumen emulsion may facilitate the removal of asphaltenes from bitumen. One possible explanation for this advantage is the heteroflocculation of water droplets, fine solids and asphaltenes into larger and denser flocs. In the process described herein, added water and optionally added water-wet fine solids may be made to flocculate with the residual solids and residual water remaining in solvent extracted bitumen and the precipitated asphaltenes to form flocs that may be larger and denser than those formed in the absence of added water. For this reason, the flocs formed according to the process described herein may settle at a much faster rate and result in much faster throughputs for the deasphalting unit compared to in traditional deasphalting processes.

[0915] In an exemplary embodiment of the process, a water-containing stream is added in a sufficient amount such that when the mixture is partially deasphalted and introduced into a gravity settling vessel, the dominant fluid within the lower portion of the settling vessel is water. The presence of water as the dominant fluid limits the entrainment of bitumen (specifically maltenes) and solvent within the underflow of the settler. Thus, this embodiment allows for higher bitumen yield. Also, the reduced amount of solvent in the underflow may allow for a TSRU that consists of flash drums rather than the energy intensive fractionation towers used in traditional deasphalting units.

[0916] In traditional deasphalting processes, the TSRU must be heated above the minimum asphalt pumping temperature to ensure that the asphaltenes will be pumpable after the solvent is removed. This high temperature requirement reduces the thermal efficiency of the deasphalting unit. The addition of a water-containing stream to the solvent extracted bitumen, as described herein, eliminates the need to melt the asphaltenes. The presence of water ensures that the precipitated asphaltenes and other solids remain fluidized both within the bottom of the settling vessel and within the TSRU at moderate temperatures.

[0917] Appropriate sources of water and water-wet fines for use in the process described herein include WBE streams such as mature fines tailings, middlings and flotation tails. Mixing one or more of these streams with the bitumen product from the SBE, may allow for the recovery of some of the bitumen entrained within these WBE streams. Thus, increase bitumen recovery from low hydrocarbon-containing streams of WBE may be realized in the application of the water-assisted deasphalting process described herein.

[0918] The solvent extracted bitumen product mixed with water and optionally water-wet fines, bears similarity to deaerated bitumen froth formed in a conventional WBE. For this reason, conventional PFT methodologies can be readily adapted with minor modification, to serve as the basis of the water-assisted deasphalting technology for the mixture of the solvent extracted bitumen product and the water-containing stream.

[0919] Processes are described herein for product cleaning of bitumen from a SBE to produce a fungible bitumen product. The bitumen may have a combined solids and water content of about 2 to 5 wt. %, while the cleaned bitumen product may be a fungible product with less than 300 ppm solids. To achieve pipeline specifications, a product can be produced having 0.5 wt. % or less of bottom sediment and water. The product cleaning may be accomplished using the water-assisted deasphalting process described herein.

[0920] Embodiments of the water-assisted deasphalting process described herein result in a solvent extracted bitumen stream with a reduced solids and water content. The resulting bitumen product may be a fungible product appropriate for transportation and refining. For example, a fungible product may be one with a fines content of less than 300 ppm on a bitumen basis. Should the pipeline and downstream refining requirements be adjusted to require a solids content of less than 300 ppm, the water-assisted deasphalting process has been shown to produce bitumen product of much less than 300 ppm solids content on a bitumen basis. For example, product quality of 50 ppm or less is achievable.

[0921] Embodiments of the process may differ from previously described deasphalting processes for product cleaning of bitumen in that water, and optionally water-wet fines, may be mixed with a solvent extracted bitumen stream prior to asphaltene precipitation. Mixing occurs, so that a water-in-bitumen emulsion is formed which contains water droplets, on average of less than 100 microns in size. The addition of water to the solvent extracted bitumen stream may result in advantages in the deasphalting process, compared to traditional deasphalting processes used in the absence of a significant amount of water, such as those used in refineries to process heavy crude oils to upgrade heavy bottoms streams to deasphalted oil. Potential advantages include increased thermal efficiency, increased settling rates leading to higher throughputs, and a higher product yield. Processes and systems which can be integrated with SBE are described herein.

[0922] The SBE, with which the water-assisted deasphalting processes and systems described in this section may be integrated, produces a low solids bitumen product. The SBE may be, but is not limited to, SBEs described herein.

[0923] In a solvent extraction and solids agglomeration process such as described herein, the resulting diluted bitumen stream may have a solid content of approximately 0.1 to 2 wt. % on a bitumen basis. The water content of the diluted bitumen may be much less than 1 wt. %. Although the solids and water content of the solvent extracted bitumen stream are much less than that of bitumen froth produced in a typical WBE, the residual fine solids and water content still render the solvent extracted bitumen stream unsuitable for marketing. Removing residual fine solids and water from the solvent extracted bitumen is difficult using conventional solid separation methods such as gravity settling, centrifugation or filtering. For this reason, a water-assisted deasphalting process, similar to what is used to produce a fungible bitumen product from bitumen produced in a WBE, is employed in the processes described herein, for the final product cleaning of solvent extracted bitumen.

[0924] The water-assisted deasphalting process described herein is generally integrated with the SBE and solids agglomeration process in the following manner. Solvent extraction of bitumen occurs in an extraction stage using a solvent that dissolves the bitumen from the oil sand to form an oil sand slurry. Some asphaltene precipitation may be allowed to occur in the extraction step if it is deemed beneficial to product cleaning and/or solids agglomeration. A bridging liquid, such as water, is added to the slurry to agglomerate the solids. The agglomerated slurry is sent to a solids separation stage where most of the solids are removed from the diluted bitumen. In an embodiment described herein, the low solids content diluted bitumen stream is then sent to a SRU where the extraction solvent is separated from the bitumen to form a low solids bitumen product.

[0925] The resulting low solids bitumen, which is no longer diluted by solvent, is then directed to the product cleaning unit, where it is mixed in a controlled fashion with a water-containing stream and optionally with a solvent. Examples of water-containing streams include, but are not limited to, process water and WBE streams such as bitumen froth, middlings, flotation tails, froth treatment tails and mature fine tailings. The water-containing stream may be added in an amount no greater than that which keeps the hydrocarbon phase as the dominant phase by volume of the mixture. However, the water-containing stream may also be added in a sufficient amount such that when the mixture is partially deasphalted and introduced into a gravity settling vessel, relatively large asphaltene flocs comprised of water, solids and precipitated asphaltenes form. Large asphaltenes flocs are generally defined as flocs that are significantly greater in size than the asphaltene flocs that would form in the absence of added water. Specifically the large asphaltene flocs have a hydraulic diameter in the range of 1000 to 10 μm, or more preferably in the range of 500 to 100 μm. Additionally, the water-containing stream may be added in an amount no greater than that which keeps the hydrocarbon phase as the dominant phase by volume of the mixture. However, the water-containing stream may also be added in a sufficient amount such that a water-continuous phase is present at the bottom of the separation vessel such that the settling flocs transition between a hydrocarbon continuous phase to a water continuous phase. The water-continuous phase acts to separate interstitial hydrocarbon fluid among the settling flocs. Furthermore, the bitumen and water-containing stream mixture is well mixed so that the formed water-in-bitumen emulsion contains water droplets of less than 100 microns in size. A mixture with these properties is similar to WBE froth, and thus the mixture may be partially deasphalted in a system similar to existing PFT units. Thus, the known advantages of PFT units over conventional deasphalting units may be applied to the product cleaning of solvent extracted bitumen.

[0926] The integration of a deasphalting process with a SBE and agglomeration process may have potential advantages over existing product cleaning processes for solvent extracted bitumen. For instance, the fungible product may be produced regardless of the wetting behaviour of the residual solids. A single solvent or a solvent mixture of two or more solvents (for examples, aromatic and paraffinic solvents) may be used for a combined bitumen extraction in the agglomerator and water-assisted deasphalting in the product cleaning unit. Such a system would require only one SRU. Additionally, the TSRU for the product cleaning unit may be integrated with that of an existing SBE.

[0927] Advantageously, a water-in-bitumen emulsion, as described herein, may facilitate the partial or full deasphalting of a bitumen stream. See *Fuel Processing Technology* Vol 89 (2008) 933-940 and *Fuel Processing Technology*, Vol 89 (2009) 941-948. These articles suggest that a water-in-bitumen emulsion may facilitate the removal of asphaltene from bitumen. Although the mechanism by which emulsified water-in-bitumen facilitates the removal of asphaltenes from bitumen is not fully understood, one possible explanation, given in the above articles, is the heteroflocculation of water droplets, fine solids and asphaltenes into larger and denser flocs. As described herein, added water and optionally added water-wet fine solids are made to flocculate with the residual solids and residual water remaining in solvent extracted bitumen and the precipitated asphaltene to form flocs that are larger and denser than those formed when added water is absent. For this reason, the flocs formed according to the process described herein may settle at a faster rate and result in faster throughputs for the water-assisted deasphalting unit than traditional deasphalting units.

[0928] As described herein, a water-containing stream is said to be added at a sufficient amount such that when the mixture is partially deasphalted and introduced into a gravity separation vessel, the dominant fluid within the bottom of the settling vessel is a water phase.

The presence of water as the dominant fluid limits the entrainment of bitumen (specifically maltenes) and solvent within the underflow of the settler. This advantageously allows for higher bitumen production. Also, a reduced amount of solvent in the underflow may allow for a TSRU that consists of flash drums rather than the energy intensive fractionation towers used in traditional deasphalting units.

[0929] In traditional deasphalting technology, the TSRU must be heated above the minimum asphalt pumping temperature to ensure that the asphaltenes will be pumpable after the solvent is removed. This high temperature requirement reduces the thermal efficiency of the deasphalting unit. The addition of water to the solvent extracted bitumen as described herein eliminates the need to melt the asphaltenes. The presence of water ensures that the precipitated asphaltenes, and other solids, remain fluidized both within the bottom of the separation vessels and within the TSRU at moderate temperatures.

[0930] Good sources of water and water-wet fines as described herein include WBE streams such as mature fines tailings, middlings and flotation tails. Mixing one or more of these streams with the bitumen product from the SBE may allow for the recovery of some of the bitumen within these WBE streams. Thus, embodiments described herein may permit increased bitumen recovery when integrated with WBE streams that contain bitumen.

[0931] The solvent extracted bitumen product mixture with water, and optionally water-wet fines, may be similar to the deaerated bitumen froth of the WBE. For this reason, a conventional PFT technology can be adapted for use in streams derived from SBE with minor modifications, and thus can possibly be used as the deasphalting unit for the mixtures within embodiments described. Advantageously, in one embodiment, a solvent extracted bitumen product is mixed in a ratio of 1:3, or less, with a deaerated bitumen froth from a WBE. In this way, the solvent extracted bitumen product can undergo product cleaning in existing PFT units of a WBE facilities.

[0932] Figure 12 provides an overview of an exemplary process (12-1700) for product cleaning a bitumen stream derived from a SBE. The process permits removal of solids from oil sand. An oil sand slurry is formed (12-1702) by mixing the oil sand with a first solvent, where the amount of solvent added is greater than 10 wt. % of the oil sand. Subsequently a majority of the solids are separated (12-1704) from the oil sand slurry, forming a solids-rich stream and a bitumen-rich stream, wherein the bitumen-rich stream comprises residual solids and residual water. The bitumen-rich stream is emulsified (12-1706) with a water-containing stream to form a hydrocarbon-external emulsion, wherein hydrocarbons form an external phase of the emulsion. The hydrocarbon-external emulsion is mixed (12-1708) with a second solvent in sufficient quantity to cause some asphaltene precipitation, wherein precipitated asphaltenes flocculate with at least a portion of the residual solids and water droplets. Subsequently the asphaltene flocs, comprised of water, solids and precipitated asphaltenes, are separated (12-1710) from the hydrocarbon-external emulsion, thereby forming a cleaned hydrocarbon stream comprising fungible bitumen and solvent, and tailings comprising water, solids, and precipitated asphaltenes. The hydrocarbon-external emulsion formed in the process may comprise a hydrocarbon dominated phase as overflow and an underflow with water as the dominant fluid.

[0933] Figure 13 provides a schematic representation of the integration of SBE with a water-assisted deasphalting process (13-1850) for the production of a fungible bitumen product. An optional stage of solvent recovery (13-1807) is used to remove some or all of the solvent from the bitumen extract. The resulting stream of low solids bitumen (13-1808) is mixed with a water containing stream (13-1812) in an emulsification unit (13-1811). Examples of water-containing streams include, but are not limited to, process water, bitumen froth, mature fine tailings, middlings, flotation tails and froth treatment tailings. In general, the requirement of the water-containing stream is that it is added to the bitumen stream in a sufficient amount that when the formed emulsion is deasphalted, water is the dominant fluid within the bottom portion of the settling vessel, where the settling components is comprised of precipitated asphaltenes, water and solids. The water-containing stream may optionally have water-wet fines within.

[0934] In the depicted process (13-1850), an oil sand feed (13-1800) is extracted in an extraction stage (13-1802), in the presence of an extraction solvent (13-1801). A diluted bitumen slurry (13-1803) is formed. For a SBE and solid agglomeration process, such as described herein, the extraction stage may include a mixbox and an agglomerator. The mixbox is used to from a slurry comprised of the oil sand feed (13-1800) and extraction solvent

(13-1801). Bridging liquid may be added to the slurry within the agglomerator to agglomerate the fine solids. The diluted bitumen slurry (13-1803) is forwarded to a solid liquid separation stage (13-1804), whereupon solvent wet solids (13-1806) are removed in and sent to a TSRU (13-1809), from which dry tailings (13-1810) are produced. Diluted bitumen (13-1805) derived from the solid liquid separation stage (13-1804) is sent on to solvent recovery (13-1807), from which a stream of low solids bitumen (13-1808) is derived. A countercurrent washing is often included in the solid-liquid separation stage to minimize the amount of bitumen extract remaining with the solids. For example, solid-liquid separation may involve a combination of a gravity settler and filter with countercurrent washing. A second solvent of lower boiling point and/or lower solids adsorption energy than the extraction solvent (13-1801) may be used as the washing solvent in order to improve solvent recovery in the tailing SRU (13-1809).

[0935] In the SBE and solids agglomeration process described herein, the stream of low solids bitumen (13-1808) may be of sufficient quality that it may be directed to an on-site upgrader. However, if a fungible bitumen product is desired; the low solids bitumen (13-1808) must be directed to a special product cleaning unit; that is a water-assisted deasphalting unit (13-1816). As illustrated in Figures 3 to 13, the stream of low solids bitumen (13-1808) is forwarded to a water-assisted deasphalting unit (13-1816) comprising an emulsification unit (13-1811) and a deasphalting unit (13-1813). Within the water-assisted deasphalting unit (13-1816), the emulsification unit (13-1811) receives the stream of low solids bitumen (13-1808) arising from the SBE, and combines the stream with a water containing stream (13-1812). Within the emulsification unit (13-1811), a water-in-bitumen emulsion (13-1822) is formed, and forwarded to the deasphalting unit (13-1813). A deasphalting solvent (13-1814) is added to the emulsion (13-1822) within the deasphalting unit, and froth separation occurs to ultimately produce a fungible bitumen product (13-1815).

[0936] Similar to the PFT unit of a WBE, the deasphalting unit (13-1813) utilized in this process may comprise two settling units. The first settling unit (FSU 1) is used to separate the clean diluted bitumen from the water phase containing precipitated asphaltenes and solids. The second settling unit (FSU 2) is used to wash the underflow of FSU 1 in order to recover the maltenes entrained in the FSU 1 underflow.

[0937] In embodiments of the process described below with respect to Figures 14 and 15, processes are depicted in which a SBE facility is integrated with WBE facility in order to take advantage of synergies gained from the integration of the processes. One advantage of integrating SBE with WBE is that PFT, which is traditionally used to produce a fungible bitumen product from bitumen froth, may also be used to remove the residual contaminants within solvent extracted bitumen. PFT can be utilized with product streams derived from both SBE and WBE in order to remove residual solids and water from these streams.

[0938] In an embodiment of the process described herein, PFT of a WBE is integrated with a SBE. Bitumen extraction occurs in an extraction stage of the SBE using a solvent that readily dissolves the bitumen from oil sand, thereby forming a slurry. The oil sand slurry is sent to a solids separation stage where most of the solids are removed from the oil sand slurry to form a low solids bitumen extract. A residual amount of solids and water remain with the low solids bitumen extract. Further residual solids and water need to be removed from the bitumen extract because they hinder downstream processing of the bitumen. The bitumen extract is then sent to a SRU where the extraction solvent is separated from the bitumen. The solvent-free bitumen with residual solids and residual water (low solids bitumen) is then directed to the PFT unit of a WBE in order to remove residual solids and water from the low solids bitumen.

[0939] In another embodiment of the process described herein, a low solids bitumen product derived from a SBE, which has a solids and water content higher than desired in a fungible product, may be combined with a cleaner stream derived from PFT of a WBE to achieve, on balance, a fungible product. A fungible bitumen product contains bitumen together with a solids content of less than 300 ppm on a bitumen basis. Removing residual fine solids from the solvent extracted bitumen is difficult using conventional solid separation methods such as gravity settling, centrifugation or filtering, and thus, allowing some residual solids and water to remain in a solvent extracted product, while mixing with a fungible bitumen product, which has a solids content much less than 300 ppm, permits formation of a combined product that still meets the required specifications.

[0940] Figure 14 provides an overview of a process (14-1900) in which PFT of a WBE is used to remove residual solids and residual water within a bitumen product stream derived from

SBE. The process (14-1900) permits removal of solids from oil sand comprising bitumen and solids. Oil sand are mixed (14-1902) with a first solvent to form an oil sand slurry, wherein the amount of solvent added is greater than 10 wt. % of the oil sand. A majority of the solids are separated (14-1904) from the oil sand slurry to form a solids-rich stream and an initial bitumen-rich stream, where the initial bitumen-rich stream comprises residual solids and residual water. The solvent is removed (14-1906) from the initial bitumen-rich stream to form a solvent depleted bitumen-rich stream. Optionally, additional oil sand are mixed (14-1908) with water, wherein the amount of water added is greater than 50 wt. % of the oil sand, to form bitumen froth, wherein the bitumen froth comprises bitumen, solids and water. The optionally formed bitumen froth is directed (14-1910) to a PFT process of a WBE. Further, at least a portion of the solvent-depleted bitumen-rich stream is directed (14-1910) to the PFT process of a WBE. A fungible bitumen product is thus derived (14-1912) from the PFT process.

[0941] Figure 15 shows a typical PFT unit (15-2000) having at least two settling vessels or settling regions. The first froth settling unit FSU 1 (15-2004) is used to precipitate a fraction of the asphaltenes found in the bitumen froth (15-2008). Precipitated asphaltenes form large flocs with the residual solids and water that rapidly settle out by gravity separation or enhanced gravity separation. In FSU 1 (15-2004) it desirable to minimize the amount of asphaltenes precipitated to the minimum amount needed to flocculate all the solids and water.

[0942] Low solids bitumen may feed into the PFT unit of Figure 15 at various potential stages upstream of the PFT unit FSU 1 (15-2004).

[0943] A low solids bitumen stream derived from a SBE can be mixed with the other feeds going to FSU 1 (15-2004). Although not depicted, the low solids bitumen may mix with a feed going to an intermediate settling vessel. It is not desired to mix low solids bitumen with the feed entering the last settling vessel of a PFT unit, depicted here as the second froth settling unit FSU 2 (15-2006), because this settling vessel is typically used to limit loss of bitumen to the tailings, and specifically the loss of the maltene components of bitumen to the tailings.

[0944] Bitumen froth (15-2008) is provided to a mixer (15-2010), optionally with the low solids bitumen (15-2002b) derived from the SBE. A mixed solution including overflow (15-2012) from the second froth settling unit (15-2006) can also be added. The composition so mixed is directed to FSU 1 (15-2004), from which underflow is mixed with solvent from the SRU (15-2014), and then the mixture is directed to FSU 2 (15-2006). The underflow of the FSU 2 (15-2006) can be directed to a TSRU (15-2016), from which a tailings stream (15-2018) comprising asphaltenes, solids and water is derived. The overflow (15-2005) from FSU 1 is directed to a SRU (15-2014) to ultimately produce a fungible bitumen product (15-2024). The bitumen product (15-2026) derived from SRU (15-2014) may optionally be combined with additional low solids bitumen (15-2002a) from a SBE not shown, in order that the combined streams becomes a fungible product (15-2024), as it meets the threshold of fungible specifications. The resulting fungible product (15-2024) can be transported via pipeline and utilized in downstream refining processes.

[0945] In an optional embodiment, Figure 15 represents a process in which the bitumen product (15-2026) arising from SRU (15-2014) produced by PFT may have a solids content that is much less than the fungible limit. In that case, the low solids bitumen (15-2002a) from the SBE may bypass the PFT process and directly mix with the bitumen product (15-2026) arising from SRU (15-2014) and still yield a combined stream (15-2024) that meets fungible specifications.

V.B Directing Solvent Extracted Bitumen Product to WBE

[0946] It is desirable to utilize integration of bitumen-containing streams from SBE processes for preparing an input feed for WBE process so as to achieve a bitumen enriched stream within the WBE process.

[0947] A process is described herein for recovering hydrocarbon from oil sand. The process includes contacting a first oil sand ore with a solvent to form a solvent-based slurry comprising solids and a bitumen extract; separating the solids from the solvent-based slurry to produce a low solids bitumen extract; removing solvent from the low solids bitumen extract to form a solvent extracted bitumen product; contacting a second oil sand ore with water to form an aqueous slurry; mixing the solvent extracted bitumen product with the aqueous slurry to form a bitumen enriched slurry; and recovering bitumen from the bitumen enriched second slurry.

[0948] The enriched bitumen stream may lead to an increase in overall bitumen recovery and bitumen froth quality. Furthermore, since recovered bitumen from the WBE process may undergo paraffinic froth treatment to produce a fungible bitumen product, this integration of extraction processes permits further cleaning of the streams derived from SBE which may not yet be of a fungible quality, or adequately pure to meet pipeline specifications.

[0949] Optionally, the aqueous slurry comprises a WBE stream upstream of primary separation in a WBE, for example a middlings stream of primary separation in a WBE. Alternatively, the aqueous slurry may comprise a tailings stream of primary, secondary or tertiary separation in a WBE.

[0950] The solvent extracted bitumen product may be mixed with process water prior to mixing with the aqueous slurry.

[0951] The solvent-based slurry may be mixed with a bridging liquid, such as process water, to agglomerate solids within the solvent-based slurry.

[0952] Recovery of bitumen may occur within a settling vessel, or within flotation cells.

[0953] The step of mixing the solvent extracted bitumen product with the aqueous slurry may occur upstream of froth treatment. Optionally, the step of mixing the solvent extracted bitumen product with the aqueous slurry can occur within a hydrotransport pipeline.

[0954] The embodiment described herein involves directing the product of a SBE into a WBE at one or more stages prior to froth treatment, resulting in increased bitumen recovery and a higher quality bitumen froth.

[0955] Often a poor froth quality and low recovery rates ($\leq$ 90 %) of bitumen from extraction of low grade oil sand ore are problems encountered when using conventional WBE. Recovery of bitumen from oil sand via a WBE may drop below the desired recover rate of 90% or greater when the oil sand feed quality (ore grade) contains relatively low amounts of bitumen ($\leq$ 10 wt. %) and relatively high amounts of solid fines. Additionally, the quality of the recovered bitumen froth from the WBE of low grade ore is also poor. Good bitumen froth has a bitumen content of approximately 60 wt. %. However, the extraction of low grade ore typically yields a froth with bitumen content less than 50 wt. %. The mining and extraction of oil sand is an energy intensive and expensive process. For these reasons, maximizing the recovery of mined bitumen is determinative of an operation's rate of return.

[0956] In WBE for low grade oil sand, the majority of un-recovered bitumen remains in the middlings. Due to the reduced amount of bitumen, the small bitumen droplets in the middlings fail to collide at a sufficient frequency to coalesce into larger droplets that can readily attach to the air bubbles needed for recovery. The aeration of the bitumen droplets is also hindered by fine particles or "fines" coating the surface of the small bitumen droplets. Fines may act as barriers preventing both coalescing of bitumen droplets and air bubble attachment.

[0957] Improved bitumen recovery and froth quality from low grade oil sand can be realized in a conventional WBE by blending of different grades of oil sand in order to create a more consistent feed to the front end stage of the WBE, such as in the oil sand crushing stage. Blending of varying grade of oil sand ores allows for high grade oil sand (≥ 10 wt. % bitumen) to be blended with low grade oil sand (≤10 wt. % bitumen) in order to produce an average grade ore that gives more consistent bitumen recoveries of ≥ 90 % and froths that have of approximately 60 wt. % bitumen content. However, the blending of varying ores has significant capital expenditure (CAPEX) and operational expenditure (OPEX) implications as mining logistics complexity increases and trucking requirements increase.

[0958] According to a process described herein, the bitumen product generated in a SBE, which is a low-solids bitumen product, is blended with a bitumen feed and directed to a stage within a water-based process of bitumen recovery, which is preferably upstream of the froth treatment process. Examples of such feed streams with which the SBE product stream can be mixed include the oil sand slurry in the slurry preparation plant and hydrotransport pipeline. The low-solids bitumen product from SBE may also be mixed with middlings streams undergoing the secondary and/or tertiary bitumen recovery stages within a WBE. The increased levels of bitumen in the process will improve the recovery of the original bitumen that was in the WBE stream. The increased level of bitumen within the combined stream will also improve the quality of the recovered bitumen stream formed at the end of the WBE.

[0959] While the mechanism behind the improved bitumen extraction is not limited by any one particular physical explanation, it is nevertheless possible that the added bitumen coalesces with the small bitumen droplets during stages of the WBE to form larger bitumen droplets that are readily recoverable, for example by attaching to air bubbles more readily. Large bitumen droplets are more likely to attach to small bitumen droplets even in presence of fine particles which may coat the bitumen droplets. Furthermore, the added bitumen may also increase the level of bitumen derived surfactants in the slurry, assisting in the overall recovery process.

[0960] Figure 16 depicts a flow chart of a process (16-2100) in which a stream from SBE is added to an input stream of a WBE. According to this process, a first oil sand ore is contacted (16-2102) with a solvent to form a solvent-based slurry comprising solids together with a bitumen extract. The solids are separated (16-2104) from the solvent-based slurry to produce a low solids bitumen extract. Subsequently, solvent is removed (16-2106) from the low solids bitumen extract to form a solvent extracted bitumen product. In a step that need not be conducted sequentially, but which may be conducted in parallel, a second oil sand ore is contacted (16-2108) with water to form an aqueous slurry. Exemplary aqueous slurries may be from a WBE such as slurry preparation unit effluent, primary separation feed, and secondary and tertiary recovery unit feeds. Subsequently, the solvent extracted bitumen formed as a result of the SBE is mixed (16-2110) with the aqueous slurry to form a bitumen enriched slurry. Bitumen may then be recovered (16-2112) from the bitumen enriched slurry in the extraction stages of a WBE.

[0961] Figure 17 shows a schematic of a process (17-2200) in which solvent extracted bitumen is used to improve bitumen recovery in a WBE. In the depicted process, various locations within a generic WBE facility are depicted where the solvent extracted bitumen may be added. Regarding the ore preparation stage (17-2208), hydrotransport pipeline stage (17-2212), and separation stage (17-2214), solvent extracted bitumen (17-2202a, 17-2202b, 17-2202c) may be added at any one or more of these stages. In general, solvent extracted bitumen (17-2202a, 17-2202b, 17-2202c) from a SBE is added to a WBE at some stage prior to the froth treatment stage (17-2204). An added advantage of the described embodiment is that the added solvent extracted bitumen will ultimately be processed in the froth treatment stage (17-2204) of a froth treatment unit in the WBE facilities. Thus, in the case of PFT, the residual solids and residual water that are within the solvent extracted bitumen will be removed in this final bitumen product cleaning stage of the WBE to produce a fungible bitumen product.

[0962] In the depicted process (17-2200), oil sand (17-2206) is prepared for extraction in an ore preparation stage (17-2208). It may be at this stage, when water (17-2210) is added, that solvent extracted bitumen (17-2202a) may be added, forming a stream containing water, crushed ore, and solvent extracted bitumen. It is preferable the solvent extracted bitumen is added after the oil sand (17-2206) and water (17-2210) slurry is prepared; that is, the effluent of slurry preparation stage. It is optional to add the solvent extracted bitumen at this stage, as downstream optional additions may alternatively be utilized. From the "slurry preparation" or ore preparation stage (17-2208), solvent extracted bitumen may be directed to any acceptable location upstream of the separation stage (17-2214), such as within a hydrotransport pipeline (17-2212) as depicted here. During transport along the hydrotransport pipeline (17-2212), solvent extracted bitumen (17-2202b) may optionally be added to the aqueous slurry comprising oil sand. The solvent extracted bitumen (17-2202b) may be added at any point along the hydrotransport pipeline. However, it is advantageous to add the solvent extracted bitumen further upstream of the pipeline so as to provide the mixing energy needed to properly disperse the solvent extracted bitumen into the aqueous slurry.

[0963] The separation stage (17-2214) typically comprises of a primary separation step and a secondary separation and optionally a tertiary separation steps. In the primary separation vessel, the upper phase may comprise froth, while the lowermost phase comprises of tailings. The mid-level phase of such a vessel is comprised of middlings. The middlings and tailings may be directed to secondary and tertiary separation steps to recover additional bitumen froth. The low bitumen content of the middlings and tails makes additional bitumen recovery in the secondary and/or tertiary separation steps difficult. The solvent extracted bitumen (17-2202c) may be added to the secondary and tertiary separation vessels so as to increase the bitumen content within these vessels. The added bitumen may coalesce with the small bitumen droplets from the middlings and tailings during the separation stages of the WBE to form larger bitumen droplets that are more readily separated from the slurry. For example, large bitumen droplets are more likely to attach to small bitumen droplets even in presence of fine particles which may coat the bitumen droplets. Furthermore, the added bitumen may also increase the level of bitumen derived surfactants in the slurry, assisting in the overall recovery process.

[0964] The bitumen (17-2218) produced within the separation stage (17-2214) may be in the form of bitumen froth, comprised of both water extracted bitumen and the added bitumen from the SBE. The bitumen froth is then directed to a froth treatment stage (17-2204), while tailings (17-2216) of the separation stage (17-2214) are processed separately. The froth treatment stage is preferably a PFT unit, which would yield a fungible bitumen product (17-2222) and froth treatment tailings (17-2220). Thus, the described embodiment has the added advantage that the solvent extracted bitumen, which is not a fungible bitumen product, may ultimately be processed in a PFT unit of a WBE to produce a fungible bitumen product suitable from for pipeline transport and downstream refining.

V.C Washing Agglomerated Fines

[0965] The present section provides methods for processing an oil sand slurry or a bitumen extract stream.

[0966] Under certain conditions, effective agglomeration of solids may require a solids concentration within an oil sand slurry of greater than 30 wt. %, or greater than 40 wt. %. Figure 82 is a graph of the resulting permeability of a bed of agglomerates. Figure 82 shows a significant reduction in the bed permeability of agglomerates as the concentration of an oil sand slurry is reduced. The bitumen extract stream may have a solids concentrations of less than 30 wt. %, or more likely less than 20 wt. %, which is lower than a solids concentration which may allow for effective agglomeration of solids. It may be desirable to concentrate the fine solids to produce an oil sand slurry more suitable for solids agglomeration, thereby allowing for effective agglomeration of solids. The fine solids that have been concentrated may be referred to as concentrated fines. The concentrated fines may be agglomerated by agitating the solids in a mixing tank, a rotating vessel, or within a pipeline. A bridging liquid may be added to the concentrated fines to assist in the agglomeration process. The concentrated fines may be mixed with additional solids prior to agglomeration. For example, the concentrated fines may be mixed with an oil sand slurry prior to agglomeration.

[0967] The methods described in the present section may be combined with aspects of other solvent-based recovery processes, including but not limited to solvent extraction with a solids agglomeration process. The solvent extraction process need not be solvent extraction with a solids agglomeration process.

[0968] In this section, a "solvent-based recovery process" or "solvent extraction process" or "oil sands 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, SBE recovery process (SEP), thermal SBE 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.

[0969] In this section, a "bitumen extract stream" is generally defined as a stream comprising bitumen dissolved in a solvent, and also comprising suspended fines. The bitumen extract stream may have a solids content of less than 30 wt. %, or less than 20 wt. %.

[0970] In this section, a "low fines bitumen extract stream" is generally defined as a bitumen extract stream having a low solids content, such as less than 0.5 wt. %, or less than 0.1 wt. %, on a dry bitumen basis.

[0971] In this section, a "concentrated fines stream" is generally defined as a fines stream having a high solids content, such as greater than 30 wt. %, or greater than 40 wt. %.

[0972] In this section, a "bitumen product stream" is generally defined as a bitumen product that may be suitable for transport within pipelines and processing within downstream refineries.

The bitumen product stream may have a solids content of less than 0.5 wt. %, or less than 0.1 wt. %, on a dry bitumen basis.

[0973] A method may comprise: a) providing a bitumen extract stream, comprising bitumen dissolved in a first solvent, and suspended fines; b) separating the bitumen extract stream into a concentrated fines stream and a low fines bitumen extract stream; c) producing agglomerated fines by agglomerating the concentrated fines stream; d) forming washed agglomerated fines by washing the agglomerated fines with a washing solvent that removes residual bitumen extract from the agglomerated fines; e) producing dry solids by removing the washing solvent from the washed agglomerated fines; and f) producing a bitumen product stream by removing the first solvent from the low fines bitumen extract stream.

[0974] Prior to (a), the method may further comprise: forming an oil sand slurry, comprising a bitumen extract and solids, by contacting a bituminous feed with an extraction liquor; forming an agglomerated slurry by adding a bridging liquid to the oil sand slurry to agglomerate the solids as agglomerated solids; and forming the bitumen extract stream by separating the bitumen extract from the agglomerated solids.

[0975] Prior to (a), the method may further comprise: forming an oil sand slurry, comprising a bitumen extract and solids, by contacting a bituminous feed with an extraction liquor; and separating the oil sand slurry into the bitumen extract stream and a coarse solids stream, wherein a weight majority of fine solids within the oil sand slurry are in the bitumen extract stream and a weight majority of coarse solids within the oil sand slurry are in the coarse solids stream.

[0976] Precipitated asphaltenes may be formed by precipitating asphaltenes within the bitumen extract stream. The asphaltenes may be precipitated in the bitumen extract stream by adding a second solvent to the bitumen extract stream. The second solvent may be a paraffinic solvent. Precipitating asphaltenes may comprise changing a temperature of the bitumen extract stream. Precipitating asphaltenes may comprise changing the pressure of the bitumen extract stream.

[0977] A method and system for processing a bitumen extract stream (83-202) is depicted in Figures 83 and 86. The method and system may comprise providing the bitumen extract stream (83-202), (86-502). The bitumen extract stream (83-202) may comprise bitumen dissolved in a first solvent. The bitumen extract stream (83-202) may comprise suspended fines.

[0978] The method and system may comprise separating the bitumen extract stream (83-202) into a concentrated fines stream (83-208) and a low fines bitumen extract stream (83-206), (86-504). The bitumen extraction stream (83-202) may be separated in a separator (83-204). The bitumen extract within the bitumen extract stream (83-202) may be separated from fines within the bitumen extract stream (83-202) to produce the low fines bitumen extract stream (83-206) and the concentrated fines stream (83-208). The concentrated fines stream (83-208) may have a solids content of greater than 30 wt. %, or greater than 40 wt. %. The separator (83-204) may comprise any suitable separator. For example, the separator (83-204) may comprise gravity separation or an enhanced gravity process. Other examples of a separator (83-204) include, but are not limited to, clarifiers, thickeners, centrifuges, and cyclonic devices.

[0979] Separating the bitumen extract stream (83-202) can be assisted by precipitating asphaltenes and/or by adding additives to help aggregate the fines in the bitumen extract stream (83-202) into larger particles that can be more readily separated from the bitumen extract. The precipitated asphaltenes and the fines may be separated from a weight majority of the bitumen.

[0980] The low fines bitumen extract stream (83-206) may have a solids content of less than 0.5 wt. %, or less than 0.1 wt. %, on a dry bitumen basis. Achieving this level of solids content in the low fines bitumen extract stream (83-206) may require the removal of the oleophilic fines that are in a stable suspension with the bitumen extract stream (83-202). The removal of these oleophilic fines can be assisted by precipitating asphaltenes and/or by adding additives to help aggregate the fines in the bitumen extract stream (83-202) into larger particles that can be more readily separated from the bitumen extract stream (83-202). Asphaltene precipitation can be induced by at least one of adding or removing solvent from the bitumen extract stream (83-202), changing the temperature of the bitumen extract stream (83-202), and changing the pressure of the bitumen extract stream (83-202). The solvent may be referred to as a second solvent. One way to induce asphaltene precipitation is to add a paraffinic solvent, such as but not limited to pentane, to the bitumen extract stream (83-202). Applicable additives that can be used to help aggregate the fines in the bitumen extract stream (83-202) include chemical additives, such as surfactants, flocculants, and coagulants. The chemical additive can be water soluble where an aqueous solution of the chemical additive is mixed with the bitumen extract stream (83-202). The chemical additive can be miscible with the bitumen extract stream (83-202). The chemical additive can be directly miscible in the hydrocarbon phase. Other classes of applicable additives that may be suitable include solid additives. Examples of solid additives include, but are not limited to, clays, molecular sieves, activated carbon, and carbon black. The solid additives, which may be much larger particles than the fines in the bitumen extract stream, may absorb and/or adsorb the fines in the bitumen extract stream prior to being separated from the bitumen extract stream.

[0981] The bitumen within the bitumen extract stream may remain in the low fines bitumen extract stream (83-206). For example, when the additive added to assist in separating the bitumen extract stream into the concentrated fines stream (83-208) and the low fines bitumen extract stream (83-206) from the fines is a water soluble additive, the water soluble additive makes the bitumen extract stream remain the dominant phase in the low fines bitumen extract stream as compared to the fines.

[0982] While not shown in Figure 83, the first solvent can be removed from the low fines bitumen extract stream (83-206) to produce a bitumen product stream (83-222), (86-512). Other solvent may also be removed from the low fines bitumen extract stream (83-206) to produce the bitumen product stream (83-222). The bitumen product stream (83-222) may be suitable for transport within pipelines and processing within downstream refineries. The bitumen product stream (83-222) may have a solids content of less than 0.5 wt. %, or less than 0.1 wt. %.

[0983] The method and system may comprise producing agglomerated fines (83-212) by agglomerating the concentrated fines stream (83-208), (86-506). The concentrated fines stream (83-208) may be agglomerated in an agglomeration process (83-210). The agglomerated fines (83-212) may be produced after the concentrated fines stream (83-208) exits the separator (83-204) to enter the agglomeration process (83-210).

[0984] Agglomerating the concentrated fines stream (83-208) may comprise adding a bridging liquid to the concentrated fines stream (83-208). The bridging liquid may assist in agglomerating the concentrated fines stream (83-208). The bridging liquid may be an aqueous liquid. The bridging liquid may include additional additives, referred to as agglomerating assistive additives, to ensure agglomeration of the oleophilic fines within the concentrated fines stream (83-208). The bridging liquid is a liquid with an affinity for solids particles in the concentrated fines stream (83-208). The bridging liquid may be immiscible in the first solvent. Exemplary aqueous liquids may be recycled water from other aspects or steps of oil sand processing. The aqueous liquid need not be pure water, and may 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.

[0985] The agglomeration process (83-210) 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 concentrated fines stream (83-208) need only be severe enough and of sufficient duration to intimately contact the bridging liquid with the solids in the concentrated fines stream (83-208). 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 may be needed to keep the agglomerated fines (83-212) in suspension. In rolling type vessels, the solids content of the concentrated fines stream (83-208) may be greater than 40 wt. % so that compaction forces assist agglomerated fines (83-212). The agitation of a slurry has an impact on the growth of the agglomerated fines (83-212). 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 agglomerated fines (83-212). Agglomeration of the concentrated fines stream may occur within a pipeline.

[0986] Before agglomerating the concentrated fines stream (83-208), the concentrated fines stream (83-208) may be mixed with additional solids. For example, the concentrated fines stream (83-208) may be mixed with an additional agglomerated solids and/or an oil sand slurry prior to agglomerating the concentrated fines stream (83-208). The larger sand particles that are within an oil sand slurry may provide additional surface for the concentrated fines stream (83-208) to agglomerate.

[0987] The method and system may comprise forming washed agglomerated fines (83-218) by washing the agglomerated fines (83-212), (86-508). The agglomerated fines (83-212) may be washed in a washing process (83-214). The washed agglomerated fines (83-218) may be formed after the agglomerated fines (83-212) exit the agglomerator process (83-210) to enter the washing process (83-214). The agglomerated fines (83-212) may be washed in the washing process (83-214) with a washing solvent (83-216). The agglomerated fines (83-212) may be washed in the washing process (83-214) with the washing solvent (83-216) with the aid of a filter. The filter may assist in removing residual bitumen extract from the agglomerated fines (83-212) to form the washed agglomerated fines (83-218). The washed agglomerated fines (83-218) may be placed directly on the filter. The agglomerated fines (83-212) may be washed counter-currently with the washing solvent (83-216). The filter may comprise a drying portion where the agglomerated fines are dried. The filter may incorporate the use of a condensable vapor to provide the heating medium to dry the agglomerated fines. The drying within the filter may sufficiently remove the solvent such that no additional solvent drying is required. Alternatively, the drying portion of the filter may minimize the content of solvent within the washed agglomerated fines (83-218) prior to drying within a TSRU. The filter may comprise a drainage portion upstream of a washing portion. The drainage portion may be for draining liquid from the filter. The washing portion may be for washing the agglomerated fines with the washing solvent. The washed agglomerated fines (83-218) may be mixed with additional agglomerated solids (for instance from an agglomerated oil sand slurry) prior to being filtered by the filter.

[0988] The method and system may comprise producing dry solids (83-222) by removing the washing solvent (83-220) from the washed agglomerated fines stream (83-218), (86-510). Other solvent, such as but not limited to the first solvent, may also be removed from the washed agglomerated fines stream (83-218) while producing the dry solids (83-222). The dry solids (83-222) may be produced in a TSRU (83-227). The dry solids (83-222) may be produced after the washed agglomerated fines stream (83-218) exits the washing process (83-214) to enter the

DEMANDES OU BREVETS VOLUMINEUX

LA PRÉSENTE PARTIE DE CETTE DEMANDE OU CE BREVETS COMPREND PLUS D'UN TOME.

CECI EST LE TOME __1___ DE __2 __

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JUMBO APPLICATIONS / PATENTS

THIS SECTION OF THE APPLICATION / PATENT CONTAINS MORE THAN ONE VOLUME.

THIS IS VOLUME __1___ OF __2___

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CLAIMS:

1. A solvent bitumen extraction with solids agglomeration method, the method comprising:

(a) inerting a bituminous feed to produce an inerted bituminous feed;

(b) adding a first solvent to the inerted bituminous feed and sizing the inerted bituminous feed to produce a sized bituminous feed;

(c) contacting the sized bituminous feed with a first high velocity fluid for ablating the sized bituminous feed, wherein the first high velocity fluid comes into contact with the sized bituminous feed at a velocity at least 5 times greater than a velocity of the sized bituminous feed;

(d) dissolving the sized bituminous feed in the first high velocity fluid to produce a dissolved bituminous slurry;

(e) contacting the dissolved bituminous slurry with a second high velocity fluid to produce an agglomerated slurry, wherein the second high velocity fluid comes into contact with the dissolved bituminous slurry at a velocity at least 5 times greater than a velocity of the dissolved bituminous slurry; and

(f) filtering, washing with a second solvent and desolventizing the agglomerated slurry.

2. The method of claim 1, wherein the bituminous feed is obtained from an oil sand mining operation.

3. The method of claim 1, wherein the bituminous feed is obtained from a process stream, product stream, and or waste stream of an oil sand water-based extraction process.

4. The method of claim 1, wherein the bituminous feed is sized in one or more crushers prior to being inerted.

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5. The method of claim 1, wherein the bituminous feed is stored within storage piles with a combined storage capacity of more than an hour of solvent bitumen extraction plant operation.

6. The method of claim 1, wherein the bituminous feed is stored within storage piles with a combined storage capacity of more than a day of solvent bitumen extraction plant operation.

7. The method of claim 5 or 6, wherein the bituminous feed is sized in one or more crushers prior to being directed to the storage piles.

8. The method of claim 1, wherein the bituminous feed is sized to have solids with a maximum diameter of 24 inches or less.

9. The method of claim 1, wherein the bituminous feed is partially dewatered prior to being inerted.

10. The method of claim 1, wherein the bituminous feed is mixed with a dry solids stream to form a resulting bituminous feed comprising a water content less than the bituminous feed, and wherein the dry solids stream comprises less than 1 wt. % bitumen and less than 8 wt. % water.

11. The method of claim 1, wherein the bituminous feed is mixed with a dry solids stream from an oil sand solvent-based extraction process to form a resulting bituminous feed comprising a water content less than the bituminous feed.

12. The method of claim 11, wherein the dry solids stream has less than 5 wt. % water.

13. The method of claim 1, wherein a third solvent is added to a mixture of the sized bituminous feed and the first high velocity fluid.

14. The method of claim 1, wherein the first solvent includes bitumen.

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15. The method of claim 1, wherein the second solvent includes bitumen.

16. The method of claim 13, wherein the third solvent includes bitumen.

17. The method of claim 13, wherein the third solvent is added as a fluid jet.

18. The method of claim 13, wherein the third solvent is added to a dissolution pipeline as a vapor or a two phase mixture.

19. The method of claim 13, wherein the third solvent is added to a dissolution pipeline downstream of a slurry pump.

20. The method of claim 13, wherein the first solvent, the second solvent or the third solvent comprises a hydrocarbon solvent.

21. The method of claim 13, wherein the first solvent, the second solvent or the third solvent comprises an aliphatic solvent.

22. The method of claim 13, wherein first solvent, the second solvent or the third solvent comprises cyclopentane, cyclohexane, or a combination thereof.

23. The method of claim 14, wherein the bitumen within the first solvent is partially deasphalted bitumen or is bitumen substantially free of asphaltenes.

24. The method of claim 15, wherein the bitumen within the second solvent is partially deasphalted bitumen or is bitumen substantially free of asphaltenes.

25. The method of claim 16, wherein the bitumen within the third solvent is partially deasphalted bitumen or is bitumen substantially free of asphaltenes.

26. The method of claim 1, wherein the inerted bituminous feed has a maximum oxygen concentration less than a limiting oxygen concentration required for combustion.

27. The method of claim 26, wherein the inerted bituminous feed has a maximum oxygen concentration of less than 3 mol. % within vapor spaces of the inerted bituminous feed.

28. The method of claim 1, wherein the inerting of the bituminous feeds allows for the bituminous feed to transition from an electrically non-classified region of a facility to an electrically classified region of the facility.

29. The method of claim 1, wherein a turndown ratio of the bituminous feed to the inerting is at least 3:1.

30. The method of claim 1, wherein the bituminous feed is examined for metal pieces prior to being directed to the inerting.

31. The method of claim 1, wherein the inerted feed is examined for metal pieces after being directed to the inerting and prior to being contacted with the first solvent.

32. The method of claim 1, wherein the inerted bituminous feed is sized using one or more solvent wet crushing devices.

33. The method of claim 1, wherein the inerted bituminous feed is sized in a rotating drum.

34. The method of claim 1, wherein the inerted bituminous feed is sized in a sizing device comprising at least a secondary sizing stage and a tertiary sizing stage.

35. The method of claim 34, wherein the tertiary sizing stage is a final sizing stage of the sizing device.

36. The method of claim 1, wherein the first high velocity fluid comes into contact with the sized bituminous feed at a velocity at least 10 times greater than a velocity of the sized bituminous feed.

37. The method of claim 1, wherein the first high velocity fluid comes into contact with the sized bituminous feed at a velocity at least 25 times greater than a velocity of the sized bituminous feed.

38. The method of claim 1, wherein the first high velocity fluid comes into contact with the sized bituminous feed at a velocity at least 50 times greater than a velocity of the sized bituminous feed.

39. The method of claim 1, wherein the sized bituminous feed is dissolved in the first high velocity fluid within a dissolution pipeline to produce the dissolved bituminous slurry.

40. The method of claim 1, wherein an oversized reject stream is separated from the dissolved bituminous slurry.

41. The method of claim 40, wherein a screen is used to separate the oversized reject stream from the dissolved bituminous slurry.

42. The method of claim 41, wherein the screen comprises openings that are nominally 2 to 10 mm in size.

43. The method of claim 41, wherein the screen is disposed without a vapor space above or below the screen.

44. The method of claim 41, wherein there is a vapor space above or below the screen.

45. The method of claim 40, wherein the oversized reject stream is washed with a third solvent to produce a washed reject stream and an undersized reject stream comprising solids and solvent-rich liquid.

46. The method of claim 40, wherein an antifoaming chemical or defoamer is added to the dissolved bituminous slurry prior to or after the separation of the oversized reject stream from the dissolved bituminous slurry.

47. The method of claim 40, wherein the dissolved bituminous slurry is subjected to a liquid spray prior to or after the separation of the oversized reject stream from the dissolved bituminous slurry.

48. The method of claim 45, wherein the washed reject stream is dried to produce a dry reject stream.

49. The method of claim 45, wherein the third solvent includes bitumen.

50. The method of claim 45, wherein an amount of third solvent addition is used to control a solvent to bitumen ratio in the dissolved bituminous slurry or the agglomerated slurry.

51. The method of claim 32, wherein the first solvent is added in more than one location to each of the one or more solvent wet crushing devices.

52. The method of claim 32, wherein the inerted bituminous feed is sized using the one or more solvent wet crushing devices, and wherein all of the first solvent is added to each of the one or more solvent wet crushing devices in a secondary sizing stage of each of the solvent wet crushing devices.

53. The method of claim 1, wherein the sized bituminous feed is settled in a hopper prior to being contacted with the first high velocity fluid.

54. The method of claim 1, wherein the sized bituminous feed comprises dissolved bitumen from the bituminous feed prior to being contacted with the first high velocity fluid.

55. The method of claim 53, wherein a third solvent is added during settling of the sized bituminous feed in the hopper.

56. The method of claim 55, wherein the third solvent is added as a vapor.

57. The method of claim 55, wherein the third solvent is added as a liquid at a temperature higher than the atmospheric boiling point of the third solvent.

58. The method of claim 55, wherein the third solvent is added as a fluid jet.

59. The method of claim 55, wherein the third solvent includes bitumen.

60. The method of claim 1, wherein a non-condensable gas volume fraction within the sized bituminous feed is less than 10 vol. % prior to being contacted with the first high velocity fluid.

61. The method of claim 60, wherein the non-condensable gas volume fraction within the sized bituminous feed is less than 1 vol. % prior to being contacted with the first high velocity fluid.

62. The method of claim 1, wherein the sized bituminous feed has a solid content in a range of 30 to 85 wt.% prior to being contacted with the first high velocity fluid.

63. The method of claim 45, wherein the oversized reject stream is sized prior to, during, or after the washing of the oversized reject stream.

64. The method of claim 45, wherein the undersized reject stream is combined with the dissolved bituminous slurry.

65. The method of claim 64, wherein the combining of the undersized reject stream with the dissolved bituminous slurry increases a solvent to bitumen ratio of the dissolved bituminous slurry.

66. The method of claim 1, wherein the second high velocity fluid comes into contact with the dissolved bituminous slurry at a velocity at least 10 times greater than a velocity of the dissolved bituminous slurry.

67. The method of claim 1, wherein the second high velocity fluid comes into contact with the dissolved bituminous slurry at a velocity at least 25 times greater than a velocity of the dissolved bituminous slurry.

68. The method of claim 1, wherein the second high velocity fluid comes into contact with the dissolved bituminous slurry at a velocity at least 50 times greater than a velocity of the dissolved bituminous slurry.

69. The method of claim 1, wherein the dissolved bituminous slurry comprises a non-condensable gas volume fraction of less than 1 vol. % prior to being contacted with the second high velocity fluid.

70. The method of claim 1, wherein a solvent to bitumen ratio of the dissolved bituminous slurry is greater than 3:1.

71. The method of claim 1, wherein a solvent to bitumen ratio of the dissolved bituminous slurry is greater than 5:1.

72. The method of claim 1, wherein a solvent to bitumen ratio of the dissolved bituminous slurry is greater than 7:1.

73. The method of claim 1, wherein the sized bituminous feed is contacted with the first high velocity fluid by directing the sized bituminous feed to a first jet pump and using the first high velocity fluid as a motive fluid in the first jet pump.

74. The method of claim 45, wherein the oversized reject stream is washed and then scrubbed in a scrubbing device to produce the washed reject stream and the undersized reject stream.

75. The method of claim 74, wherein a third solvent is added within the scrubbing device.

76. The method of claim 74 or 75, wherein the scrubbing device is downstream of a wet sizing device and wherein the wet sizing device receives a portion of the third solvent.

77. The method of claim 76, wherein the wet sizing device is a wet crusher.

78. The method of claim 74, wherein the scrubbing device produces a fluid jet wash from a wash liquid at a pressure of greater than 500 psig.

79. The method of claim 74, wherein the scrubbing device produces a fluid jet wash from a wash liquid at a pressure of greater than 2000 psig.

80. The method of claim 78, wherein the fluid jet wash is produced from a rotating nozzle.

81. The method of claim 75, wherein the third solvent comprises an aqueous solution.

82. The method of claim 1, wherein the dissolved bituminous slurry is contacted with the second high velocity fluid and with a bridging liquid to produce the agglomerated slurry.

83. The method of claim 82, wherein the bridging liquid comprises mine runoff.

84. The method of claim 82, wherein the bridging liquid comprises steam.

85. The method of claim 84, wherein the steam is of a quality of 75% or less.

86. The method of claim 1, wherein the filtering, washing and desolventizing of the agglomerated slurry produces a rich extract stream, a lean extract stream, and a desolventized dry solids stream.

87. The method of claim 86, wherein an aqueous liquid is separated from the rich extract stream or the lean extract stream.

88. The method of claim 87, wherein the aqueous liquid is made to separate from the rich extract stream or the lean extract stream by changing the rich or lean extract stream temperature, solvent content or by adding chemical additives to the rich or lean extract streams.

89. The method of claim 87, wherein the aqueous liquid is made to separate from the rich extract stream or the lean extract stream by electrocoalescence of the aqueous liquid.

90. The method of claim 87, wherein the aqueous liquid is made to separate from the rich extract stream or the lean extract stream by gravity-assisted separation.

91. The method of claim 48, wherein steam or superheated steam is added to the washed reject stream to assist in producing the dry reject stream.

92. The method of claim 45, wherein hot water is added to the washed reject stream.

93. The method of claim 91 or 92, wherein the dissolved bituminous slurry is contacted with the second high velocity fluid and with a bridging liquid to produce the agglomerated slurry, and wherein collected water after the contact with the washed reject stream is used as at least a portion of the bridging liquid.

94. The method of claim 45, wherein a stripping gas is added to the washed reject stream.

95. The method of claim 94, wherein the stripping gas comprises nitrogen gas.

96. The method of claim 94, wherein the stripping gas comprises greater than 50 mol. % methane.

97. The method of claim 94, wherein after the stripping gas is added to the washed reject stream a second stripping gas is added to the washed reject stream and wherein the second stripping gas is air.

98. The method of claim 45, wherein the second high velocity fluid comprises all or a portion of the undersized reject stream.

99. The method of claim 1, wherein the dissolved bituminous slurry is contacted with the second high velocity fluid by directing the dissolved bituminous slurry to a second jet pump and using the second high velocity fluid as a motive fluid in the second jet pump.

100. The method of claim 82, wherein the second high velocity fluid is mixed with the bridging liquid prior to the second high velocity fluid coming into contact with the dissolved bituminous slurry.

101. The method of claim 100, wherein the bridging liquid forms an emulsion with the second high velocity fluid and wherein the second high velocity fluid is a continuous phase of the formed emulsion.

102. The method of claim 82, wherein a bridging liquid-in-hydrocarbon fluid emulsion is formed within the agglomerated slurry by using a mechanical device in-line to a flow of the agglomerated slurry.

103. The method of claim 102, wherein the mechanical device used to form the emulsion in-line to the flow of the agglomerated slurry is a jet pump or a static mixer.

104. The method of claim 82, wherein the second high velocity fluid is mixed with the dissolved bituminous slurry prior to the second high velocity fluid coming into contact with the bridging liquid.

105. The method of claim 82, wherein the second high velocity fluid, the dissolved bituminous slurry, and the bridging liquid are mixed together at the same time.

106. The method of claim 82, wherein the bridging liquid is emulsified within the agglomerated slurry by flowing the agglomerated slurry through in-line static mixers.

107. The method of claim 82, wherein the bridging liquid is emulsified by mixing the bridging liquid as a fluid jet with a mixture comprising the second high velocity fluid and the dissolved bituminous slurry.

108. The method of claim 82, wherein additional bridging liquid is mixed with the agglomerated slurry.

109. The method of claim 108, wherein agglomerated slurry is further agglomerated within an agglomeration pipeline.

110. The method of claim 109, wherein the additional bridging liquid is added to the agglomeration pipeline.

111. The method of claim 109, wherein the additional bridging liquid is added to the agglomeration pipeline as an emulsion.

112. The method of claim 109, wherein a section of the agglomeration pipeline comprises a screen arranged in a pipe-in-pipe fashion, wherein the screen acts to increase a solids concentration of the agglomerated slurry prior to filtering and washing the agglomerated slurry.

113. The method of claim 1, wherein an antifoaming chemical or defoamer is added to the agglomerated slurry prior to the filtering, washing or desolventizing of the agglomerated slurry.

114. The method of claim 1, wherein the agglomerated slurry is subjected to a liquid spray prior to the filtering, washing or desolventizing of the agglomerated slurry.

115. The method of claim 1, wherein the filtering, washing and desolventizing of the agglomerated slurry is conducted using a condensable gas stream.

116. The method of claim 115, wherein the condensable gas stream comprises saturated solvent vapor.

117. The method of claim 115, wherein the condensable gas stream comprises superheated solvent vapor.

118. The method of claim 115, wherein the condensable gas stream comprises saturated steam.

119. The method of claim 115, wherein the condensable gas stream comprises superheated steam.

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120. The method of claim 86, wherein solvent is recovered from at least a portion of the rich extract stream to produce at least one bitumen stream.

121. The method of claim 86, wherein the desolventized dry solids stream is conditioned to produce stackable solids.

122. The method of claim 86, further comprising recovering solvent from at least a portion of the lean extract stream to produce at least one bitumen stream.

123. The method of claim 120, wherein the filtering, washing and desolventizing of the agglomerated slurry is conducted using a condensable gas stream, and wherein the condensable gas stream comprises the solvent recovered from the rich extract stream.

124. The method of claim 115, wherein the condensable gas stream is at a temperature 50 °C greater than an atmospheric boiling point temperature of the second solvent saturating the agglomerated slurry.

125. The method of claim 115, wherein the condensable gas stream sufficiently heats the agglomerated slurry such that a vapor pressure of the second solvent is greater than 100 kPa above an operating pressure of the desolventizing process.

126. The method of claim 115, wherein the condensable gas stream sufficiently heats the agglomerated slurry such that a vapor pressure of the second solvent is greater than 200 kPa above an operating pressure of the desolventizing.

127. The method of claim 115, wherein the condensable gas stream sufficiently heats the agglomerated slurry such that a vapor pressure of the second solvent is greater than 300 kPa above an operating pressure of the desolventizing.

128. The method of claim 115, wherein the condensable gas is condensed within a heat exchanger and wherein the heat from the condensable gas is transferred to another process stream within a facility of the solvent bitumen extraction with solids agglomeration method.

129. The method of claim 1, wherein a non-condensable gas is used as a sweep gas during the filtering, washing or desolventizing of the agglomerated slurry.

130. The method of claim 1, wherein the filtering of the agglomerated slurry occurs on a filter media which has an average opening size in a range from 1% to 70% of a D50 particle size of the agglomerated slurry.

131. The method of claim 1, wherein the filtering of the agglomerated slurry occurs on a filter media which has an average opening size in a range from 1 micron to 170 microns.

132. The method of claim 1, wherein the filtering of the agglomerated slurry occurs on a filter media which has a cross-weave design.

133. The method of claim 1, wherein the filtering of the agglomerated slurry occurs on a filter media which has a linear opening design.

134. The method of claim 86, wherein residual solids are removed from the rich extract stream to produce a low solids rich extract stream wherein the solids concentration of the low solids rich extract stream is less than 1 wt. %, on a dry bitumen basis.

135. The method of claim 86, wherein residual solids are removed from the rich extract stream to produce a low solids rich extract stream wherein a solids concentration of the low solids rich extract stream is less than 0.1 wt. %, on a dry bitumen basis.

136. The method of claim 86, wherein residual solids are removed from the lean extract stream to produce a low solids lean extract stream wherein a solids concentration of the low solids lean extract stream is less than 1 wt. %, on a dry bitumen basis.

137. The method of claim 86, wherein residual solids are removed from the lean extract stream to produce a low solids lean extract stream wherein a solids concentration of the low solids lean extract stream is less than 0.1 wt. %, on a dry bitumen basis.

138. The method of claim 120, wherein residual solids are removed from the bitumen stream to produce a low solids bitumen stream wherein a solids concentration of the low solids bitumen stream is less than 1 wt. %, on a dry bitumen basis.

139. The method of claim 120, wherein residual solids are removed from the bitumen stream to produce a low solids bitumen stream wherein a solids concentration of the low solids bitumen stream is less than 0.1 wt. %, on a dry bitumen basis.

140. The method of claim 86, wherein solvent is recovered from at least a portion of the rich extract stream to produce at least one bitumen stream and wherein residual solids are removed from the bitumen stream to produce a low solids bitumen stream where the solids concentration of the low solids bitumen stream is less than 1 wt. %, on a dry bitumen basis.

141. The method of claim 140, wherein the solids concentration of the low solids bitumen stream is less than 0.1 wt. %, on a dry bitumen basis.

142. The method of any one of claims 134 to 141, wherein the residual solids are removed by precipitating asphaltenes using an aliphatic solvent in a deasphalting unit.

143. The method of claim 142, wherein the deasphalting unit comprises a first separator and a second separator arranged in series, wherein the first separator receives a feed stream comprising the rich extract stream, the lean extract stream, or the desolventized dry solids

stream and a liquid overflow from the second separator and produces a low solids product stream, and wherein the second separator receives a solids underflow from the first separator and an aliphatic solvent and produces a residual solids stream.

144. The method of claim 142, wherein the deasphalting unit comprises three or more separators arranged in series, wherein each separator except for the first separator, receives a solids underflow from an upstream separator and a liquid overflow from a downstream separator, wherein a first separator in the series receives a feed stream comprising the rich extract stream, the lean extract stream, or the desolventized dry solids stream and produces a low solids product stream, and wherein a last separator in the series receives an aliphatic solvent and produces a residual solids stream.

145. The method of claim 1, wherein a portion of the dissolved bituminous slurry is recirculated to a front end of a dissolution pipeline or equipment upstream of the dissolution pipeline.

146. The method of claim 1, wherein an overhead stream is separated from the dissolved bituminous slurry prior to contacting the dissolved bituminous slurry with the second high velocity fluid.

147. The method of claim 146, wherein an antifoaming chemical or defoamer is added to the dissolved bituminous slurry prior to or after the separation of the at least one overhead stream from the dissolved bituminous slurry.

148. The method of claim 146, wherein the dissolved bituminous slurry is subjected to a liquid spray prior to or after the separation of the oversized reject stream from the dissolved bituminous slurry.

149. The method of claim 146, wherein the overhead stream comprises a first overhead stream and a second overhead stream and wherein the first overhead stream has a higher solids concentration than the second overhead stream.

150. The method of claim 146, wherein the overhead stream comprises a first overhead stream and a second overhead stream and wherein the first overhead stream has the same solids concentration as the second overhead stream.

151. The method of claim 146, wherein all or a portion of the overhead stream is recirculated to a dissolution pipeline or equipment upstream of the dissolution pipeline.

152. The method of claim 149 or 150, wherein the second overhead stream is recirculated to a dissolution pipeline or equipment upstream of the dissolution pipeline.

153. The method of claim 145, wherein the portion of the dissolved bituminous slurry is recirculated and injected into a hopper comprising the sized bituminous feed.

154. The method of claim 146, wherein the second high velocity fluid comprises all or a portion of the overhead stream.

155. The method of claim 146, wherein the overhead stream has a solids concentration of less than 10 wt. %.

156. The method of claim 146, wherein the overhead stream is separated from the dissolved bituminous slurry within a gravity separating device.

157. The method of claim 156, wherein the gravity separating device is a hopper, a clarifier, or a thickener.

158. The method of claim 146, wherein the overhead stream comprises a first overhead stream and a second overhead stream, wherein the first overhead stream has a higher solids concentration than the second overhead stream, and wherein the first overhead stream is withdrawn from a gravity separating device at a lower level than where the second overhead stream is withdrawn from the gravity separating device.

159. The method of claim 146, wherein the overhead stream comprises a first overhead stream and a second overhead stream, wherein the first overhead stream has the same solids concentration as the second overhead stream, and wherein the first overhead stream is withdrawn from a gravity separating device at a same level as the second overhead stream is withdrawn from the gravity separating device.

160. The method of claim 156, wherein the gravity separating device comprises a vapor space where it receives the dissolved bituminous slurry.

161. The method of claim 156, wherein the gravity separating device comprises internal structures to reduce a momentum of the dissolved bituminous slurry and to assist in gas disengagement while feeding of the dissolved bituminous slurry to the gravity separating device.

162. The method of claim 161, wherein the internal structures within the gravity separating device comprise baffles or shelves.

163. The method of claim 149 or 150, wherein the second high velocity fluid comprises the first overhead stream.

164. The method of claim 1, wherein step a) is effected within an inerting system comprising a hopper.

165. The method of claim 164, wherein the bituminous feed is inerted within the inerting system comprising the hopper followed by an enclosed conveyor.

166. The method of claim 164, wherein the bituminous feed is inerted within the inerting system comprising the hopper followed by at least one additional hopper, wherein the hoppers are arranged in series.

167. The method of claim 164, wherein the hopper within the inerting system comprises a solids plug located at a bottom exit of the hopper.

168. The method of claim 167, wherein the solids plug comprises the bituminous feed.

169. The method of claim 167, wherein a height of the solids plug within the hopper is monitored continuously in order to maintain a minimum height.

170. The method of claim 164, wherein a solids residence time within the hopper is less than 10 minutes.

171. The method of claim 164, wherein a solids residence time within the hopper is less than 5 minutes.

172. The method of claim 164, wherein the inerted bituminous feed has a maximum oxygen concentration less than a limiting oxygen concentration required for combustion.

173. The method of claim 172, wherein the inerted bituminous feed has a maximum oxygen concentration of less than 3 mol. % within vapor spaces of the inerted bituminous feed.

174. The method of claim 164, wherein the inerting of the bituminous feed allows for the bituminous feed to transition from an electrically non-classified region of a facility to an electrically classified region of the facility.

175. The method of claim 164, wherein a turndown ratio of the bituminous feed to the inerting is at least 3:1.

176. The method of claim 164, wherein the bituminous feed is examined for metal pieces prior to being directed to the inerting.

177. The method of claim 164, wherein the inerted feed is examined for metal pieces after being directed to the inerting and prior to being contacted with solvent.

178. The method of claim 164, wherein the first solvent includes bitumen.

179. The method of claim 164, wherein the second solvent includes bitumen.

180. The method of claim 164, wherein a third solvent is added to a mixture of the sized bituminous feed and the first fluid.

181. The method of claim 180, wherein the third solvent includes bitumen.

182. The method of claim 180, wherein the third solvent is added as a fluid jet.

183. The method of claim 180, wherein the third solvent is added to a dissolution pipeline as a vapor or a two phase mixture.

184. The method of claim 180, wherein the third solvent is added to a dissolution pipeline downstream of a slurry pump.

185. The method of claim 180, wherein the first solvent, the second solvent or the third solvent comprises a hydrocarbon solvent.

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186. The method of claim 180, wherein the first solvent, the second solvent or the third solvent comprises an aliphatic solvent.

187. The method of claim 180, wherein first solvent, the second solvent or the third solvent comprises cyclopentane, cyclohexane, or a combination thereof.

188. The method of claim 178, wherein the bitumen within the first solvent is partially deasphalted bitumen or is bitumen substantially free of asphaltenes.

189. The method of claim 179, wherein the bitumen within the second solvent is partially deasphalted bitumen or is bitumen substantially free of asphaltenes.

190. The method of claim 181, wherein the bitumen within the third solvent is partially deasphalted bitumen or is bitumen substantially free of asphaltenes.

191. A solvent bitumen extraction with solids agglomeration method, the method comprising:

(a) inerting a bituminous feed to produce an inerted bituminous feed;

(b) adding a first solvent to the inerted bituminous feed and sizing the inerted bituminous feed to produce a sized bituminous feed;

(c) contacting the sized bituminous feed with a first high velocity fluid within a jet pump for ablating the sized bituminous feed, wherein the first high velocity fluid is a motive fluid of the jet pump, wherein the jet pump is made to operate at a condition of cavitation, and wherein the first high velocity fluid comes into contact with the sized bituminous feed at a velocity at least 5 times greater than a velocity of the sized bituminous feed;

(d) dissolving the sized bituminous feed in the first high velocity fluid to produce a dissolved bituminous slurry;

(e) contacting the dissolved bituminous slurry with a second fluid to produce an agglomerated slurry; and

(f) filtering, washing with a second solvent and desolventizing the agglomerated slurry.

192. The method of claim 191, wherein the jet pump comprises multiple jet pumps that are arranged in parallel.

193. The method of claim 191, wherein the jet pump operates at a condition of cavitation by increasing a velocity of the first high velocity fluid.

194. The method of claim 191, wherein the jet pump operates at a condition of cavitation by increasing a temperature of the bituminous slurry or the first high velocity fluid.

195. The method of claim 191, wherein the jet pump operates at a condition of cavitation by having a mixing section of the jet pump be large enough to promote further pressure drop in the mixing section.

196. The method of claim 191, wherein a mixing section of the jet pump is large enough to facilitate lump ablation and scrubbing action within the mixing section.

197. The method of claim 191, wherein the jet pump operates at a condition of cavitation by having an opening of a motive fluid nozzle be a non-circular geometry.

198. The method of claim 191, wherein the jet pump operates at a condition of cavitation by reducing a backpressure to the jet pump.

199. The method of claim 192, wherein a number of the multiple jet pumps that are operating and receiving the sized bituminous feed is adjusted depending on operating conditions of the jet pumps.

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200. The method of claim 191, wherein one or more slurry pumps is placed downstream of the jet pump to increase a pressure of combined mixture of the sized bituminous feed and the first high velocity fluid.

201. The method of claim 191, wherein a third solvent is added to a mixture of the sized bituminous feed and the first high velocity fluid.

202. The method of claim 201, wherein the third solvent includes bitumen.

203. The method of claim 201, wherein the third solvent is added as a fluid jet.

204. The method of claim 201, wherein the third solvent is added to a dissolution pipeline as a vapor or a two phase mixture.

205. The method of claim 201, wherein the third solvent is added to a dissolution pipeline downstream of a slurry pump.

206. The method of claim 204, wherein one or more static mixers are disposed along a length of the dissolution pipeline.

207. The method of claim 191, wherein the first solvent includes bitumen.

208. The method of claim 191, wherein the second solvent includes bitumen.

209. The method of claim 201, wherein the first solvent, the second solvent or the third solvent comprises a hydrocarbon solvent.

210. The method of claim 201, wherein the first solvent, the second solvent or the third solvent comprises an aliphatic solvent.

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211. The method of claim 201, wherein first solvent, the second solvent or the third solvent comprises cyclopentane, cyclohexane, or a combination thereof.

212. The method of claim 207, wherein the bitumen within the first solvent is partially deasphalted bitumen or is bitumen substantially free of asphaltenes.

213. The method of claim 208, wherein the bitumen within the second solvent is partially deasphalted bitumen or is bitumen substantially free of asphaltenes.

214. The method of claim 202, wherein the bitumen within the third solvent is partially deasphalted bitumen or is bitumen substantially free of asphaltenes.

215. A solvent bitumen extraction with solids agglomeration method, the method comprising:

(a) inerting a bituminous feed to produce an inerted bituminous feed;

(b) adding a first solvent to the inerted bituminous feed and sizing the inerted bituminous feed to produce a sized bituminous feed;

(c) contacting the sized bituminous feed with a first fluid;

(d) dissolving the sized bituminous feed in the first fluid to produce a dissolved bituminous slurry;

(e) contacting the dissolved bituminous slurry with a high velocity fluid to produce an agglomerated slurry within a jet pump, wherein the high velocity fluid is a motive fluid of the jet pump, wherein the jet pump is made to operate at a condition of cavitation and wherein the high velocity fluid comes into contact with the dissolved bituminous slurry at a velocity at least 5 times greater than a velocity of the dissolved bituminous slurry; and

(f) filtering, washing with a second solvent and desolventizing the agglomerated slurry.

216. The method of claim 215, wherein the jet pump comprises multiple jet pumps that are arranged in parallel.

217. The method of claim 215, wherein the jet pump operates at the condition of cavitation by increasing a velocity of the high velocity fluid.

218. The method of claim 215, wherein the jet pump operates at the condition of cavitation by increasing a temperature of the dissolved bituminous slurry or the high velocity fluid.

219. The method of claim 216, wherein a number of the jet pumps that are operating and receiving the dissolved bituminous slurry is adjusted depending on operating conditions of the jet pumps.

220. The method of claim 216, wherein the sized bituminous feed is contacted with the fluid within a jet pump.

221. The method of claim 220, wherein the jet pump is made to operate at a condition of cavitation.

222. The method of claim 215, wherein one or more slurry pumps are disposed downstream of the jet pump to increase a pressure of the agglomerated slurry.

223. The method of claim 215, wherein the dissolved bituminous slurry is contacted with the high velocity fluid and with a bridging liquid to produce the agglomerated slurry.

224. The method of claim 223, wherein the bridging liquid is emulsified by introducing the bridging liquid within the jet pump.

225. The method of claim 215, wherein the filtering, washing and desolventizing of the agglomerated slurry produces a rich extract stream, a lean extract stream, and a desolventized dry solids stream.

226. The method of claim 225, wherein an aqueous liquid is separated from the rich extract stream or the lean extract stream.

227. The method of claim 226, wherein the aqueous liquid is made to separate from the rich extract stream or the lean extract stream by changing the rich or lean extract stream temperature, solvent content or by adding chemical additives to the rich or lean extract streams.

228. The method of claim 226, wherein the aqueous liquid is made to separate from the rich extract stream or the lean extract stream by electrocoalescence of the aqueous liquid.

229. The method of claim 226, wherein the aqueous liquid is made to separate from the rich extract stream or the lean extract stream by gravity-assisted separation.

230. The method of claim 225, wherein residual solids are removed from the rich extract stream to produce a low solids rich extract stream and wherein a solids concentration of the low solids rich extract stream is less than 1 wt. %, on a dry bitumen basis.

231. The method of claim 225, wherein residual solids are removed from the rich extract stream to produce a low solids rich extract stream and wherein a solids concentration of the low solids rich extract stream is less than 0.1 wt. %, on a dry bitumen basis.

232. The method of claim 225, wherein residual solids are removed from the lean extract stream to produce a low solids lean extract stream and wherein a solids concentration of the low solids lean extract stream is less than 1 wt. %, on a dry bitumen basis.

233. The method of claim 225, wherein residual solids are removed from the lean extract stream to produce a low solids lean extract stream and wherein a solids concentration of the low solids lean extract stream is less than 0.1 wt. %, on a dry bitumen basis.

234. The method of claim 225, wherein solvent is recovered from at least a portion of the rich extract stream to produce at least one bitumen stream wherein residual solids are removed from the bitumen stream to produce a low solids bitumen stream and wherein a solids concentration of the low solids bitumen stream is less than 1 wt. %, on a dry bitumen basis.

235. The method of claim 234, wherein the solids concentration of the low solids bitumen stream is less than 0.1 wt. %, on a dry bitumen basis.

236. The method of claim 215, wherein a third solvent is added to a mixture of the sized bituminous feed and the first fluid.

237. The method of claim 215, wherein the first solvent includes bitumen.

238. The method of claim 215, wherein the second solvent includes bitumen.

239. The method of claim 236, wherein the third solvent includes bitumen.

240. The method of claim 236, wherein the first solvent, the second solvent or the third solvent comprises a hydrocarbon solvent.

241. The method of claim 236, wherein the first solvent, the second solvent or the third solvent comprises an aliphatic solvent.

242. The method of claim 236, wherein the first solvent, the second solvent or the third solvent comprises cyclopentane, cyclohexane, or a combination thereof.

243. The method of claim 237, wherein the bitumen within the first solvent is partially deasphalted bitumen or is bitumen substantially free of asphaltenes.

244. The method of claim 238, wherein the bitumen within the second solvent is partially deasphalted bitumen or is bitumen substantially free of asphaltenes.

245. The method of claim 239, wherein the bitumen within the third solvent is partially deasphalted bitumen or is bitumen substantially free of asphaltenes.

246. A solvent bitumen extraction with solids agglomeration method, the method comprising:

(a) inerting a bituminous feed to produce an inerted bituminous feed;

(b) adding a first solvent to the inerted bituminous feed and sizing the inerted bituminous feed to produce a sized bituminous feed;

(c) contacting the sized bituminous feed with a first fluid;

(d) dissolving the sized bituminous feed in the first fluid to produce a dissolved bituminous slurry;

(e) contacting the dissolved bituminous slurry with a second fluid to produce an agglomerated slurry;

(f) filtering, washing with a second solvent and desolventizing the agglomerated slurry to produce a rich extract stream and a lean extract stream;

(g) recovering solvent from at least a portion of the rich extract stream to produce at least one bitumen stream;

(h) removing residual solids from the rich extract stream, the lean extract stream, or the bitumen stream by precipitating asphaltenes using an aliphatic solvent to produce a residual solids stream; and

(i) adding water to the residual solids stream to produce a water containing slurry and recovering solvent from the water containing slurry in a tailings solvent recovery unit.

247. The method of claim 246, wherein the tailings solvent recovery unit recovers solvent from the water containing slurry by dropping a pressure of the water containing slurry and using steam to strip the solvent from the water containing slurry.

248. The method of claim 246, wherein the tailings solvent recovery unit comprises at least two columns and wherein the at least two columns are arranged in series or parallel.

249. The method of claim 246, wherein the tailings solvent recovery unit comprises at least one column operated under vacuum.

250. The method of claim 246, wherein the water containing slurry has a water content of at least 50 wt%.

251. The method of claim 246, wherein the water added to the residual solids stream to produce the water containing slurry is added in an amount sufficient to manage flow assurance within the tailings solvent recovery unit.

252. The method of claim 246, wherein the tailings solvent recovery unit is a tailings solvent recovery unit that is part of the paraffinic froth treatment process of a water-based extraction facility.

253. The method of claim 246, wherein the residual solids are removed from the rich extract stream to produce a low solids rich extract stream and wherein a solids concentration of the low solids rich extract stream is less than 1 wt. %, on a dry bitumen basis.

254. The method of claim 246, wherein the residual solids are removed from the rich extract stream to produce a low solids rich extract stream and wherein a solids concentration of the low solids rich extract stream is less than 0.1 wt. %, on a dry bitumen basis.

255. The method of claim 246, wherein the residual solids are removed from the lean extract stream to produce a low solids lean extract stream and wherein a solids concentration of the low solids lean extract stream is less than 1 wt. %, on a dry bitumen basis.

256. The method of claim 246, wherein residual solids are removed from the lean extract stream to produce a low solids lean extract stream and wherein the solids concentration of the low solids lean extract stream is less than 0.1 wt. %, on a dry bitumen basis.

257. The method of claim 246, wherein the residual solids are removed from the bitumen stream to produce a low solids bitumen stream and wherein a solids concentration of the low solids bitumen stream is less than 1 wt. %, on a dry bitumen basis.

258. The method of claim 246, wherein the residual solids are removed from the bitumen stream to produce a low solids bitumen stream and wherein a solids concentration of the low solids bitumen stream is less 0.1 wt. %, on a dry bitumen basis.

259. The method of claim 246, wherein step (h) is effected in a deasphalting unit.

260. The method of claim 259, wherein the deasphalting unit comprises a first separator and a second separator arranged in series, wherein the first separator receives a feed stream comprising the rich extract stream, the lean extract stream, or the bitumen stream and a liquid overflow from the second separator and produces a low solids product stream, and wherein the second separator receives the aliphatic solvent and a solids underflow from the first separator and produces the residual solids stream.

261. The method of claim 259, wherein the deasphalting unit comprises three or more separators arranged in series, wherein each separator except for a first separator, receives a solids underflow from an upstream separator and a liquid overflow from a downstream separator, wherein the first separator in the series receives a feed stream comprising the rich extract stream, the lean extract stream, or the bitumen stream and produces a low solids product stream, and wherein a last separator in the series receives the aliphatic solvent and produces the residual solids stream.

262. The method of any one of claims 246 to 261, wherein the first fluid is a first high velocity fluid, wherein the first high velocity fluid comes into contact with the sized bituminous feed at a velocity at least 5 times greater than a velocity of the sized bituminous feed.

263. The method of any one of claims 246 to 262, wherein the second fluid is a second high velocity fluid, wherein the second high velocity fluid comes into contact with the dissolved bituminous slurry at a velocity at least 5 times greater than a velocity of the dissolved bituminous slurry.

264. The method of any one of claims 246 to 263, wherein an aqueous liquid is separated from the rich extract stream or the lean extract stream.

265. The method of claim 264, wherein the aqueous liquid is made to separate from the rich extract stream or the lean extract stream by changing the rich or lean extract stream temperature, solvent content or by adding chemical additives to the rich or lean extract streams.

266. The method of claim 264, wherein the aqueous liquid is made to separate from the rich extract stream or the lean extract stream by electrocoalescence of the aqueous liquid.

267. The method of claim 264, wherein the aqueous liquid is made to separate from the rich extract stream or the lean extract stream by gravity-assisted separation.

268. A solvent bitumen extraction with solids agglomeration method, the method comprising:

(a) inerting a bituminous feed to produce an inerted bituminous feed;

(b) adding a first solvent to the inerted bituminous feed and sizing the inerted bituminous feed to produce a sized bituminous feed;

(c) settling the sized bituminous feed;

(d) contacting the sized bituminous feed with a first fluid;

(e) dissolving the sized bituminous feed in the first fluid in a dissolution pipeline to produce a dissolved bituminous slurry;

(f) separating an oversized reject stream from the dissolved bituminous slurry;

(g) washing the oversized reject stream with a second solvent to produce a washed reject stream and an undersized reject stream comprising solids and solvent-rich liquid;

(h) drying the washed reject stream to produce a dry reject stream;

(i) separating an overhead stream from the dissolved bituminous slurry;

(j) contacting the dissolved bituminous slurry with a second fluid to produce an agglomerated slurry;

(k) further agglomerating the agglomerated slurry in an agglomeration pipeline to produce a further agglomerated slurry;

(l) filtering, washing with a third solvent and desolventizing with a condensable gas stream the further agglomerated slurry to produce a rich extract stream, a lean extract stream, and a desolventized dry solids stream;

(m) recovering solvent from at least a portion of the rich extract stream to produce at least one bitumen stream; and

(n) conditioning the desolventized dry solids stream to produce stackable solids.

269. The method of claim 268, wherein the first solvent includes bitumen.

270. The method of claim 268, wherein the second solvent includes bitumen.

271. The method of claim 268, wherein the third solvent includes bitumen.

272. The method of claim 268, wherein the third solvent is added as an ablating jet.

273. The method of claim 268, wherein the third solvent is added to a dissolution pipeline as a vapor or a two phase mixture.

274. The method of claim 268, wherein the third solvent is added to a dissolution pipeline downstream of a slurry pump.

275. The method of claim 268, wherein the first solvent, the second solvent or the third solvent comprises a hydrocarbon solvent.

276. The method of claim 268, wherein the first solvent, the second solvent or the third solvent comprises an aliphatic solvent.

277. The method of claim 268, wherein first solvent, the second solvent or the third solvent comprises cyclopentane, cyclohexane, or a combination thereof.

278. The method of claim 269, wherein the bitumen within the first solvent is partially deasphalted bitumen or is bitumen substantially free of asphaltenes.

279. The method of claim 270, wherein the bitumen within the second solvent is partially deasphalted bitumen or is bitumen substantially free of asphaltenes.

280. The method of claim 271, wherein the bitumen within the third solvent is partially deasphalted bitumen or is bitumen substantially free of asphaltenes.

281. The method of claim 268, wherein the stackable solids comprise minimal free liquid.

282. The method of claim 268, wherein the conditioning of the desolventized solids to produce the stackable solids comprises aerating the desolventized solids such that the stackable solids comprise sufficient oxygen so as to not result in an asphyxiation risk.

283. The method of any one of claims 268 to 282, wherein the first fluid is a first high velocity fluid, wherein the first high velocity fluid comes into contact with the sized bituminous feed at a velocity at least 5 times greater than a velocity of the sized bituminous feed.

284. The method of any one of claims 268 to 282, wherein the second fluid is a second high velocity fluid, wherein the second high velocity fluid comes into contact with the dissolved bituminous slurry at a velocity at least 5 times greater than a velocity of the dissolved bituminous slurry.

285. The method of any one of claims 268 to 282, wherein the first fluid is a first high velocity fluid and wherein the second fluid is a second high velocity fluid, wherein the first high velocity fluid comes into contact with the sized bituminous feed at a velocity at least 5 times greater than a velocity of the sized bituminous feed, and wherein the second high velocity fluid comes into contact with the dissolved bituminous slurry at a velocity at least 5 times greater than a velocity of the dissolved bituminous slurry.

286. The method of claim 283, wherein the first fluid comes into contact with the sized bituminous feed at a velocity at least 10 times greater than a velocity of the sized bituminous feed.

287. The method of claim 286, wherein the first fluid comes into contact with the sized bituminous feed at a velocity at least 25 times greater than a velocity of the sized bituminous feed.

288. The method of claim 287, wherein the first fluid comes into contact with the sized bituminous feed at a velocity at least 50 times greater than a velocity of the sized bituminous feed.

289. The method of claim 284, wherein the second fluid comes into contact with the dissolved bituminous slurry at a velocity at least 10 times greater than a velocity of the dissolved bituminous slurry.

290. The method of claim 289, wherein the second fluid comes into contact with the dissolved bituminous slurry at a velocity at least 25 times greater than a velocity of the dissolved bituminous slurry.

291. The method of claim 290, wherein the second fluid comes into contact with the dissolved bituminous slurry at a velocity at least 50 times greater than a velocity of the dissolved bituminous slurry.

292. The method of claim 268, wherein an aqueous liquid is separated from the rich extract stream or the lean extract stream.

293. The method of claim 292, wherein the aqueous liquid is made to separate from the rich extract stream or the lean extract stream by changing the rich or lean extract stream temperature, solvent content or by adding chemical additives to the rich or lean extract streams.

294. The method of claim 292, wherein the aqueous liquid is made to separate from the rich extract stream or the lean extract stream by electrocoalescence of the aqueous liquid.

295. The method of claim 292, wherein the aqueous liquid is made to separate from the rich extract stream or the lean extract stream by gravity-assisted separation.

296. A solvent bitumen extraction with solids agglomeration method, the method comprising:

(a) mining, sizing, and transporting oil sand ore to form a bituminous feed;

(b) feeding the bituminous feed into a first hopper with inert gas to inert the bituminous feed to produce an inerted bituminous feed;

(c) adding a first solvent to the inerted bituminous feed in a wet crushing device to reduce lump size and to produce a sized bituminous feed;

(d) settling the sized bituminous feed in a second hopper to provide initial dissolution of bitumen and improve flowability to produce a settled sized bituminous feed;

(e) optionally adding an additional solvent to the second hopper;

(f) contacting the settled sized bituminous feed with a first fluid, wherein the first fluid is optionally a solvent, in a first jet pump to ablate and mix the settled sized bituminous feed, wherein the first fluid is optionally used as a motive fluid in the first jet pump, to produce a bituminous slurry;

(g) optionally pumping the bituminous slurry;

(h) dissolving the bituminous slurry in a dissolution pipeline to produce a dissolved bituminous slurry;

(i) optionally adding an additional hot solvent to the dissolution pipeline to heat the bituminous slurry;

(j) separating an oversized reject stream from the dissolved bituminous slurry in a primary oversize wash step;

(k) sending the oversized reject stream to an oversize system and optionally washing the oversized reject stream with a second solvent, to produce a washed reject stream and an undersized reject stream comprising solids and solvent-rich liquid;

(l) washing the washed reject stream to produce a dry reject stream;

(m) separating an overhead stream from the dissolved bituminous slurry;

(n) sending the dissolved bituminous slurry to a third hopper for settling and additional dissolution to produce a high solids slurry and a supernatant with a low solids content;

(o) sending the supernatant to a pump;

(p) contacting the high solids slurry with a second fluid comprising the supernatant and a bridging liquid, optionally in a second jet pump using the second fluid as a second motive fluid, and further agglomerating the high solids slurry, optionally in a pipeline, to create an agglomerated slurry with more uniformly sized agglomerates;

(q) filtering, washing with washed with a third solvent, and desolventizing with a condensable gas stream, the agglomerated slurry to produce a rich extract, a lean extract, and a desolventized dry solids stream;

(r) conditioning the desolventized dry solids stream in a tailings inerting process to produce stackable solids;

(s) combining the rich extract with the lean extract to form a combined rich and lean extract;

(t) separating solvent from the combined rich and lean extract in a solvent recovery unit (SRU) and forming a recovered solvent and a recovered bitumen; and

(u) (i) combining the recovered bitumen with water and sending to a paraffinic froth treatment (PFT) process, which optionally comprises a solvent recovery unit, and using the PFT process to produce a PFT solids-containing stream, which is optionally subjected to a solvent recovery process, to produce a recovered PFT solvent, PFT solids for disposal, and a fungible PFT bitumen; or

(ii) subjecting the recovered bitumen to deasphalting, which optionally comprises a solvent recovery unit, to produce a recovered deasphalted solvent, a recovered deasphalted solids and a fungible deasphalted bitumen; and

(iii) adding diluent to the fungible PFT bitumen and/or the fungible deasphalted bitumen to produce a dilbit.

297. The method of claim 296, wherein step (q) comprises:

(i) combining the agglomerated slurry with a second bridging liquid to control particle size distribution;

(ii) mixing the agglomerated slurry in a mixer;

(iii) passing the agglomerated slurry to a filter, optionally a rotating pan filter;

(iv) using the filter to drain, wash, and desolventize the agglomerated slurry to produce the rich extract, the lean extract, and the desolventized dry solids stream, respectively;

(v) recovering steam used in the desolventizing along with the third solvent, wherein the third solvent is recovered from at least a portion of the rich extract to produce at least one bitumen stream;

(vi) flowing a vapor, optionally a fourth solvent and/or nitrogen, through a filter cake formed on the filter, to reduce the moisture of the filter cake; and

(vii) optionally using a vacuum system to create a vacuum in the filter.

298. The method of claim 296 or 297, wherein the first hopper is a dual solids plug feed hopper and wherein the inert gas comprises nitrogen or an inert sweep gas.

299. The method of any one of claims 296 to 298, wherein the first solvent, the additional solvent, or the first fluid comprises one or more of the combined rich and lean extracts, the recovered solvent, and the recovered bitumen.

300. The method of any one of claims 296 to 299, wherein step (r) comprises adding a vapor to the desolventized dry solids stream.

301. The method of any one of claims 296 to 300, wherein the additional solvent is added to the second hopper.

302. The method of any one of claims 296 to 301, wherein the first fluid is a solvent and wherein the first fluid is used as a motive fluid in the first jet pump.

303. The method of any one of claims 296 to 302, wherein the bituminous slurry is pumped.

304. The method of any one of claims 296 to 303, wherein the additional hot solvent is added to the dissolution pipeline to heat the bituminous slurry.

305. The method of any one of claims 296 to 304, wherein the oversized reject stream is washed with a wash solvent.

306. The method of any one of claims 296 to 305, wherein the PFT process comprises the solvent recovery unit, and wherein the PFT solids-containing stream produced in the PFT is subjected to the solvent recovery to produce the recovered PFT solvent and the PFT solids for disposal, and the fungible PFT bitumen.

307. The method of any one of claims 296 to 306, wherein the high solids slurry is contacted with the second fluid in the second jet pump using the second fluid as the second motive fluid, and wherein the high solids slurry is further agglomerated in the pipeline.

308. The method of any one of claims 296 to 307, wherein an aqueous liquid is separated from the rich extract or the lean extract.

309. The method of claim 308, wherein the aqueous liquid is made to separate from the rich extract or the lean extract by changing the rich or lean extract temperature, solvent content or by adding chemical additives to the rich or lean extract.

310. The method of claim 308, wherein the aqueous liquid is made to separate from the rich extract or the lean extract by electrocoalescence of the aqueous liquid.

311. The method of claim 308, wherein the aqueous liquid is made to separate from the rich extract or the lean extract by gravity-assisted separation.

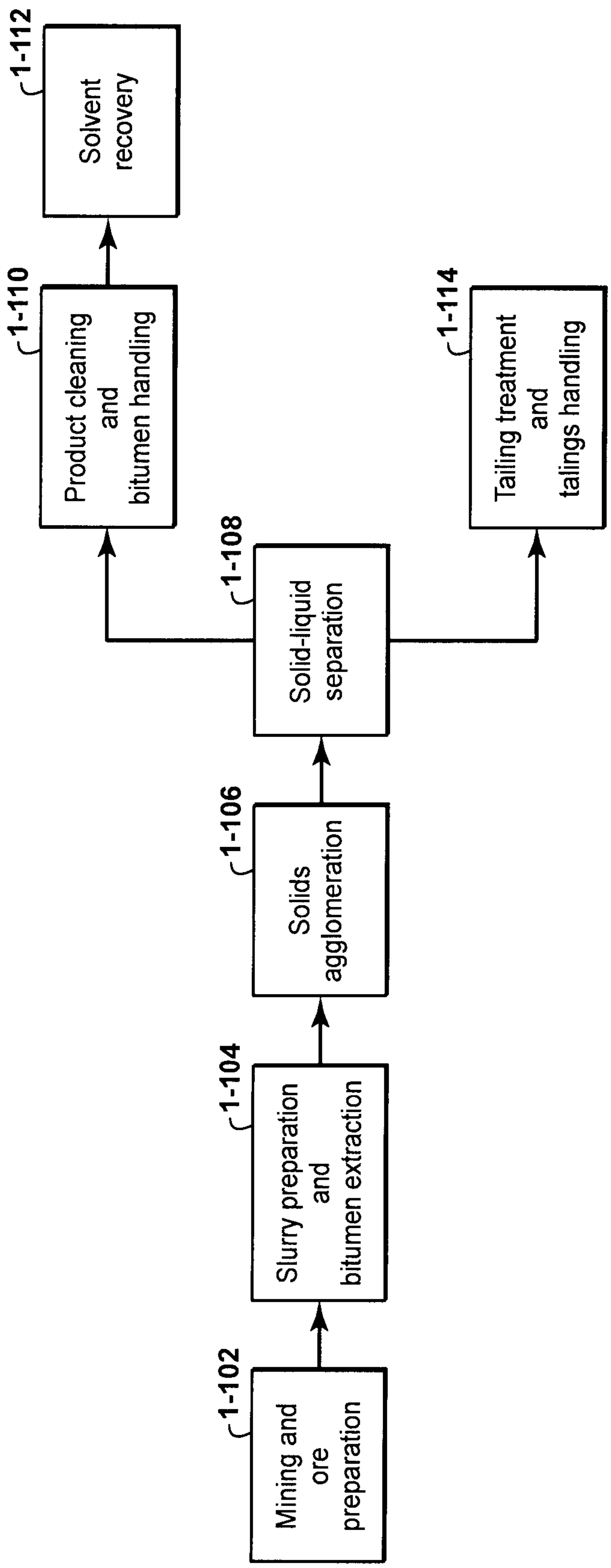

1-102
Mining and ore preparation
1-104
Slurry preparation and bitumen extraction
1-106
Solids agglomeration
1-108
Solid-liquid separation
1-110
Product cleaning and bitumen handling
1-112
Solvent recovery
1-114
Tailing treatment and talings handling

FIG. 1

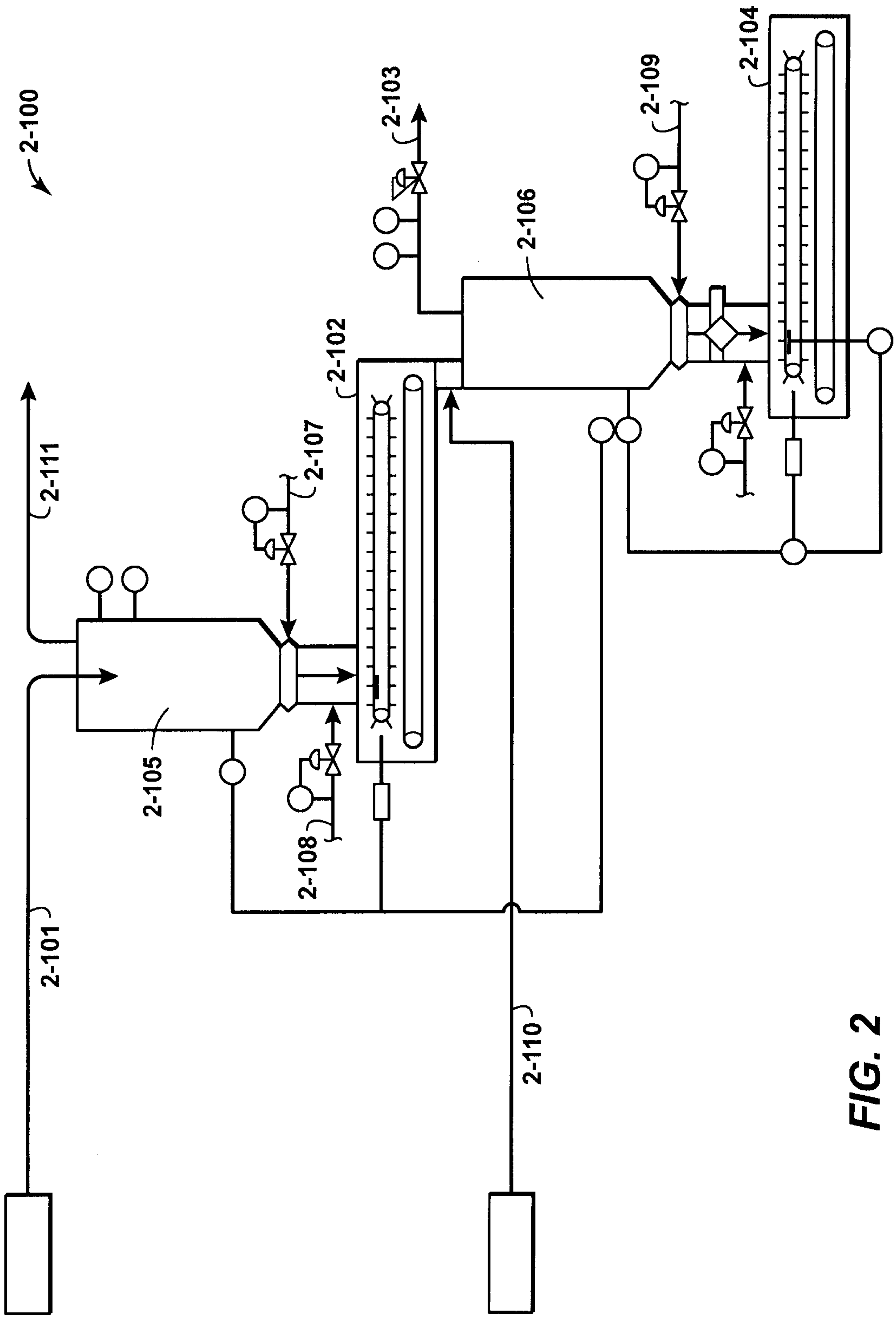


FIG. 2

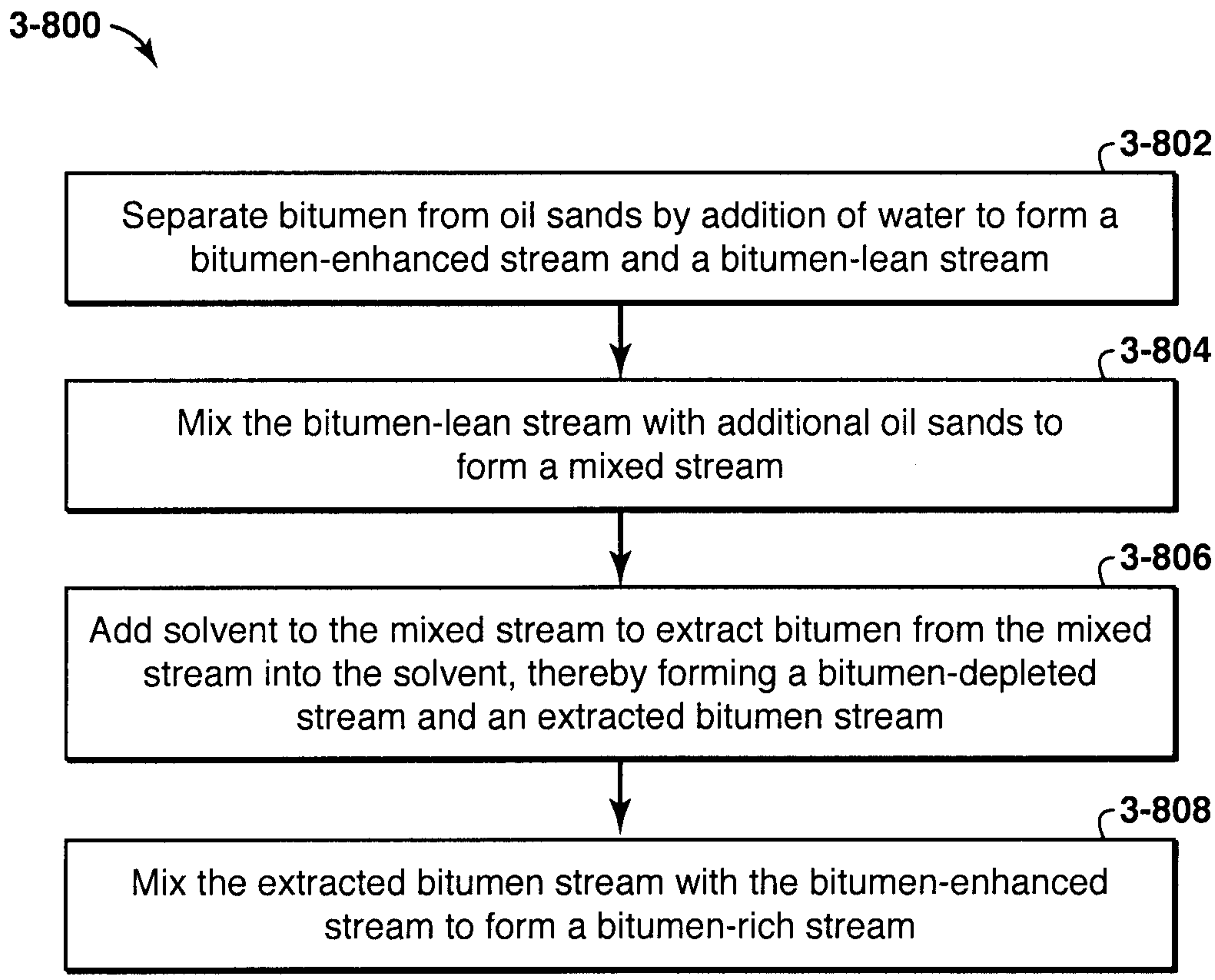

3-800
3-802
Separate bitumen from oil sands by addition of water to form a bitumen-enhanced stream and a bitumen-lean stream
3-804
Mix the bitumen-lean stream with additional oil sands to form a mixed stream
3-806
Add solvent to the mixed stream to extract bitumen from the mixed stream into the solvent, thereby forming a bitumen-depleted stream and an extracted bitumen stream
3-808
Mix the extracted bitumen stream with the bitumen-enhanced stream to form a bitumen-rich stream

FIG. 3

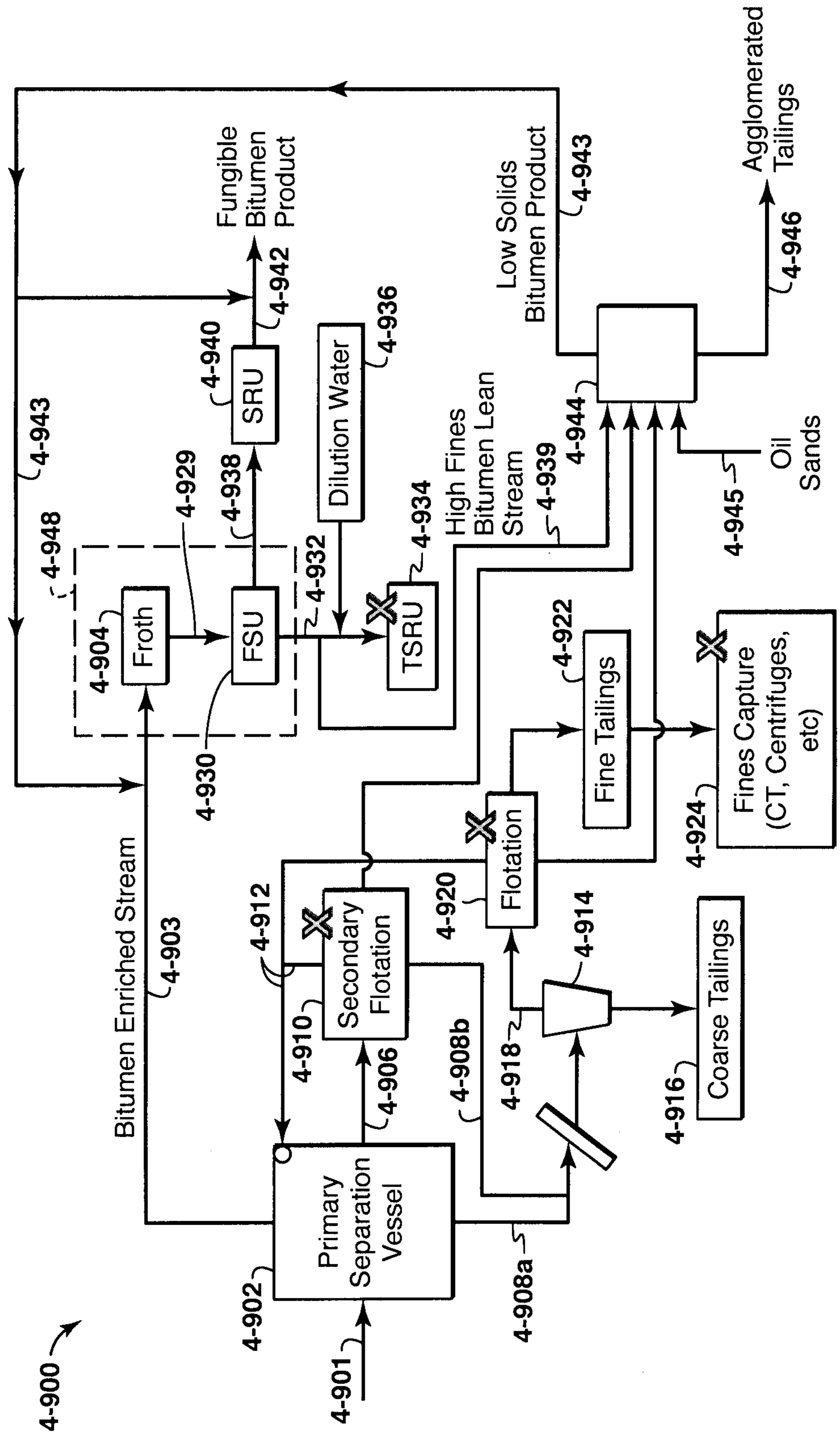

4-900
4-901
4-902
Primary Separation Vessel
4-903
Bitumen Enriched Stream
4-904
Froth
4-906
4-908a
4-908b
4-910
4-912
Secondary Flotation
4-914
4-916
Coarse Tailings
4-918
4-920
Flotation
4-922
Fine Tailings
4-924
Fines Capture (CT, Centrifuges, etc)
4-929
4-930
FSU
4-932
4-934
TSRU
4-936
Dilution Water
4-938
4-939
High Fines Bitumen Lean Stream
4-940
SRU
4-942
Fungible Bitumen Product
4-943
Low Solids Bitumen Product
4-944
4-945
Oil Sands
4-946
Agglomerated Tailings
4-948

FIG. 4

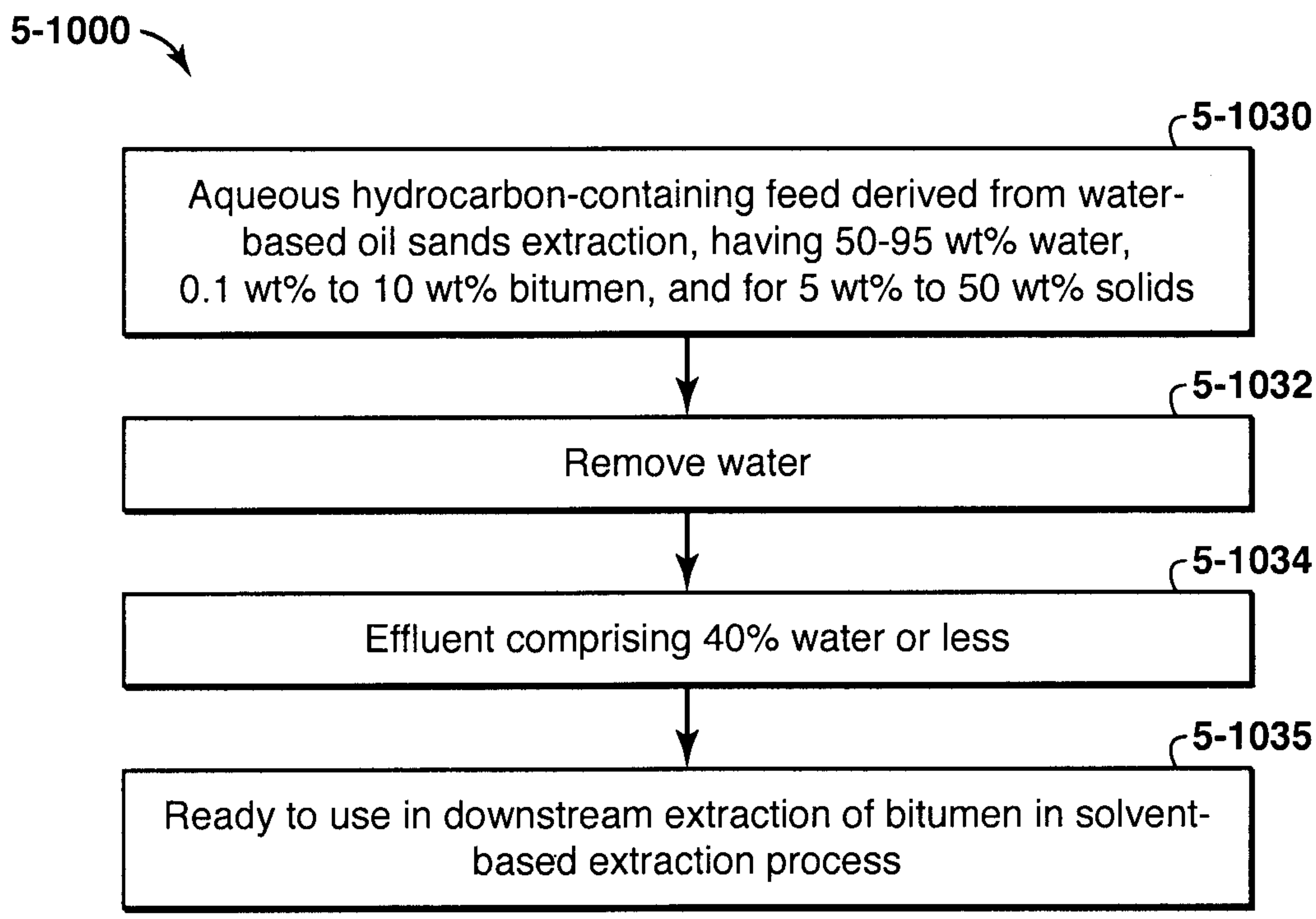

5-1000
5-1030
Aqueous hydrocarbon-containing feed derived from water-based oil sands extraction, having 50-95 wt% water, 0.1 wt% to 10 wt% bitumen, and for 5 wt% to 50 wt% solids
5-1032
Remove water
5-1034
Effluent comprising 40% water or less
5-1035
Ready to use in downstream extraction of bitumen in solvent-based extraction process

FIG. 5

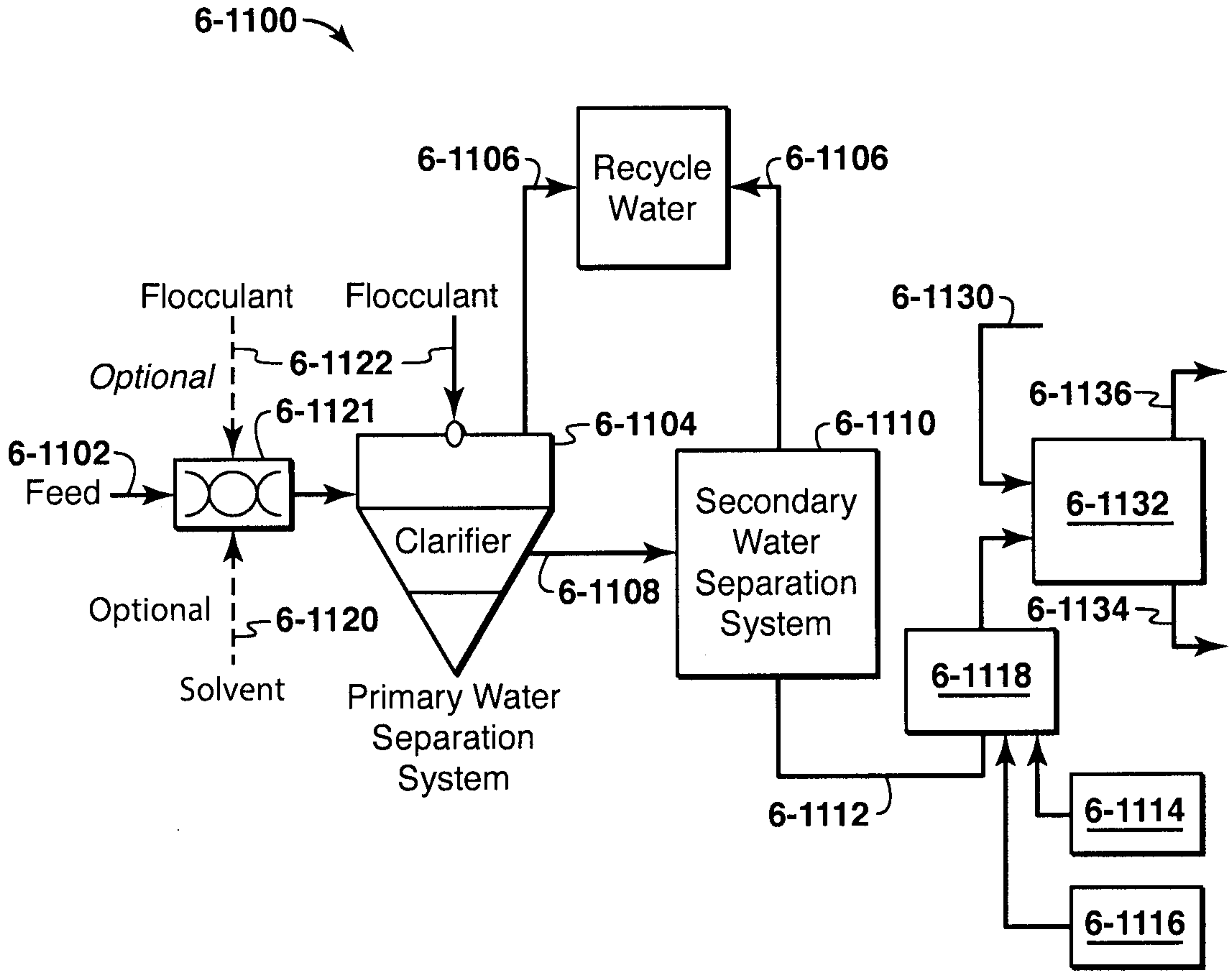

6-1100
6-1106
Recycle Water
6-1106
Flocculant
Flocculant
6-1130
Optional
6-1122
6-1121
6-1104
6-1110
6-1136
6-1102
Feed
Clarifier
Secondary Water Separation System
6-1132
6-1108
6-1134
Optional
6-1120
Solvent
Primary Water Separation System
6-1118
6-1112
6-1114
6-1116

FIG. 6

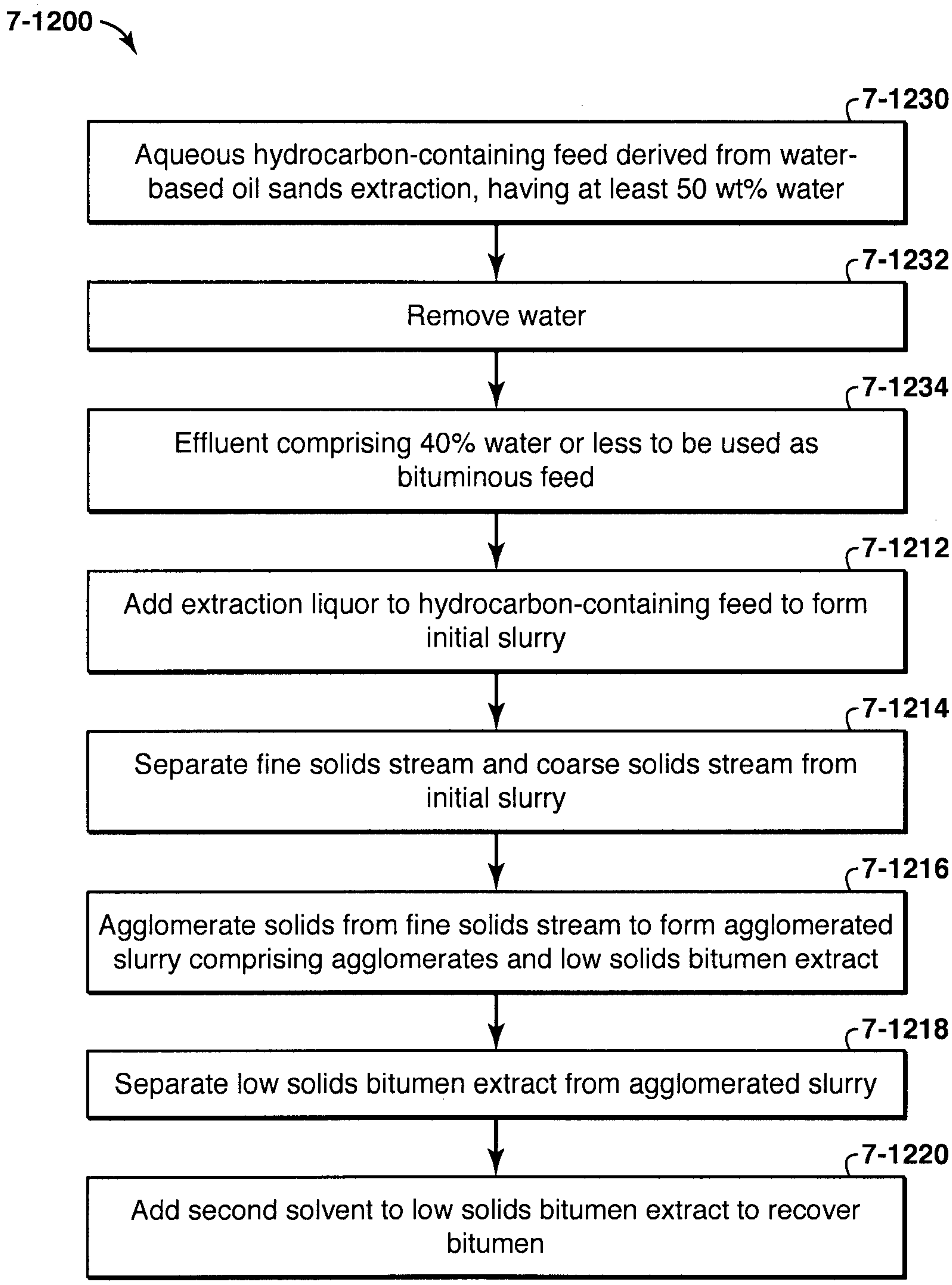

7-1200
7-1230
Aqueous hydrocarbon-containing feed derived from water-based oil sands extraction, having at least 50 wt% water
7-1232
Remove water
7-1234
Effluent comprising 40% water or less to be used as bituminous feed
7-1212
Add extraction liquor to hydrocarbon-containing feed to form initial slurry
7-1214
Separate fine solids stream and coarse solids stream from initial slurry
7-1216
Agglomerate solids from fine solids stream to form agglomerated slurry comprising agglomerates and low solids bitumen extract
7-1218
Separate low solids bitumen extract from agglomerated slurry
7-1220
Add second solvent to low solids bitumen extract to recover bitumen

FIG. 7

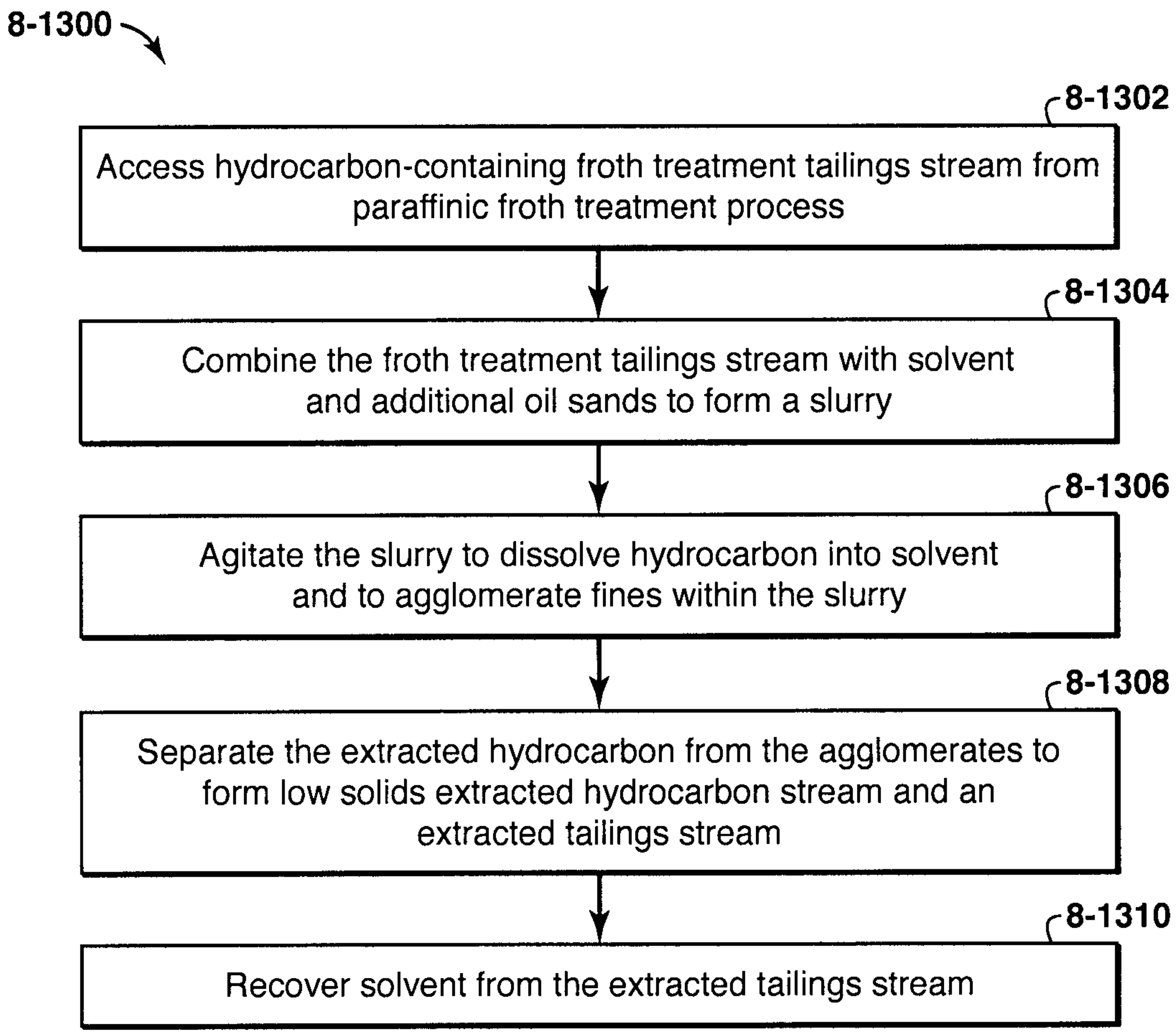

8-1300
8-1302
Access hydrocarbon-containing froth treatment tailings stream from paraffinic froth treatment process
8-1304
Combine the froth treatment tailings stream with solvent and additional oil sands to form a slurry
8-1306
Agitate the slurry to dissolve hydrocarbon into solvent and to agglomerate fines within the slurry
8-1308
Separate the extracted hydrocarbon from the agglomerates to form low solids extracted hydrocarbon stream and an extracted tailings stream
8-1310
Recover solvent from the extracted tailings stream

FIG. 8

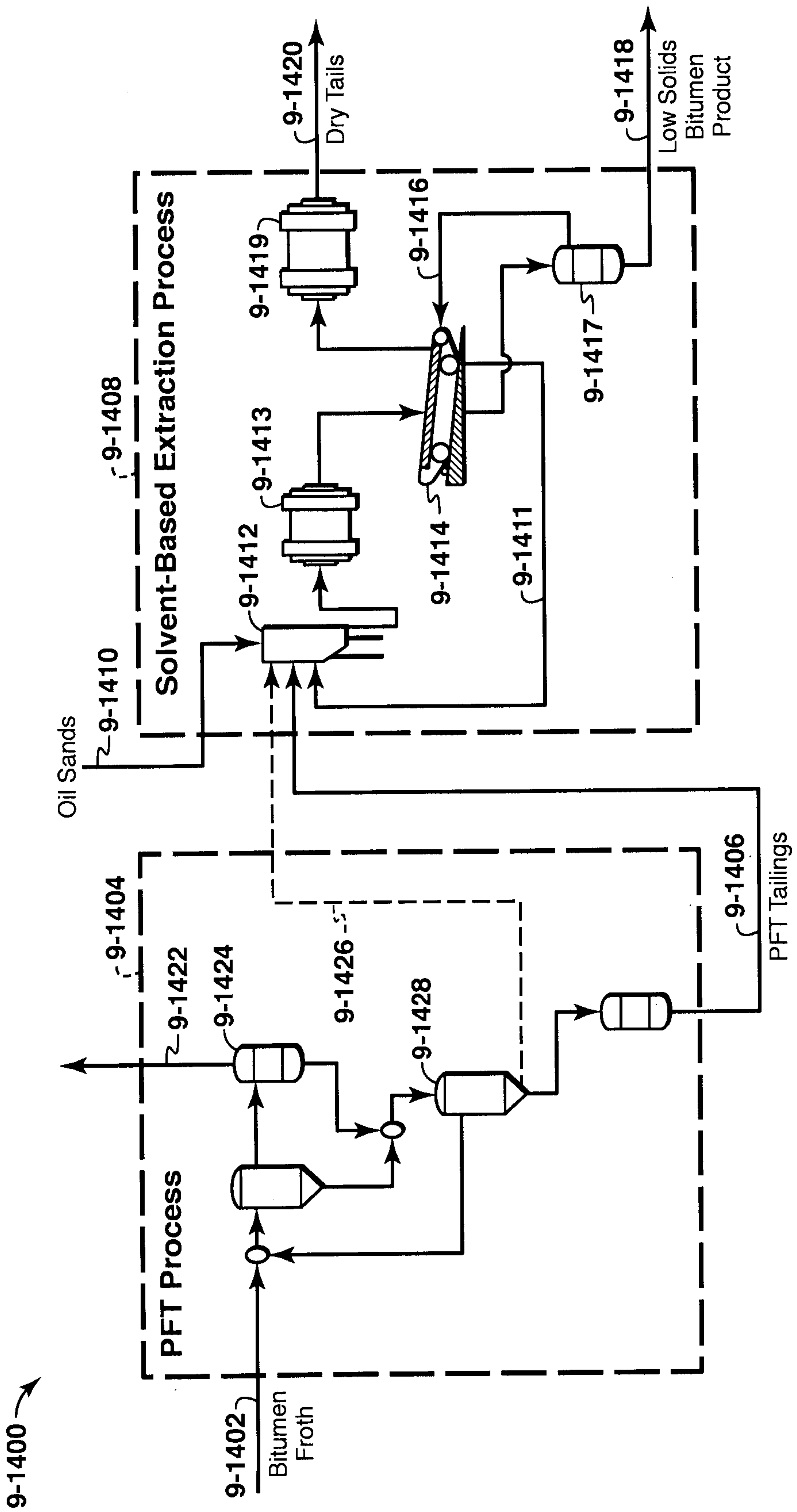

9-1400
9-1402
Bitumen Froth
PFT Process
9-1404
9-1422
9-1424
9-1426
9-1428
9-1406
PFT Tailings
Oil Sands
9-1410
Solvent-Based Extraction Process
9-1408
9-1412
9-1413
9-1414
9-1411
9-1419
9-1420
Dry Tails
9-1416
9-1417
9-1418
Low Solids Bitumen Product

FIG. 9

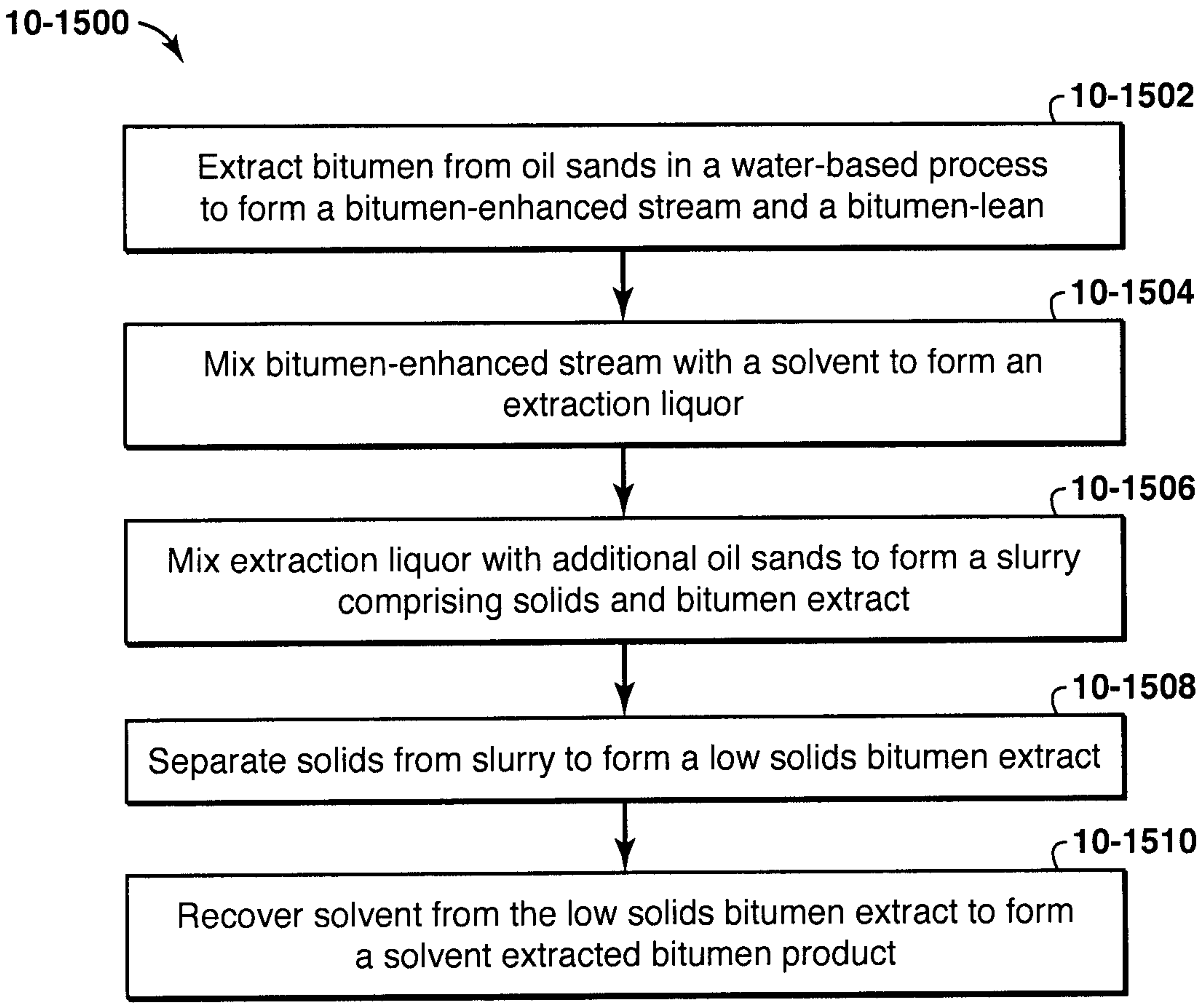

10-1500
10-1502
Extract bitumen from oil sands in a water-based process to form a bitumen-enhanced stream and a bitumen-lean
10-1504
Mix bitumen-enhanced stream with a solvent to form an extraction liquor
10-1506
Mix extraction liquor with additional oil sands to form a slurry comprising solids and bitumen extract
10-1508
Separate solids from slurry to form a low solids bitumen extract
10-1510
Recover solvent from the low solids bitumen extract to form a solvent extracted bitumen product

FIG. 10

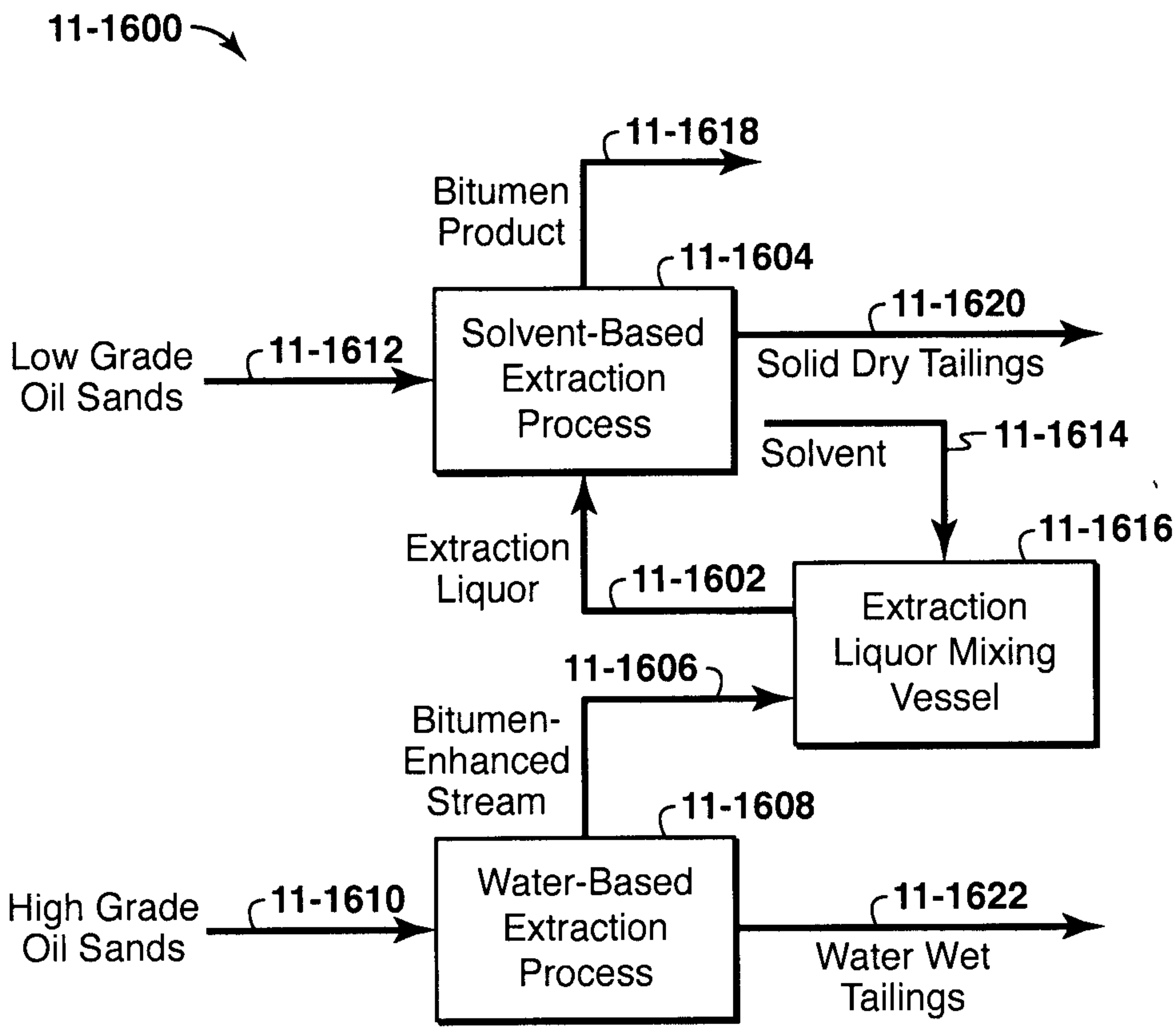

11-1600
11-1618
Bitumen Product
11-1604
11-1620
Low Grade Oil Sands
11-1612
Solvent-Based Extraction Process
Solid Dry Tailings
Solvent
11-1614
11-1616
Extraction Liquor
11-1602
Extraction Liquor Mixing Vessel
11-1606
Bitumen-Enhanced Stream
11-1608
High Grade Oil Sands
11-1610
Water-Based Extraction Process
11-1622
Water Wet Tailings

FIG. 11

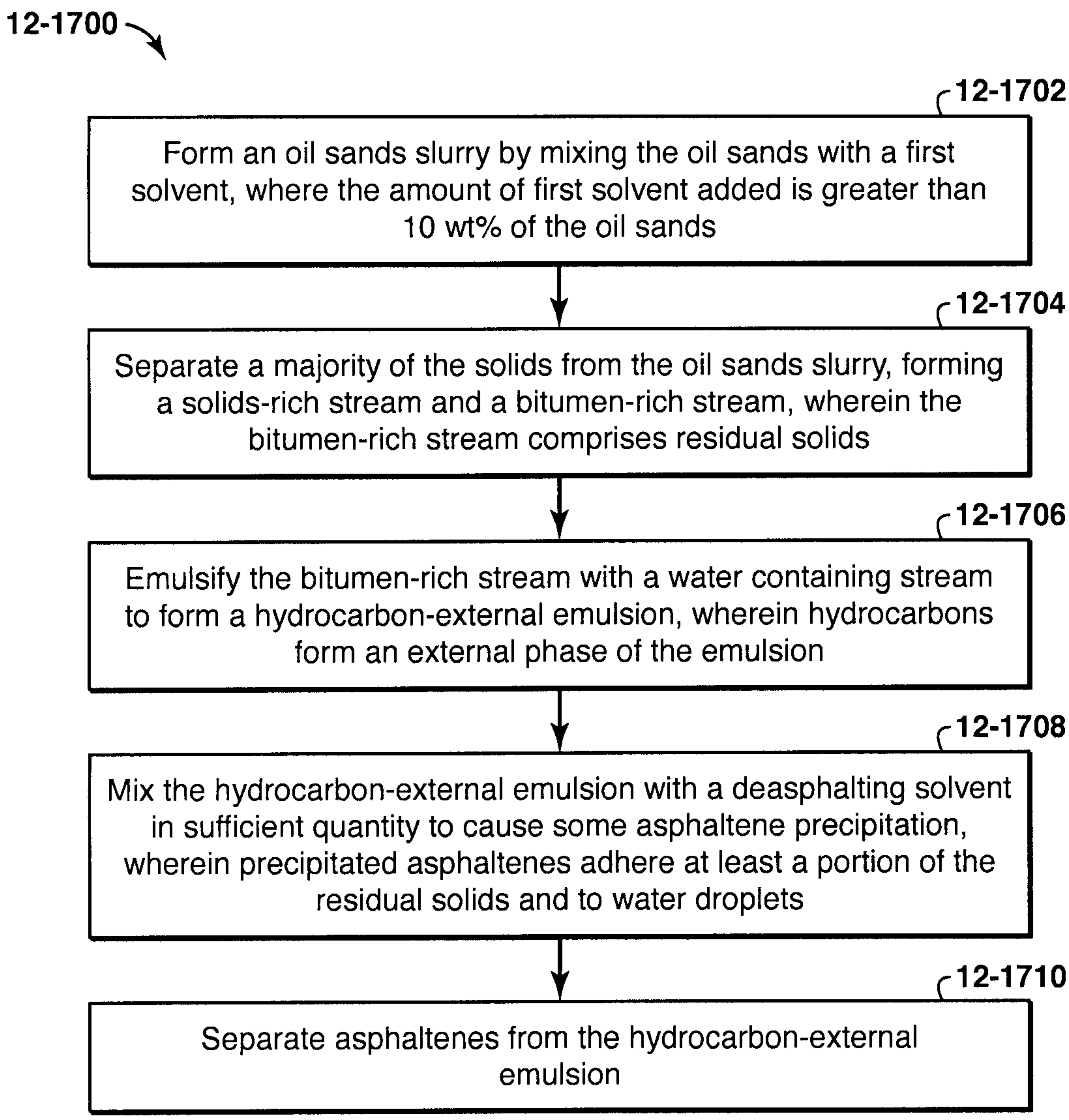

12-1700
12-1702
Form an oil sands slurry by mixing the oil sands with a first solvent, where the amount of first solvent added is greater than 10 wt% of the oil sands
12-1704
Separate a majority of the solids from the oil sands slurry, forming a solids-rich stream and a bitumen-rich stream, wherein the bitumen-rich stream comprises residual solids
12-1706
Emulsify the bitumen-rich stream with a water containing stream to form a hydrocarbon-external emulsion, wherein hydrocarbons form an external phase of the emulsion
12-1708
Mix the hydrocarbon-external emulsion with a deasphalting solvent in sufficient quantity to cause some asphaltene precipitation, wherein precipitated asphaltenes adhere at least a portion of the residual solids and to water droplets
12-1710
Separate asphaltenes from the hydrocarbon-external emulsion

FIG. 12

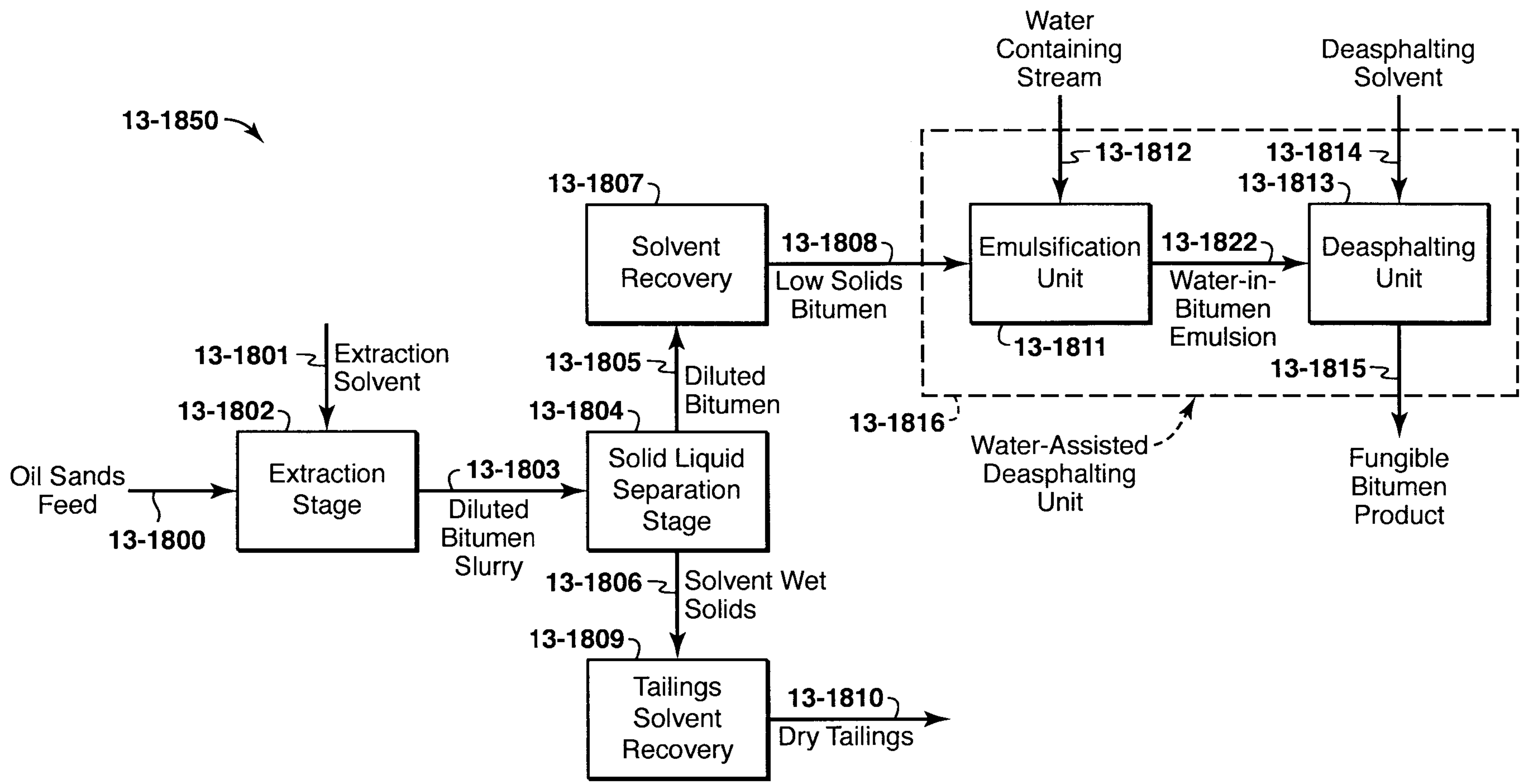

13-1850
Oil Sands Feed
13-1800
13-1801
Extraction Solvent
13-1802
Extraction Stage
13-1803
Diluted Bitumen Slurry
13-1804
Solid Liquid Separation Stage
13-1805
Diluted Bitumen
13-1806
Solvent Wet Solids
13-1807
Solvent Recovery
13-1808
Low Solids Bitumen
13-1809
Tailings Solvent Recovery
13-1810
Dry Tailings
Water Containing Stream
13-1812
Emulsification Unit
13-1811
13-1822
Water-in-Bitumen Emulsion
Deasphalting Solvent
13-1814
13-1813
Deasphalting Unit
13-1815
Fungible Bitumen Product
13-1816
Water-Assisted Deasphalting Unit

FIG. 13

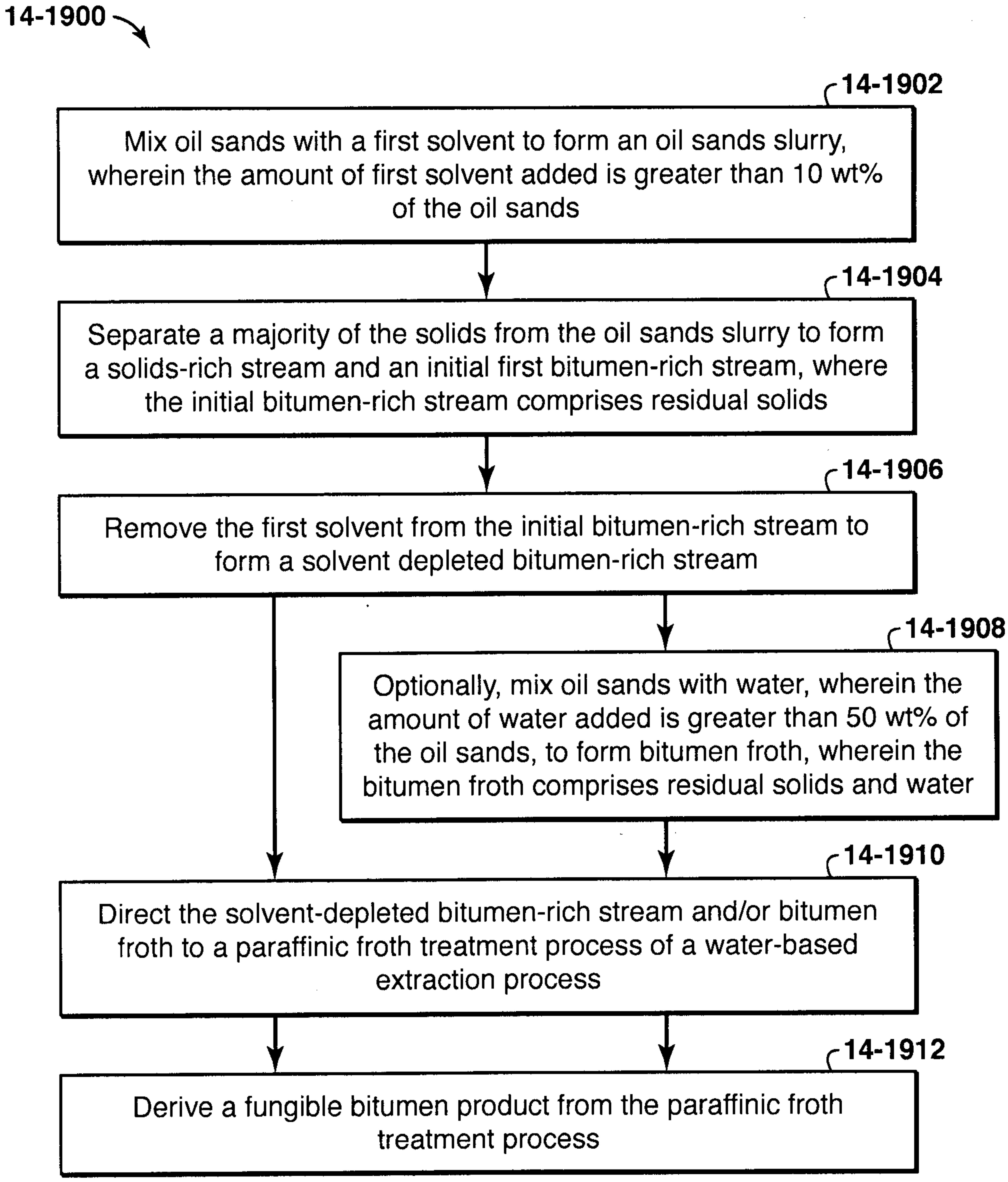

14-1900
14-1902
Mix oil sands with a first solvent to form an oil sands slurry, wherein the amount of first solvent added is greater than 10 wt% of the oil sands
14-1904
Separate a majority of the solids from the oil sands slurry to form a solids-rich stream and an initial first bitumen-rich stream, where the initial bitumen-rich stream comprises residual solids
14-1906
Remove the first solvent from the initial bitumen-rich stream to form a solvent depleted bitumen-rich stream
14-1908
Optionally, mix oil sands with water, wherein the amount of water added is greater than 50 wt% of the oil sands, to form bitumen froth, wherein the bitumen froth comprises residual solids and water
14-1910
Direct the solvent-depleted bitumen-rich stream and/or bitumen froth to a paraffinic froth treatment process of a water-based extraction process
14-1912
Derive a fungible bitumen product from the paraffinic froth treatment process

FIG. 14

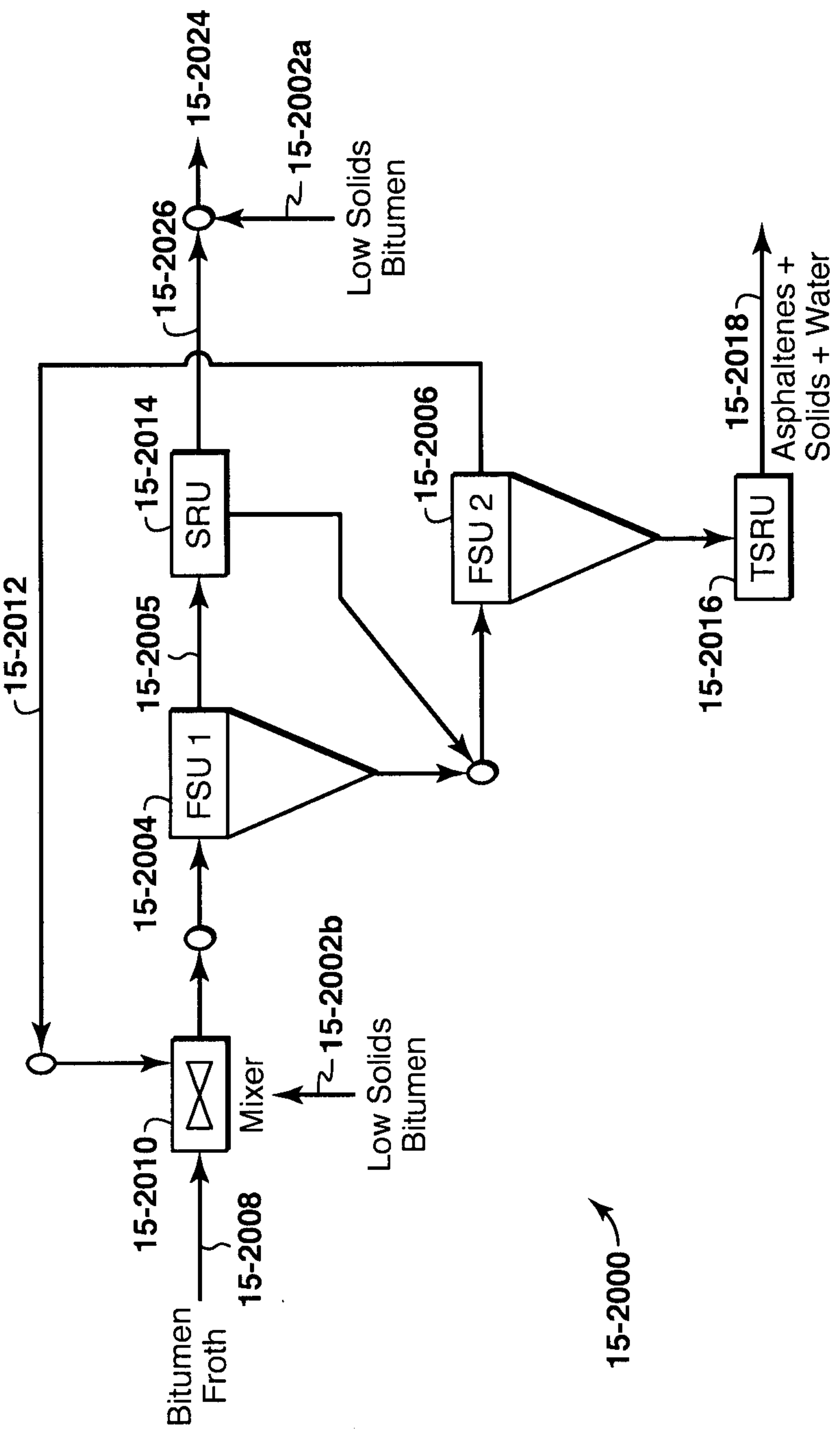

15-2024
15-2002a
15-2026
Low Solids
Bitumen
15-2014
SRU
15-2012
15-2006
FSU 2
15-2018
Asphaltenes +
Solids + Water
15-2005
15-2016
TSRU
15-2004
FSU 1
15-2002b
15-2010
Mixer
Low Solids
Bitumen
15-2008
Bitumen
Froth
15-2000

FIG. 15

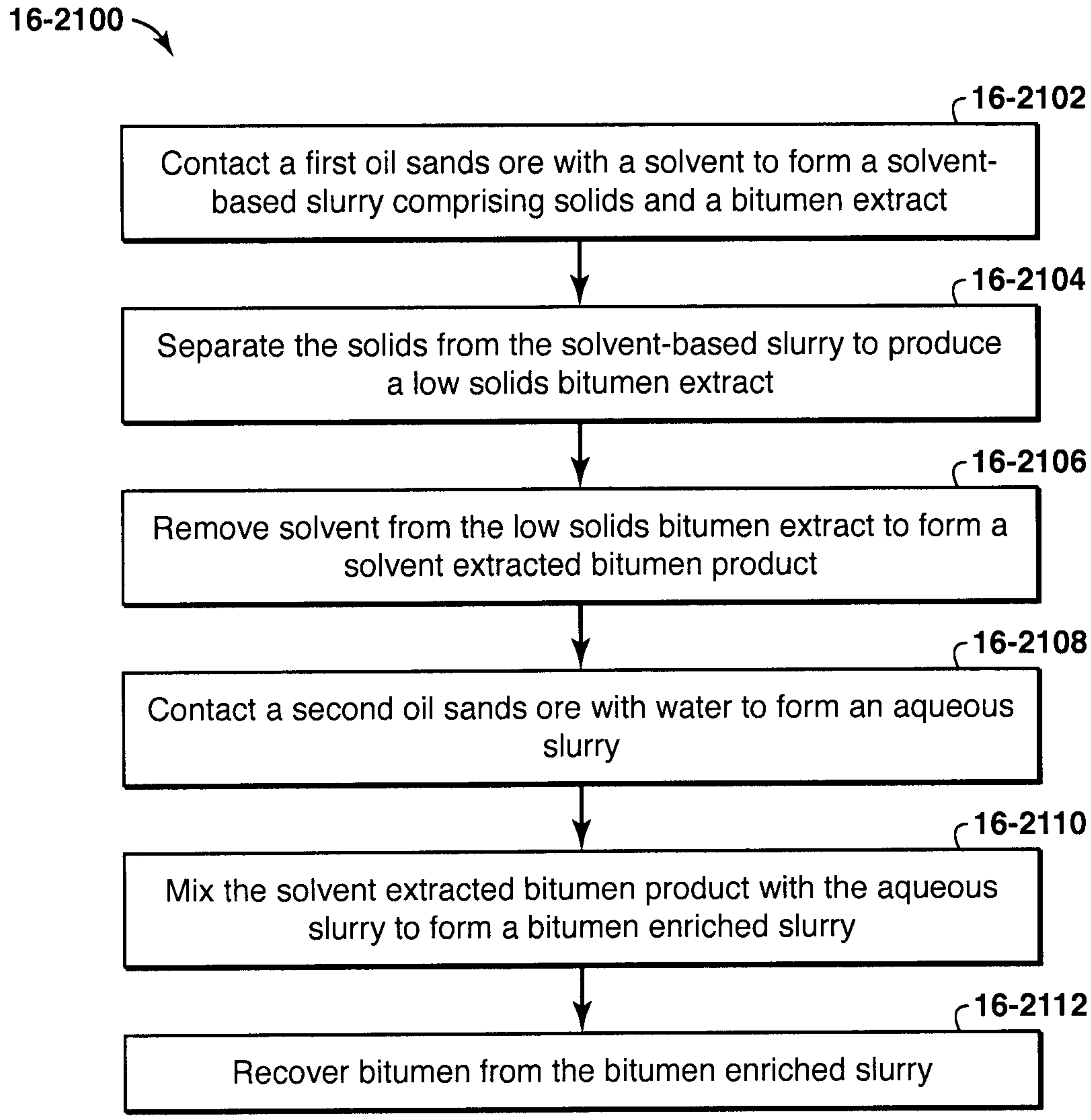

16-2100
16-2102
Contact a first oil sands ore with a solvent to form a solvent-based slurry comprising solids and a bitumen extract
16-2104
Separate the solids from the solvent-based slurry to produce a low solids bitumen extract
16-2106
Remove solvent from the low solids bitumen extract to form a solvent extracted bitumen product
16-2108
Contact a second oil sands ore with water to form an aqueous slurry
16-2110
Mix the solvent extracted bitumen product with the aqueous slurry to form a bitumen enriched slurry
16-2112
Recover bitumen from the bitumen enriched slurry

FIG. 16

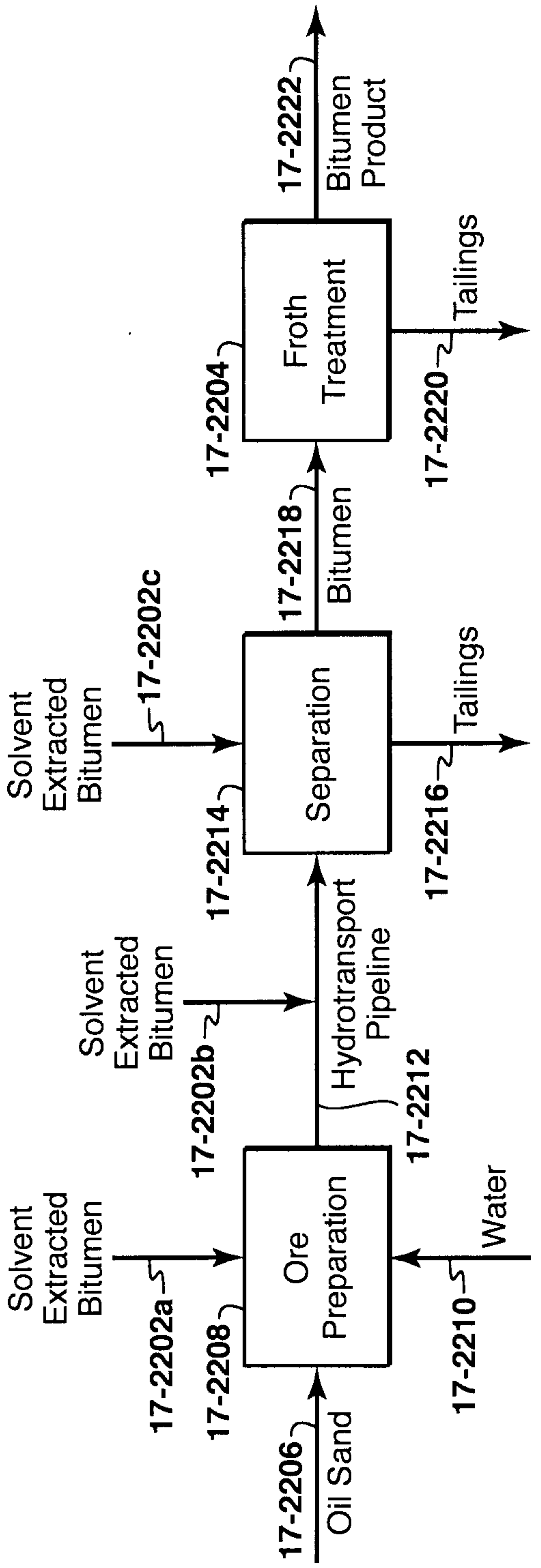

17-2200
Oil Sand
17-2206
Ore Preparation
17-2208
Solvent Extracted Bitumen
17-2202a
Water
17-2210
Hydrotransport Pipeline
17-2212
Solvent Extracted Bitumen
17-2202b
Separation
17-2214
Solvent Extracted Bitumen
17-2202c
Tailings
17-2216
Bitumen
17-2218
Froth Treatment
17-2204
Tailings
17-2220
Bitumen Product
17-2222

FIG. 17

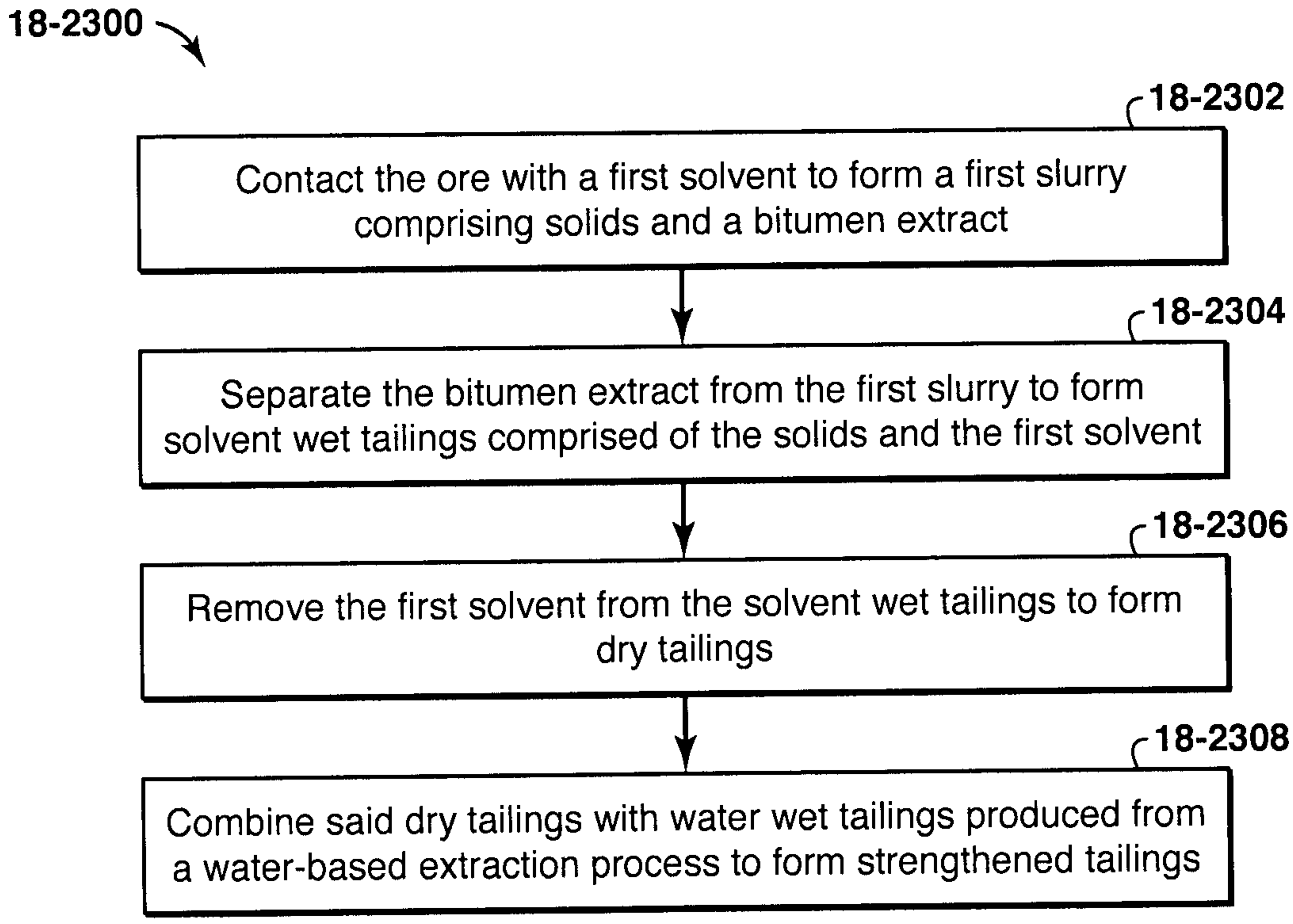

18-2300
18-2302
Contact the ore with a first solvent to form a first slurry comprising solids and a bitumen extract
18-2304
Separate the bitumen extract from the first slurry to form solvent wet tailings comprised of the solids and the first solvent
18-2306
Remove the first solvent from the solvent wet tailings to form dry tailings
18-2308
Combine said dry tailings with water wet tailings produced from a water-based extraction process to form strengthened tailings

FIG. 18

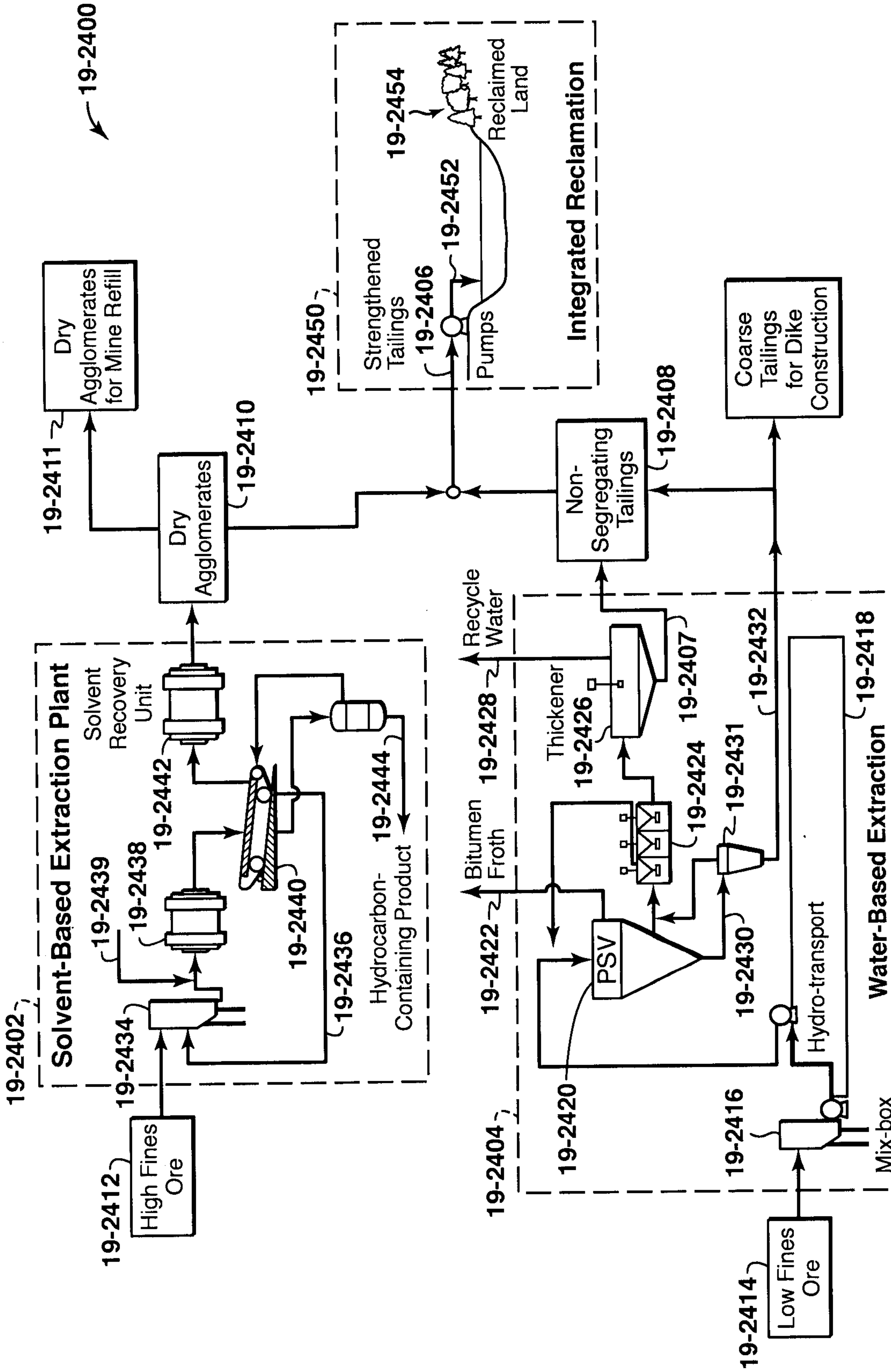

19-2400
Solvent-Based Extraction Plant
19-2402
Solvent Recovery Unit
19-2434
19-2439
19-2438
19-2442
19-2440
19-2436
19-2444
Hydrocarbon-Containing Product
19-2412
High Fines Ore
Dry Agglomerates
19-2410
19-2411
Dry Agglomerates for Mine Refill
19-2450
Strengthened Tailings
19-2406
19-2452
19-2454
Reclaimed Land
Pumps
Integrated Reclamation
Non-Segregating Tailings
19-2408
Coarse Tailings for Dike Construction
Recycle Water
19-2428
Bitumen Froth
19-2422
Thickener
19-2426
19-2407
19-2424
19-2431
19-2432
PSV
19-2420
19-2430
Hydro-transport
19-2418
19-2404
19-2416
Mix-box
Water-Based Extraction and Fines Thickening Plant
19-2414
Low Fines Ore

FIG. 19

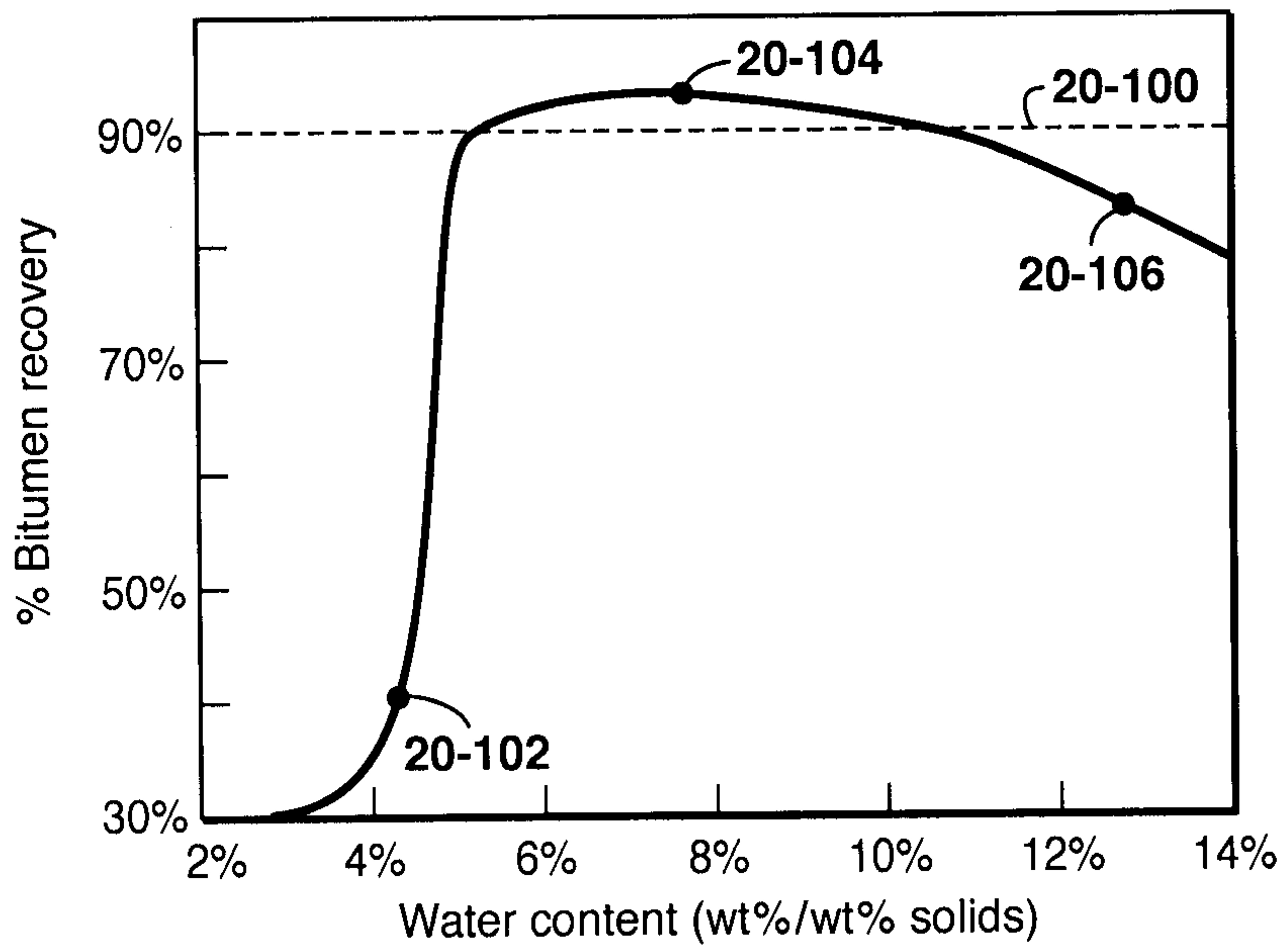

20-104
20-100
90%
20-106
70%
% Bitumen recovery
50%
20-102
30%
2%
4%
6%
8%
10%
12%
14%
Water content (wt%/wt% solids)

FIG. 20

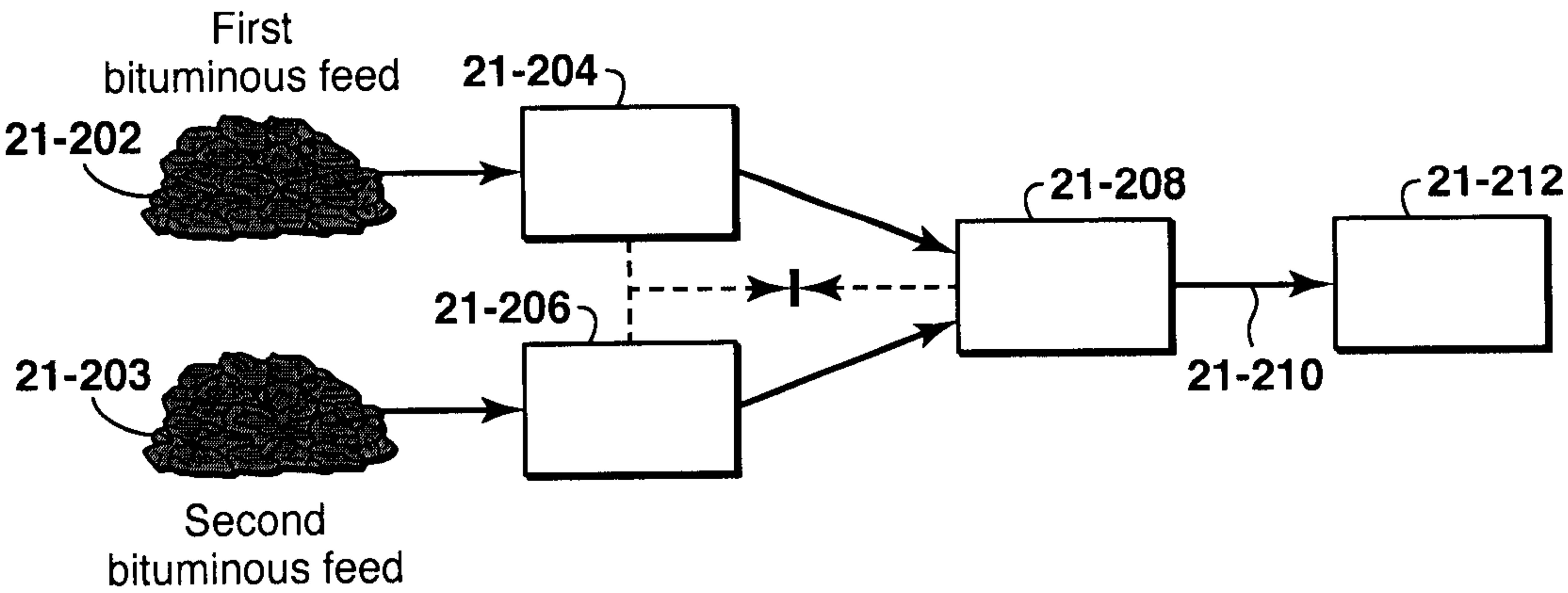

First
bituminous feed
21-204
21-202
21-208
21-212
21-206
21-203
21-210
Second
bituminous feed

FIG. 21

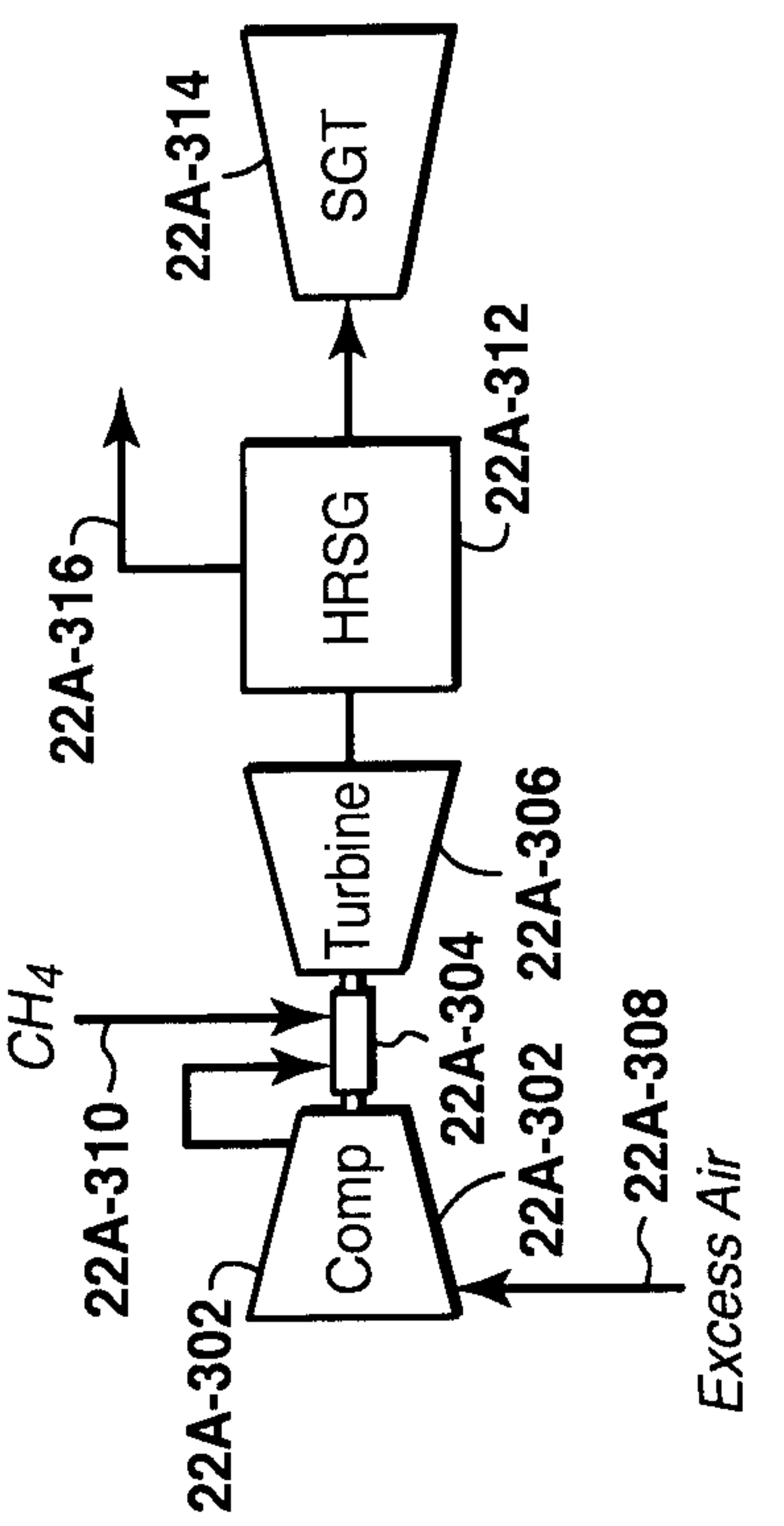


FIG. 22A

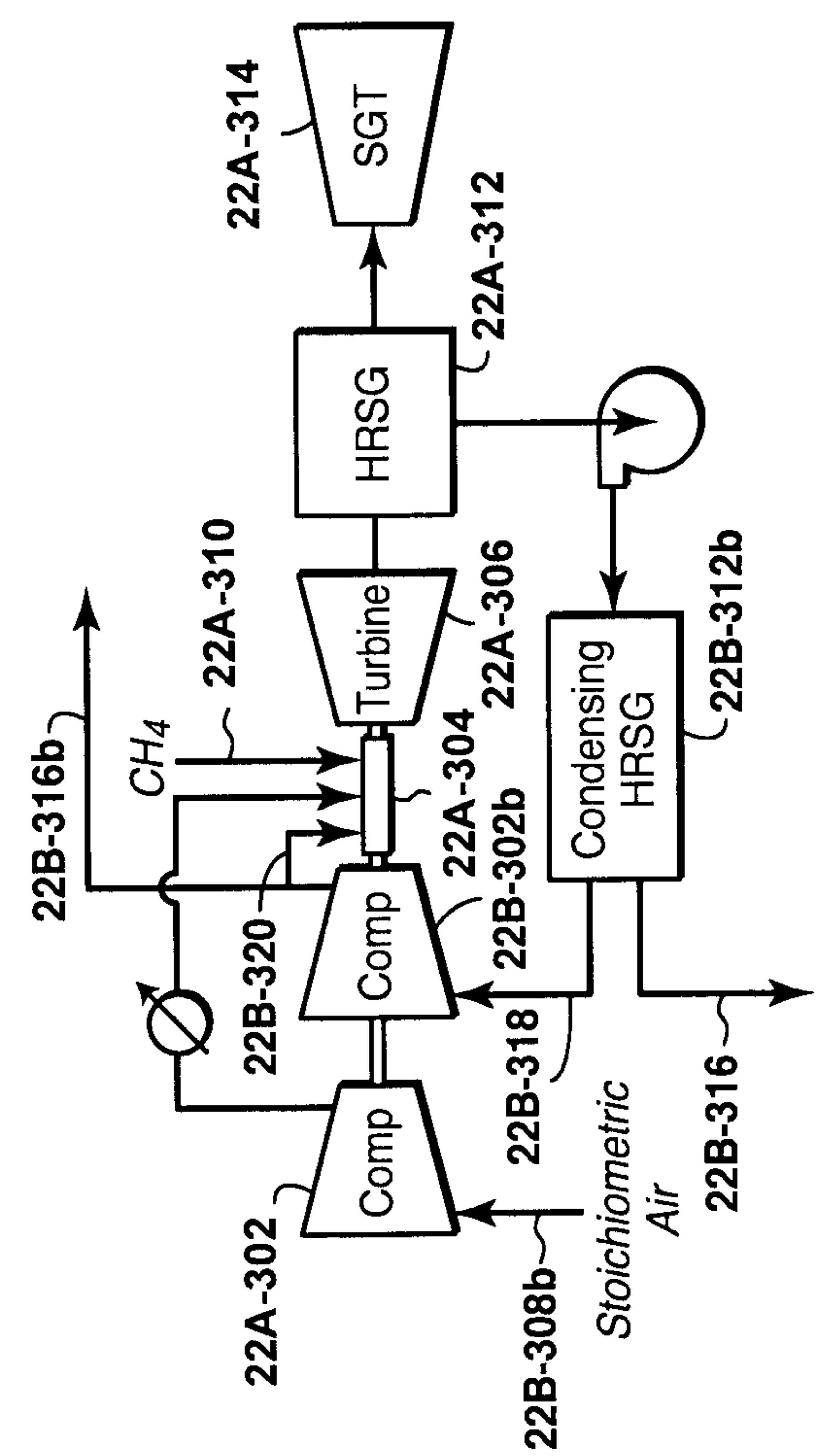
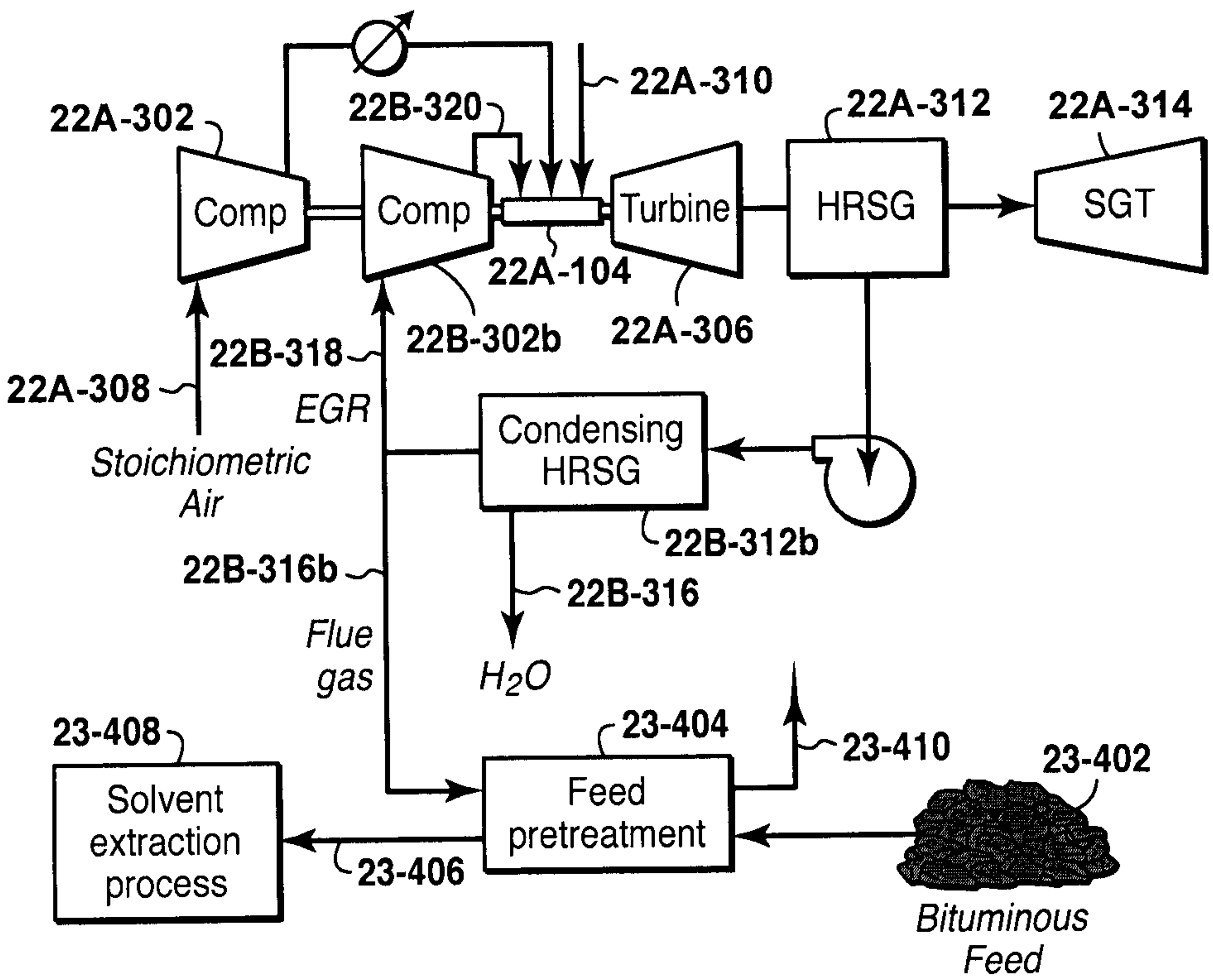
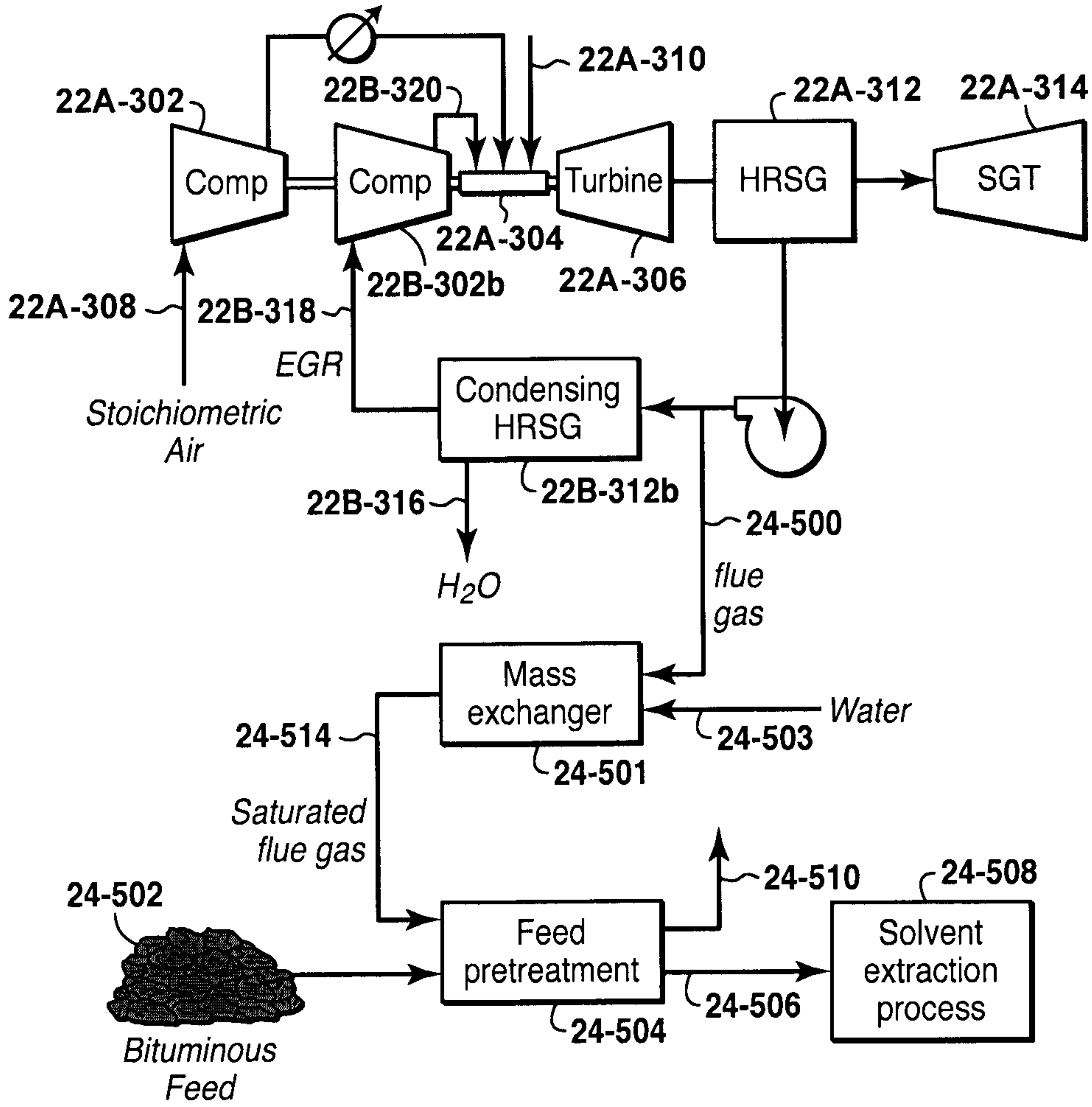


FIG. 22B



22A-302
22B-320
22A-310
22A-312
22A-314
Comp
Comp
Turbine
HRSG
SGT
22A-104
22A-306
22B-302b
22B-318
22A-308
EGR
Stoichiometric Air
Condensing HRSG
22B-312b
22B-316b
22B-316
Flue gas
H2O
23-408
23-404
23-410
23-402
Solvent extraction process
Feed pretreatment
23-406
Bituminous Feed

FIG. 23



22A-302
Comp
22B-320
22A-310
Comp
Turbine
22A-312
HRSG
22A-314
SGT
22A-304
22A-306
22B-302b
22A-308
22B-318
EGR
Stoichiometric Air
Condensing HRSG
22B-312b
22B-316
H_2O
24-500
flue gas
Mass exchanger
Water
24-503
24-501
24-514
Saturated flue gas
24-502
24-510
24-508
Feed pretreatment
Solvent extraction process
24-506
24-504
Bituminous Feed

FIG. 24

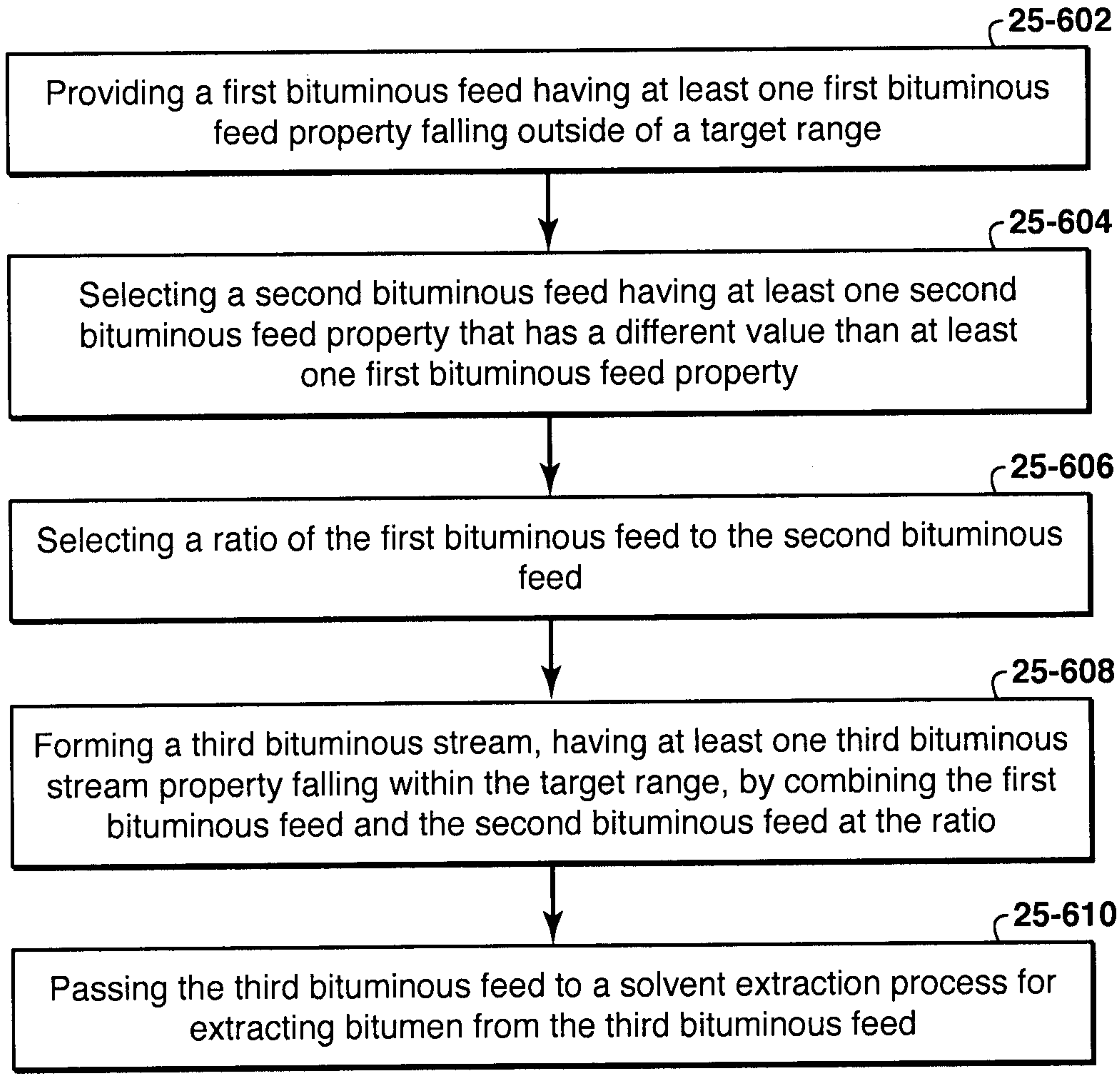

25-602
Providing a first bituminous feed having at least one first bituminous feed property falling outside of a target range
25-604
Selecting a second bituminous feed having at least one second bituminous feed property that has a different value than at least one first bituminous feed property
25-606
Selecting a ratio of the first bituminous feed to the second bituminous feed
25-608
Forming a third bituminous stream, having at least one third bituminous stream property falling within the target range, by combining the first bituminous feed and the second bituminous feed at the ratio
25-610
Passing the third bituminous feed to a solvent extraction process for extracting bitumen from the third bituminous feed

FIG. 25

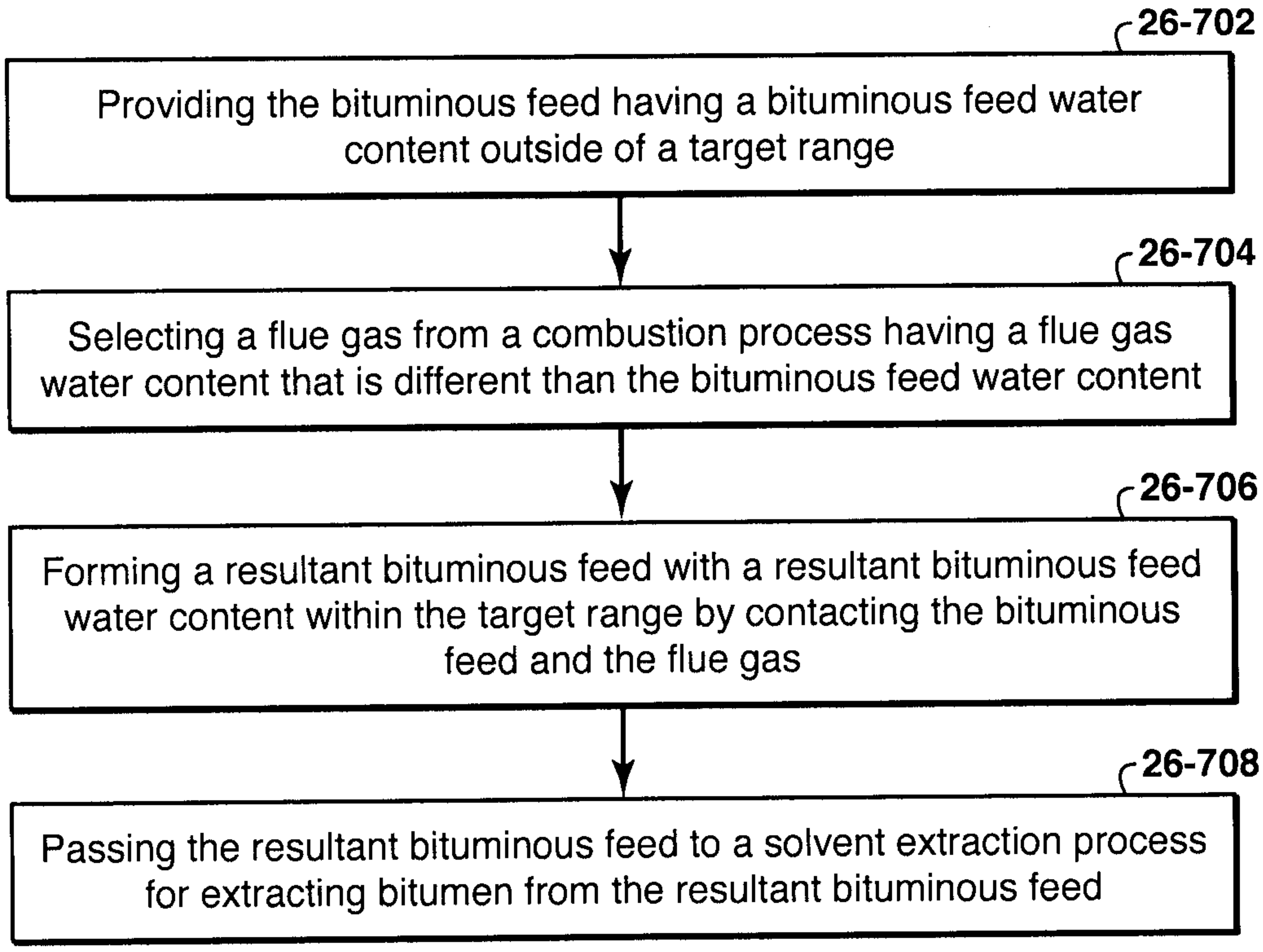

26-702
Providing the bituminous feed having a bituminous feed water content outside of a target range
26-704
Selecting a flue gas from a combustion process having a flue gas water content that is different than the bituminous feed water content
26-706
Forming a resultant bituminous feed with a resultant bituminous feed water content within the target range by contacting the bituminous feed and the flue gas
26-708
Passing the resultant bituminous feed to a solvent extraction process for extracting bitumen from the resultant bituminous feed

FIG. 26

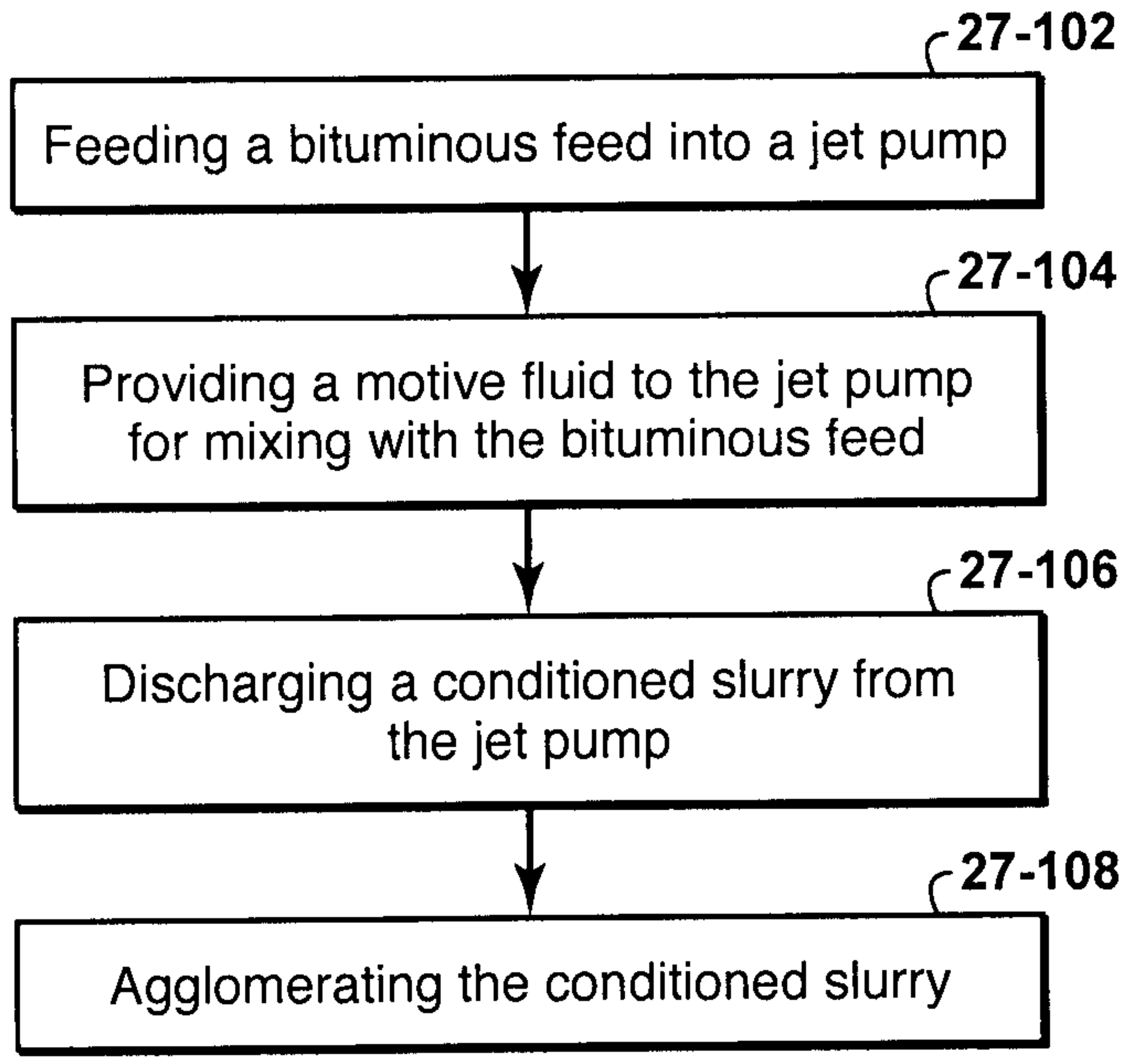

27-102
Feeding a bituminous feed into a jet pump
27-104
Providing a motive fluid to the jet pump for mixing with the bituminous feed
27-106
Discharging a conditioned slurry from the jet pump
27-108
Agglomerating the conditioned slurry

FIG. 27

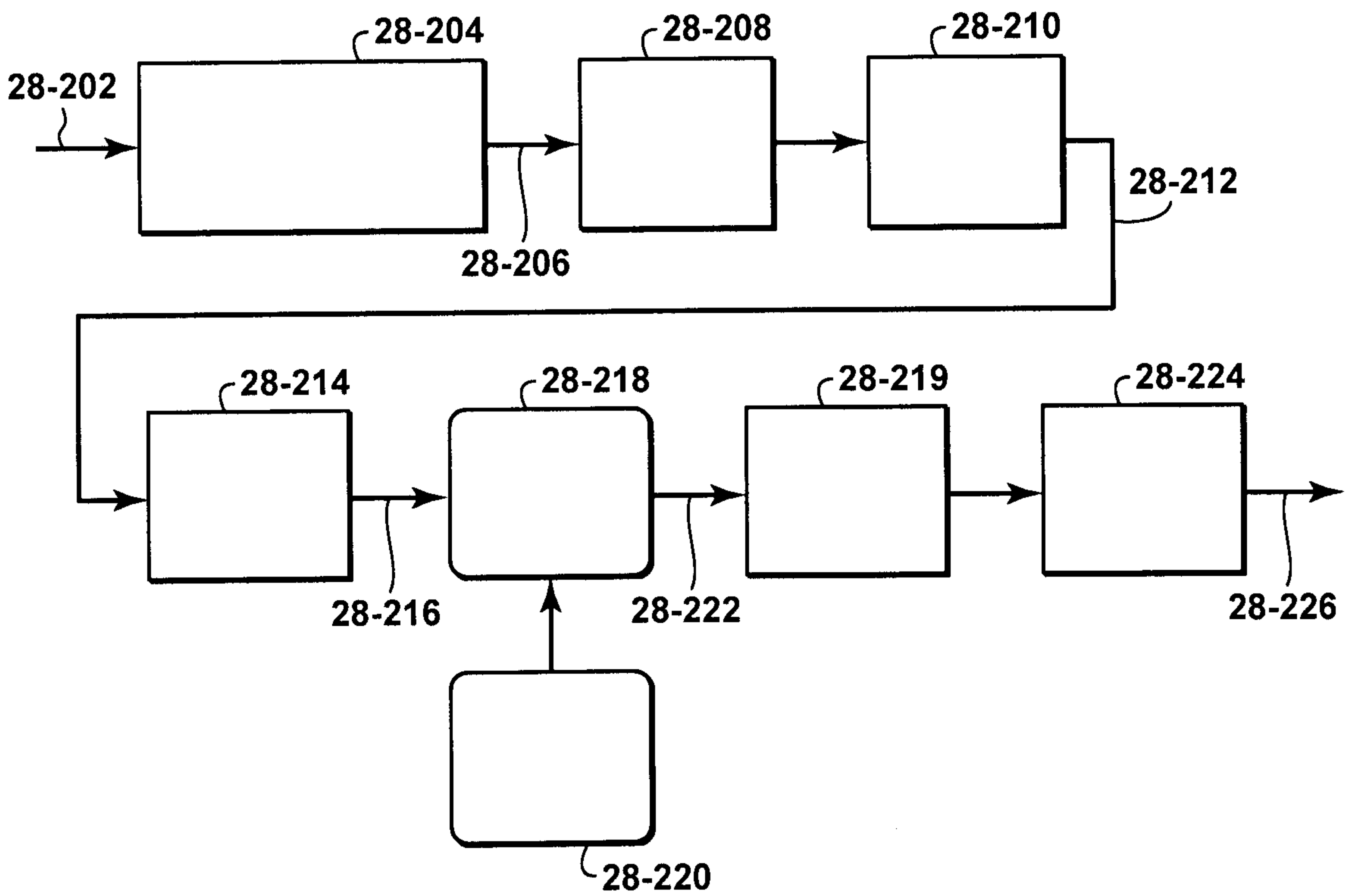

28-202
28-204
28-206
28-208
28-210
28-212
28-214
28-216
28-218
28-219
28-220
28-222
28-224
28-226

FIG. 28

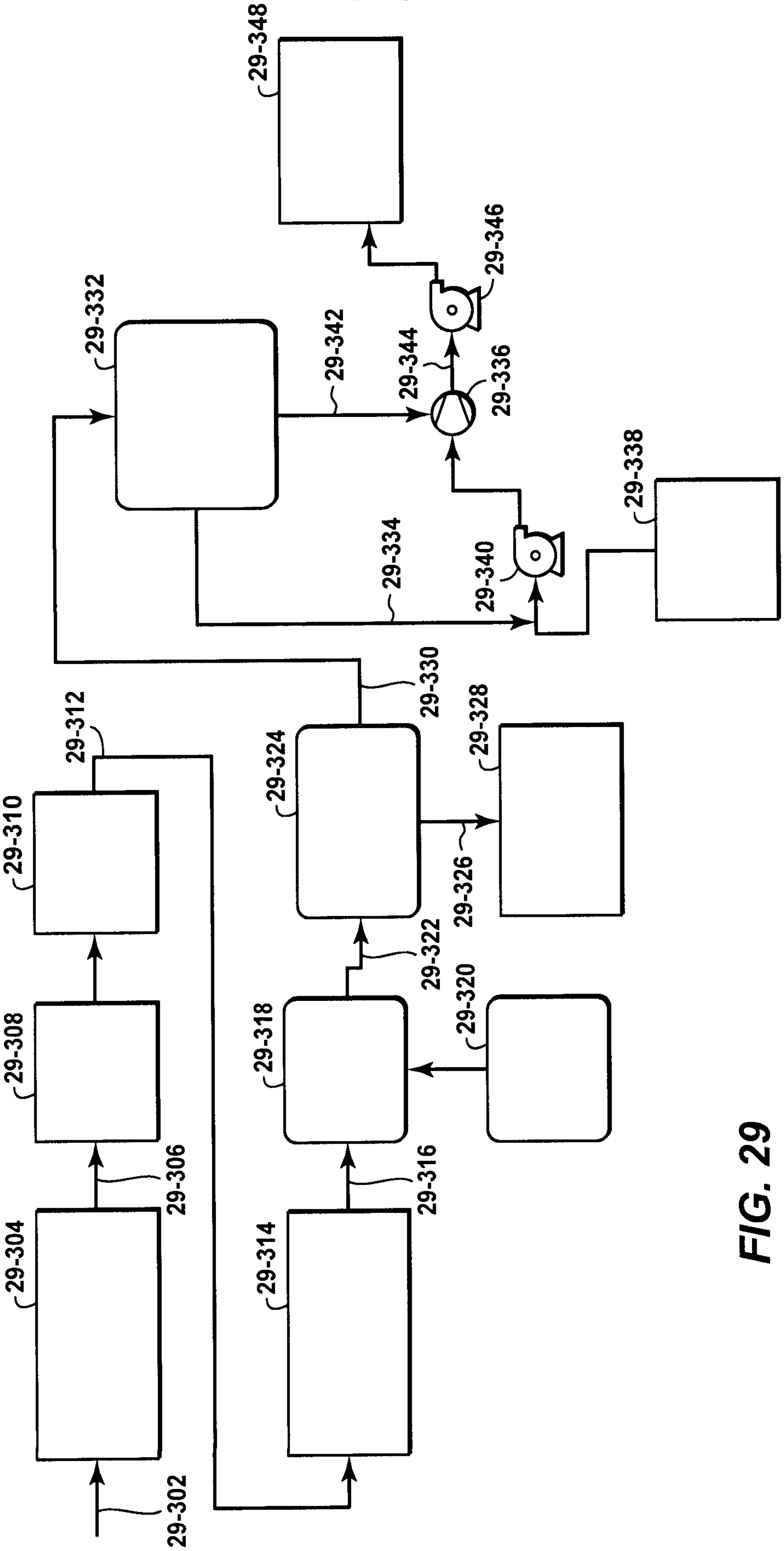

29-302
29-304
29-306
29-308
29-310
29-312
29-314
29-316
29-318
29-320
29-322
29-324
29-326
29-328
29-330
29-332
29-334
29-336
29-338
29-340
29-342
29-344
29-346
29-348

FIG. 29

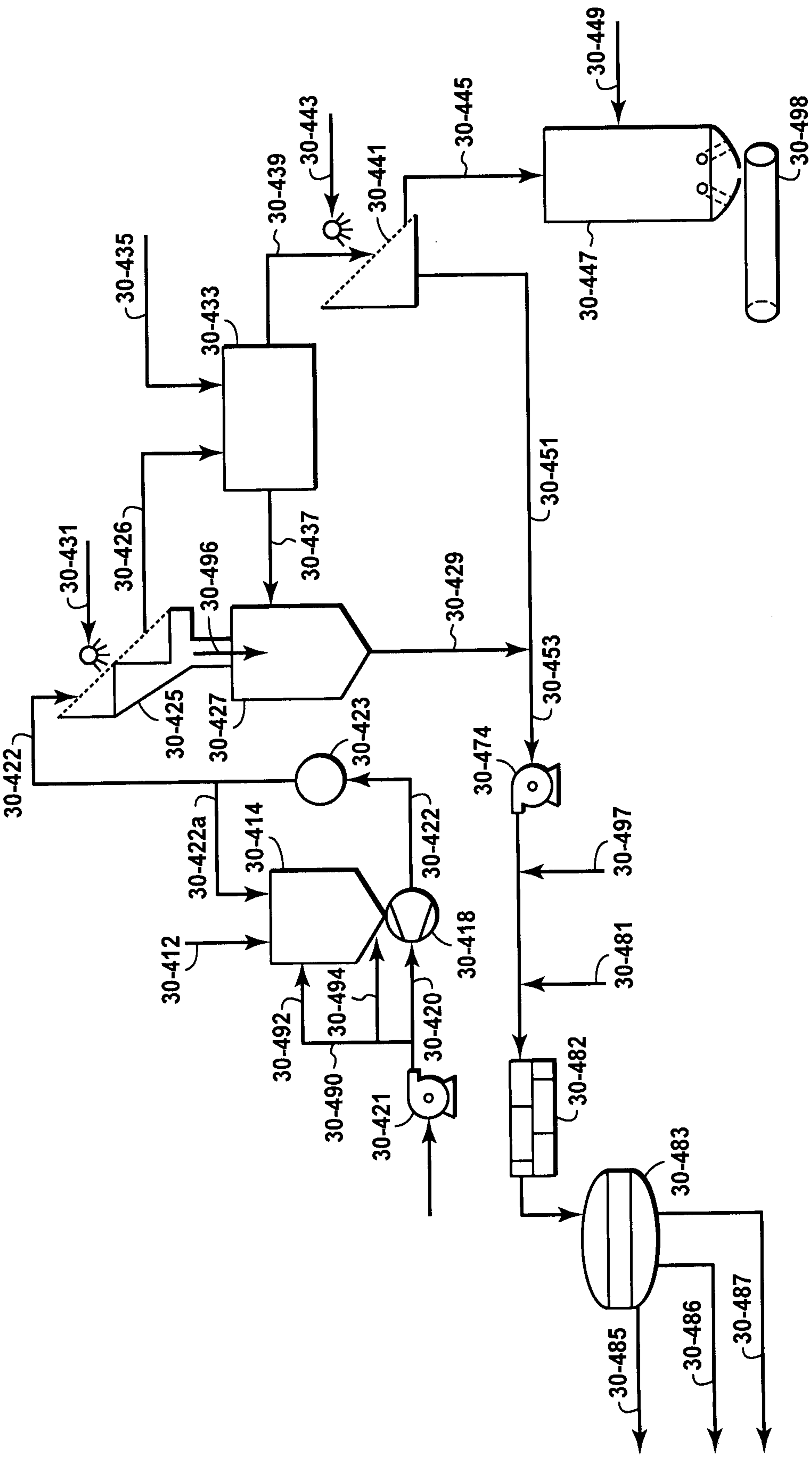

30-412
30-414
30-418
30-420
30-421
30-422
30-422a
30-423
30-425
30-426
30-427
30-429
30-431
30-433
30-435
30-437
30-439
30-441
30-443
30-445
30-447
30-449
30-451
30-453
30-474
30-481
30-482
30-483
30-485
30-486
30-487
30-490
30-492
30-494
30-496
30-497
30-498

FIG. 30

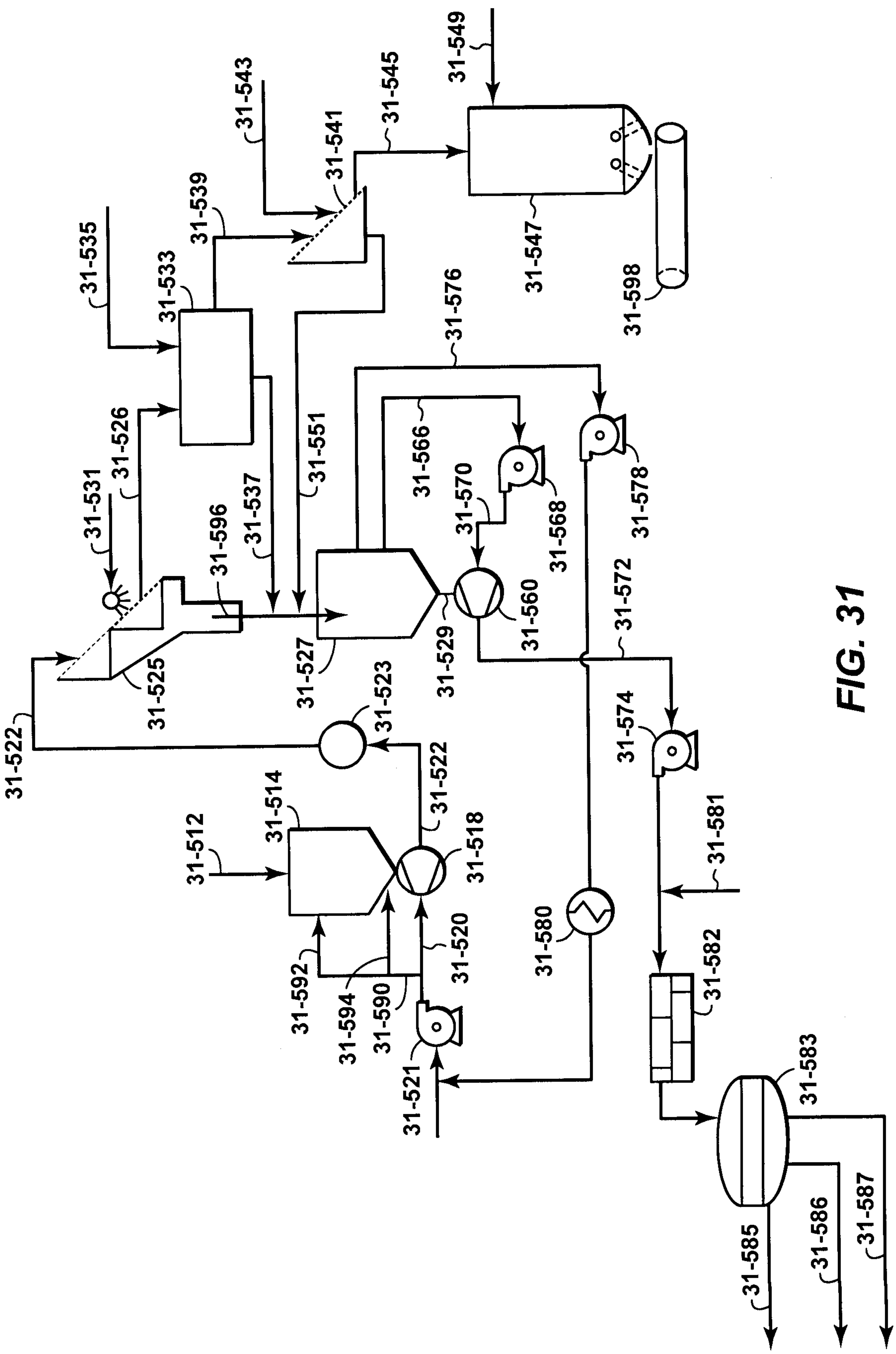

31-512
31-514
31-518
31-520
31-521
31-522
31-523
31-525
31-526
31-527
31-529
31-531
31-533
31-535
31-537
31-539
31-541
31-543
31-545
31-547
31-549
31-551
31-560
31-566
31-568
31-570
31-572
31-574
31-576
31-578
31-580
31-581
31-582
31-583
31-585
31-586
31-587
31-590
31-592
31-594
31-596
31-598

FIG. 31

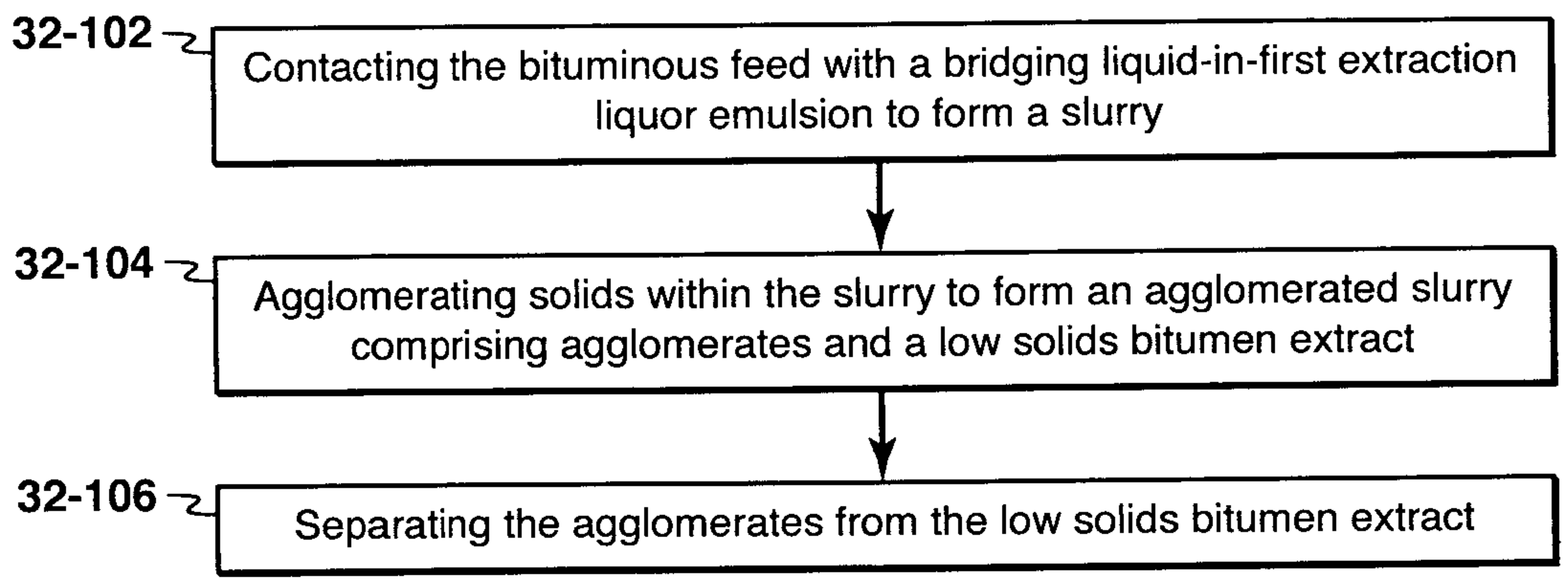

32-102
Contacting the bituminous feed with a bridging liquid-in-first extraction liquor emulsion to form a slurry
32-104
Agglomerating solids within the slurry to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract
32-106
Separating the agglomerates from the low solids bitumen extract

FIG. 32

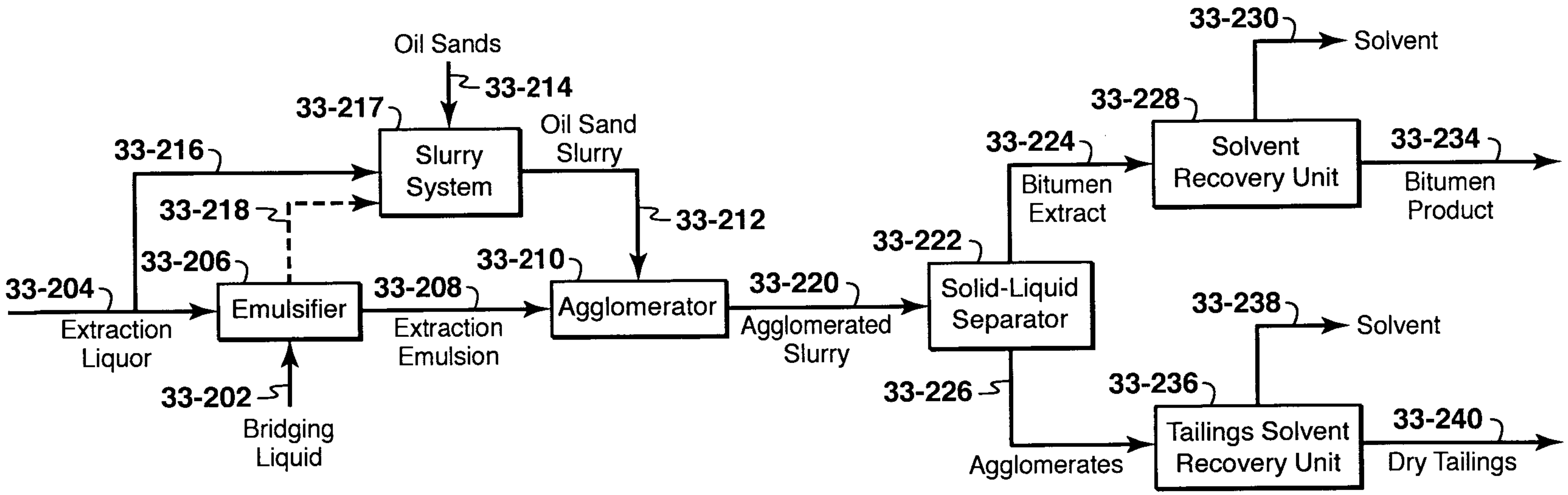
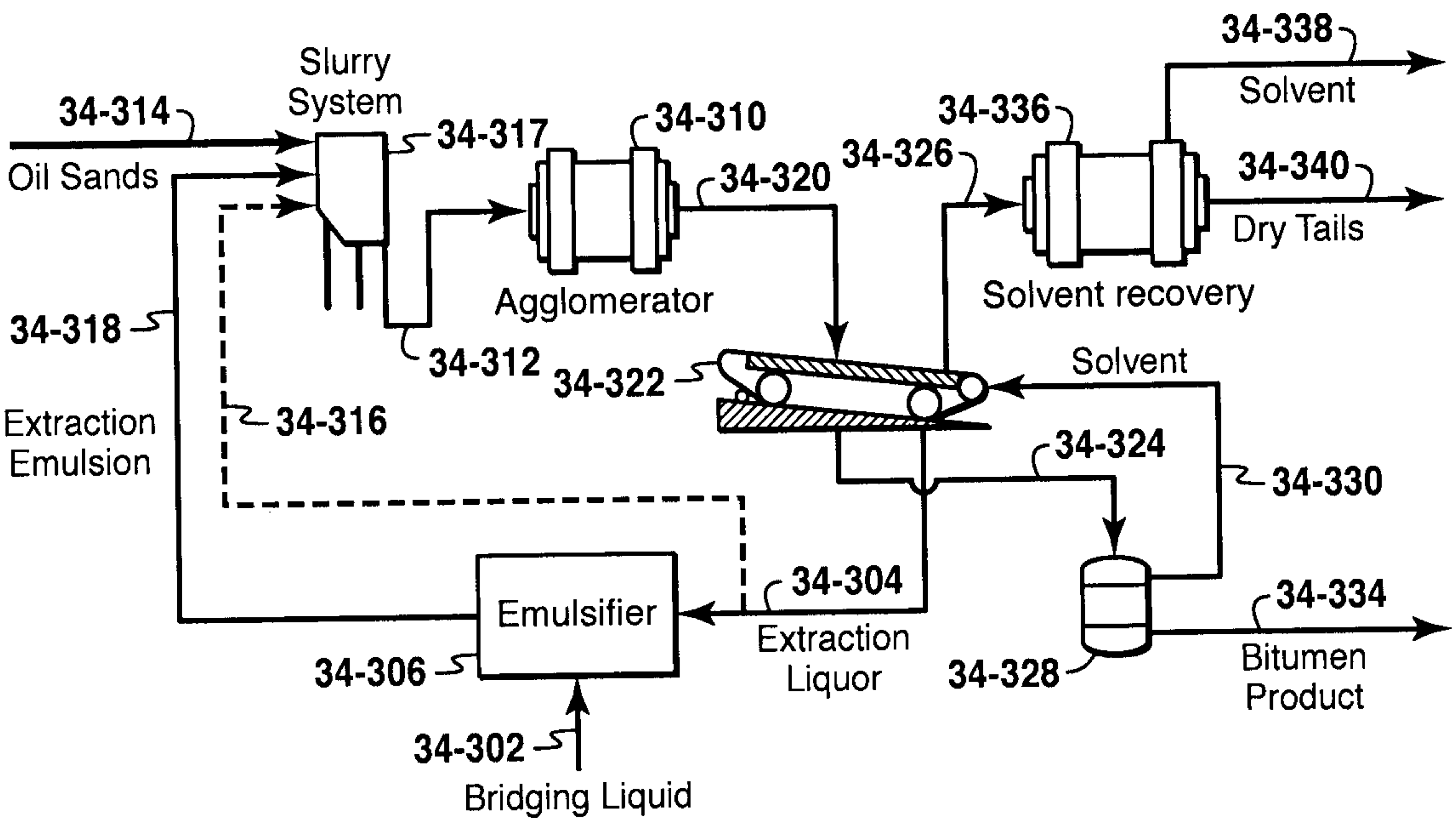
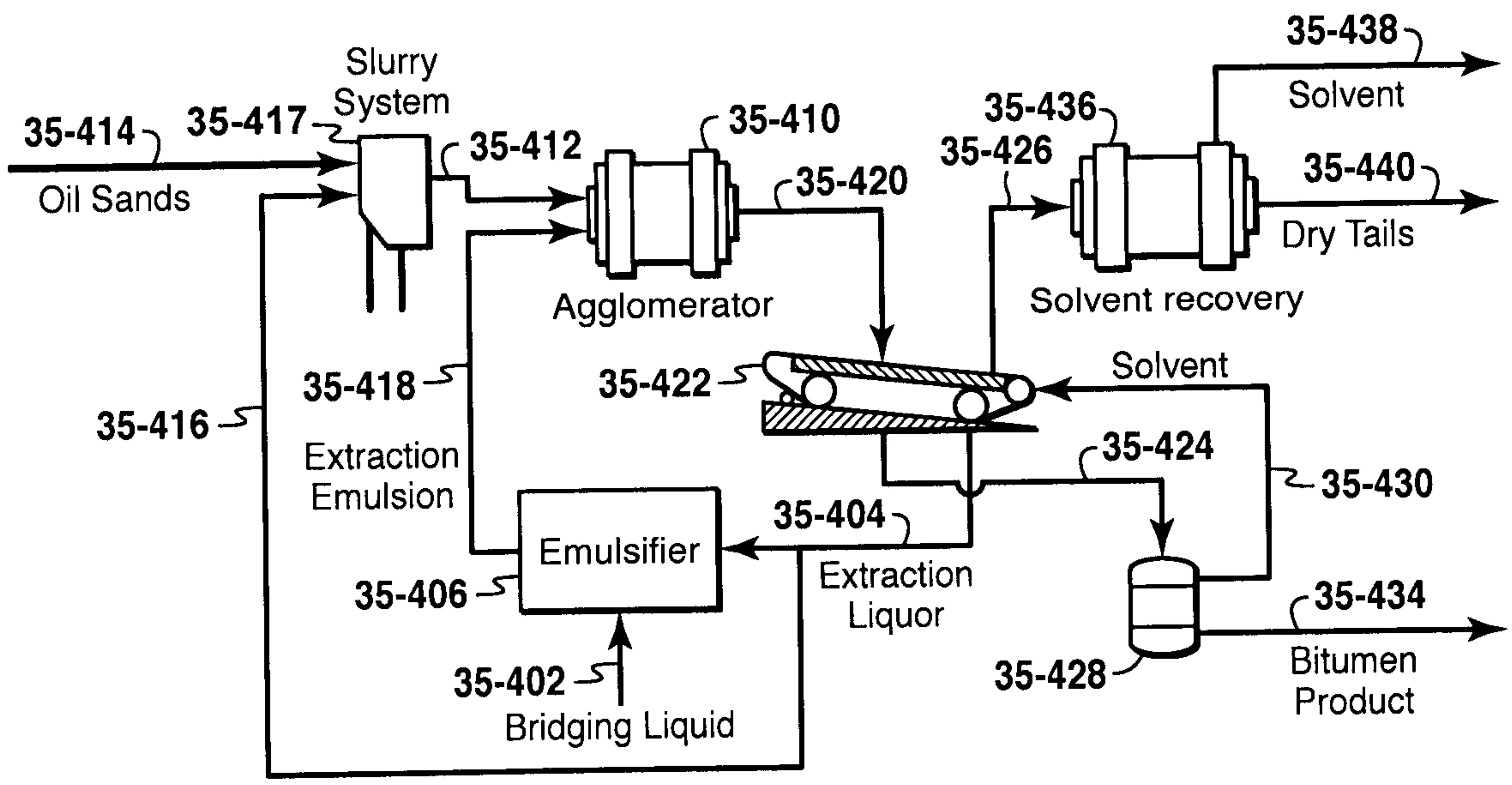

Oil Sands
33-214
33-217
Slurry System
Oil Sand Slurry
33-216
33-218
33-212
33-206
33-210
33-204
Emulsifier
33-208
Agglomerator
33-220
Extraction Liquor
Extraction Emulsion
Agglomerated Slurry
33-202
Bridging Liquid
33-222
Solid-Liquid Separator
33-224
Bitumen Extract
33-226
Agglomerates
33-228
Solvent Recovery Unit
33-230
Solvent
33-234
Bitumen Product
33-236
Tailings Solvent Recovery Unit
33-238
Solvent
33-240
Dry Tailings

FIG. 33



34-314
Oil Sands
Slurry System
34-317
34-310
34-320
34-326
34-336
34-338
Solvent
34-340
Dry Tails
Solvent recovery
Agglomerator
34-318
Extraction Emulsion
34-312
34-322
34-316
Solvent
34-324
34-330
Emulsifier
34-304
Extraction Liquor
34-334
Bitumen Product
34-306
34-328
34-302
Bridging Liquid

FIG. 34



35-414
Oil Sands
35-417
Slurry System
35-412
35-410
35-420
35-436
35-426
35-438
Solvent
35-440
Dry Tails
Solvent recovery
Agglomerator
35-418
Extraction Emulsion
35-416
35-422
Solvent
35-424
35-430
35-404
Emulsifier
Extraction Liquor
35-406
35-434
Bitumen Product
35-402
Bridging Liquid
35-428

FIG. 35

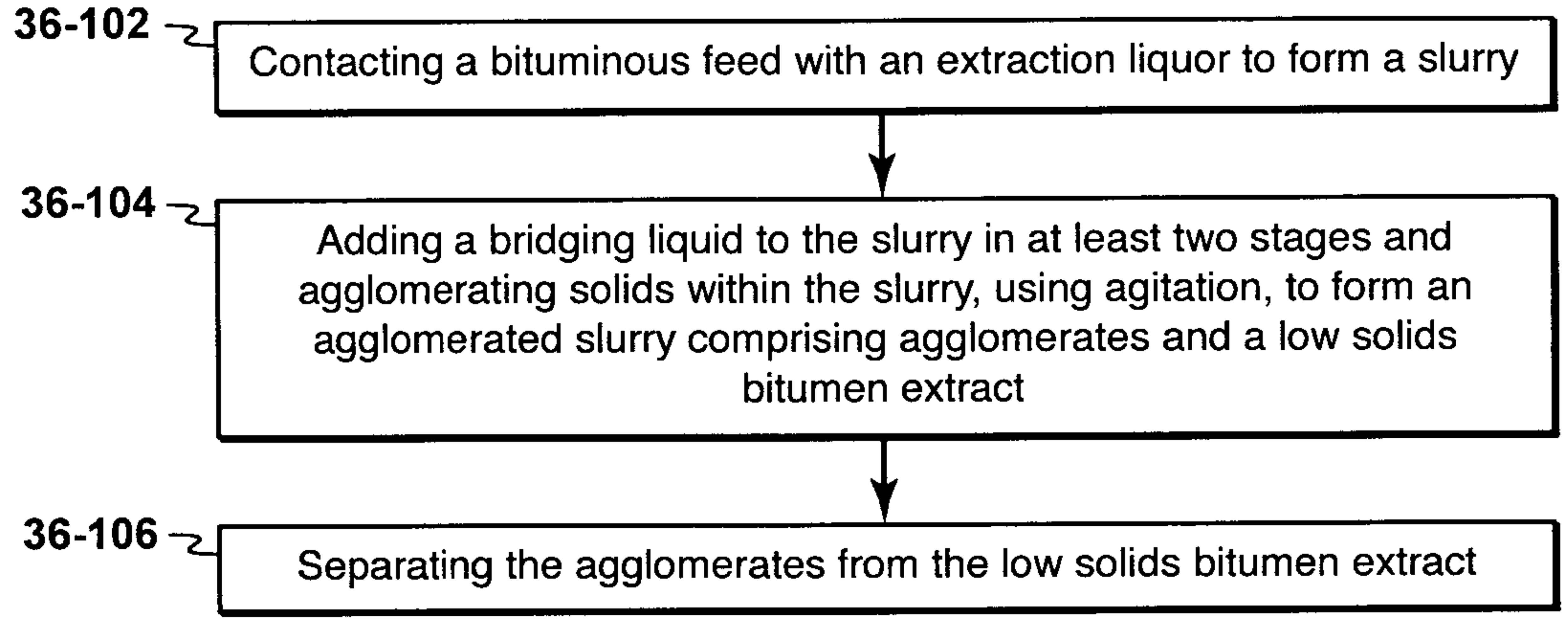

36-102
Contacting a bituminous feed with an extraction liquor to form a slurry
36-104
Adding a bridging liquid to the slurry in at least two stages and agglomerating solids within the slurry, using agitation, to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract
36-106
Separating the agglomerates from the low solids bitumen extract

FIG. 36

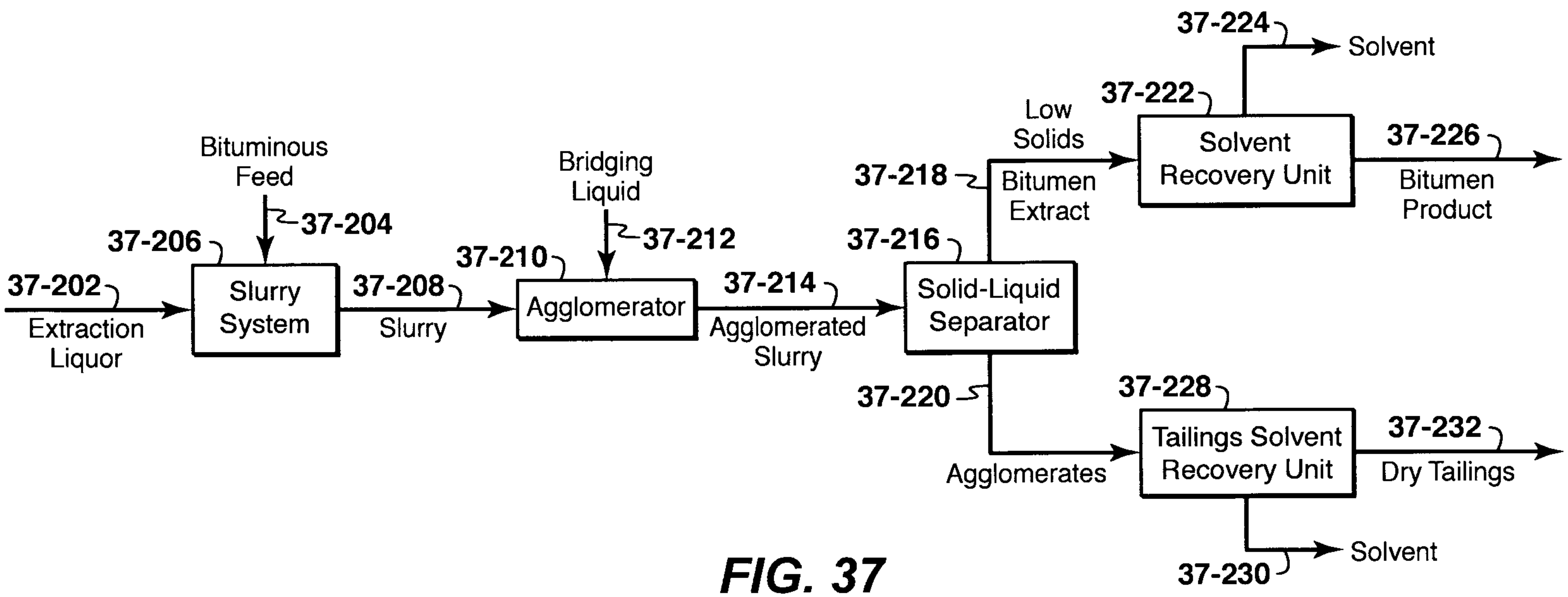

37-202
Extraction Liquor
37-206
Bituminous Feed
37-204
Slurry System
37-208
Slurry
37-210
Bridging Liquid
37-212
Agglomerator
37-214
Agglomerated Slurry
37-216
Solid-Liquid Separator
37-218
Low Solids Bitumen Extract
37-220
Agglomerates
37-222
Solvent Recovery Unit
37-224
Solvent
37-226
Bitumen Product
37-228
Tailings Solvent Recovery Unit
37-230
Solvent
37-232
Dry Tailings

FIG. 37

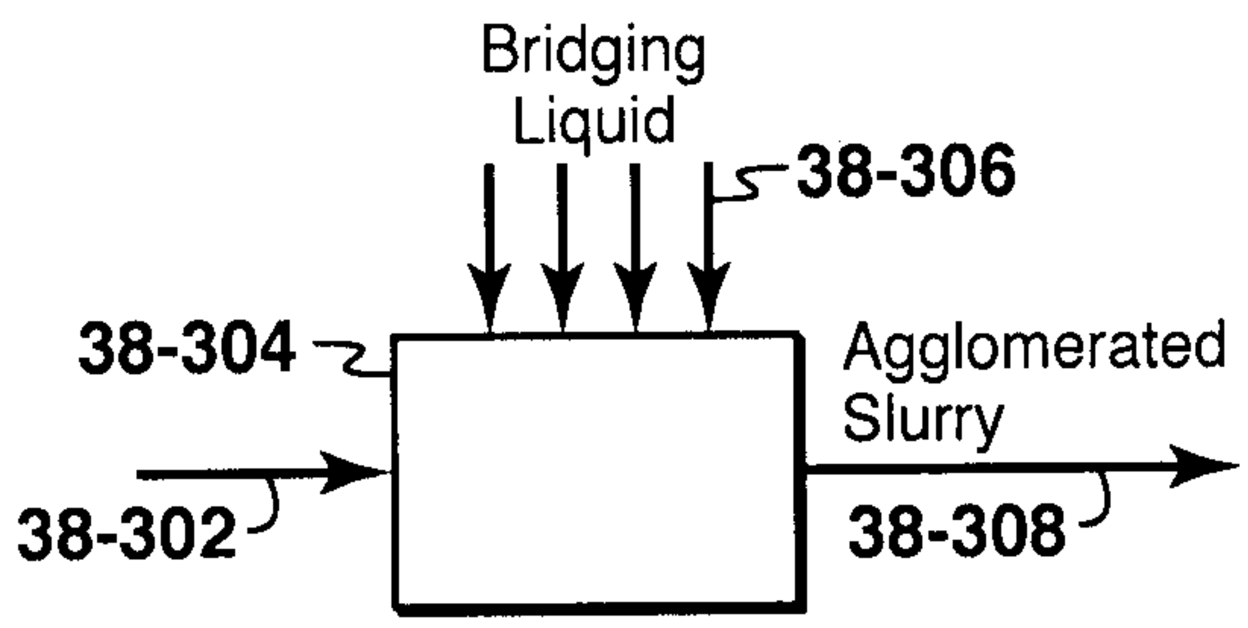


FIG. 38

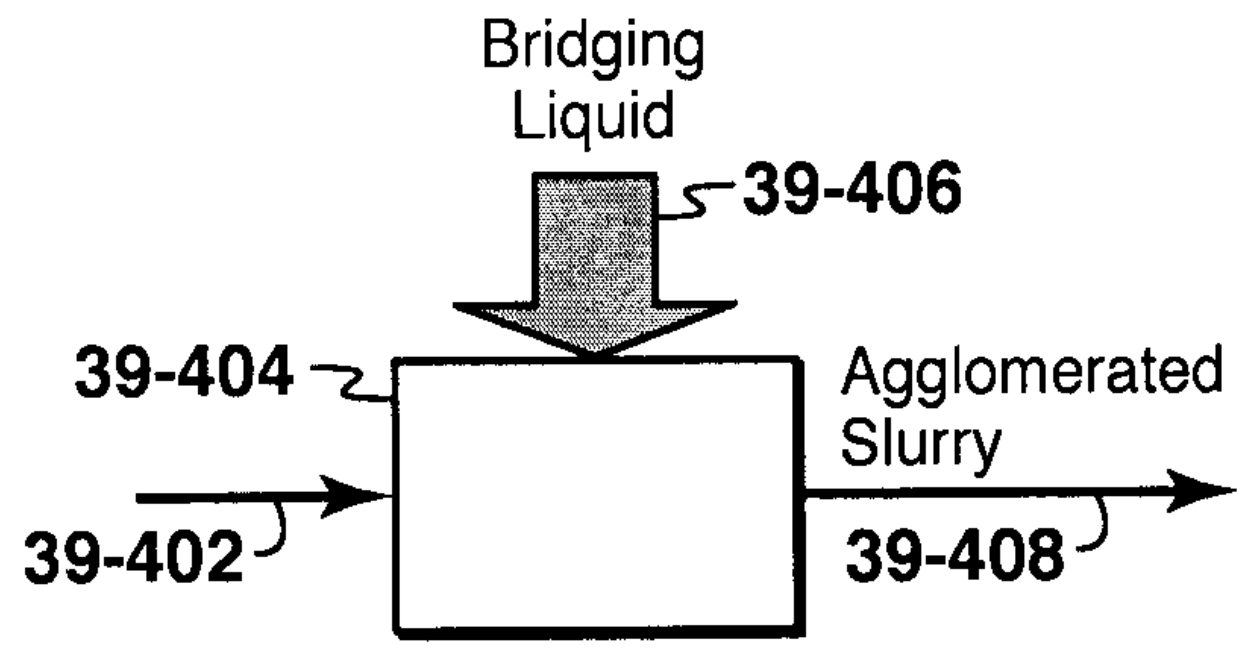


FIG. 39

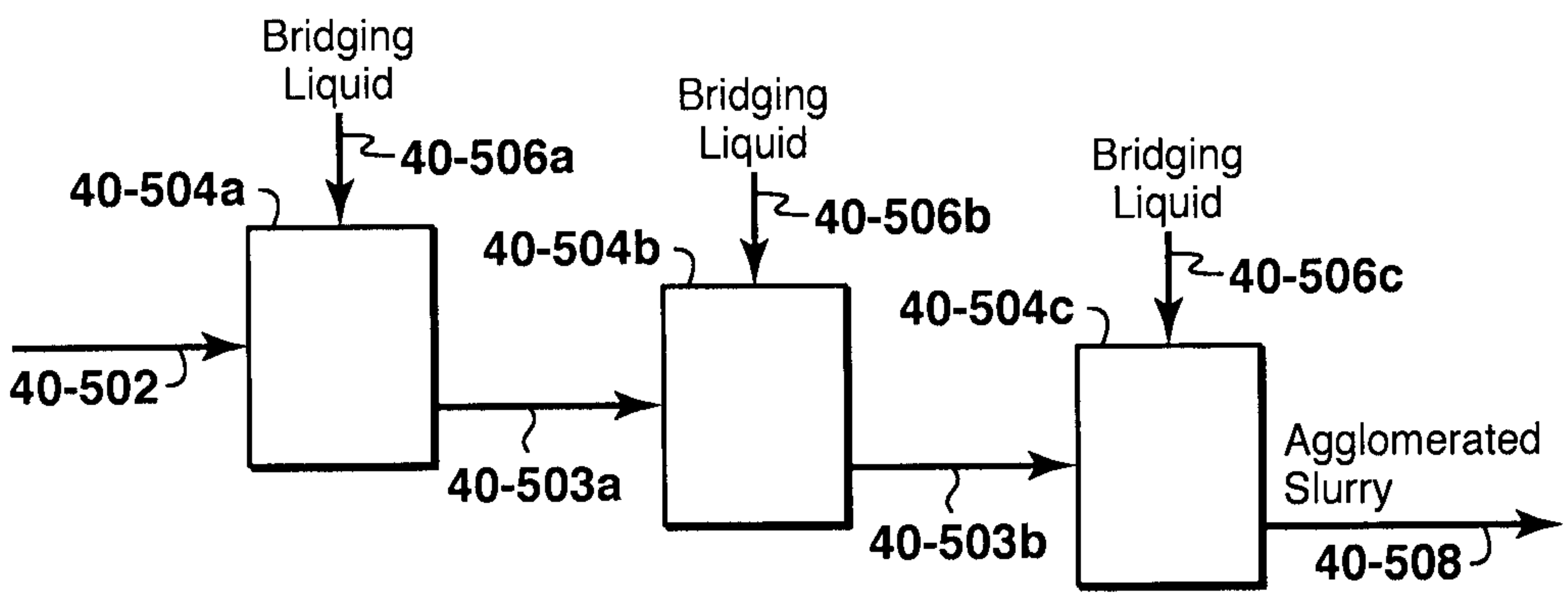


FIG. 40

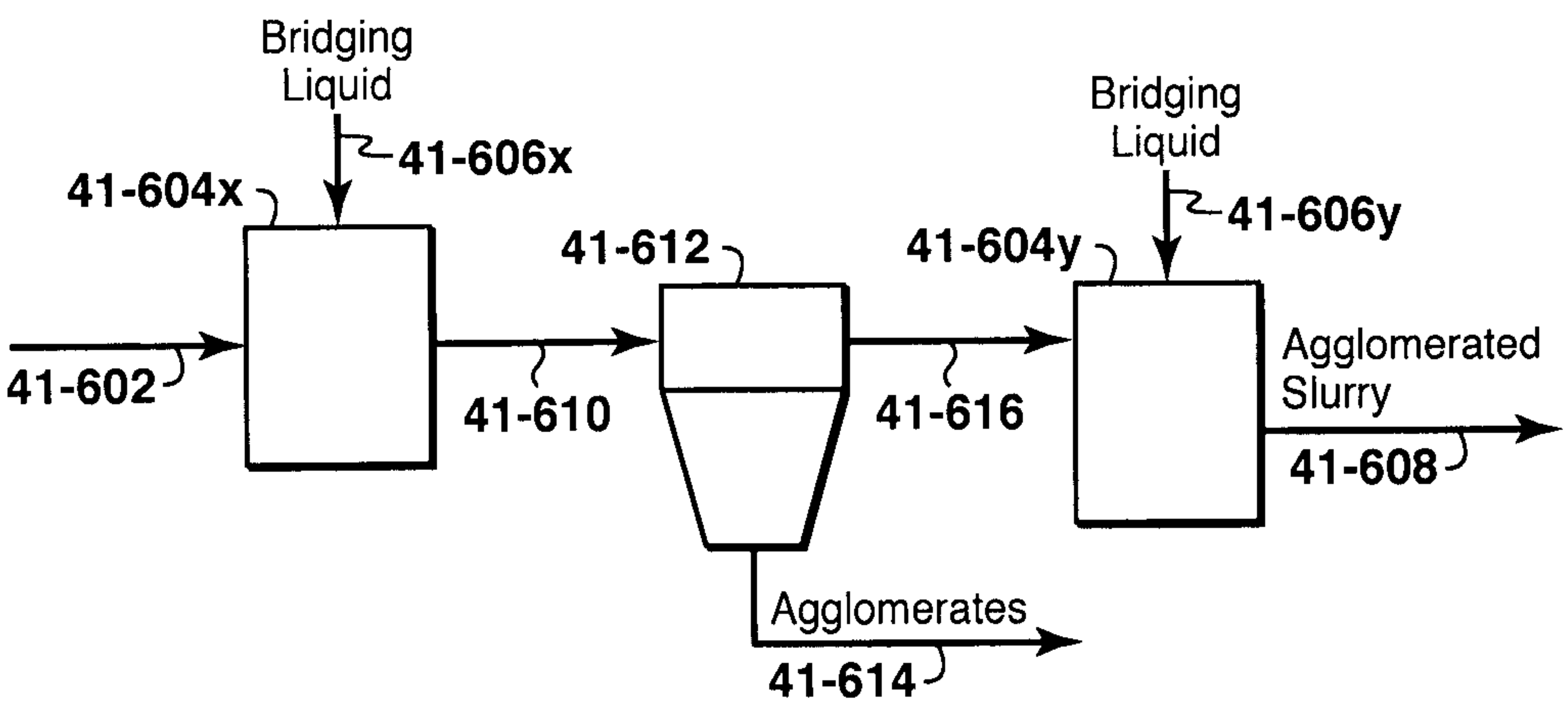


FIG. 41

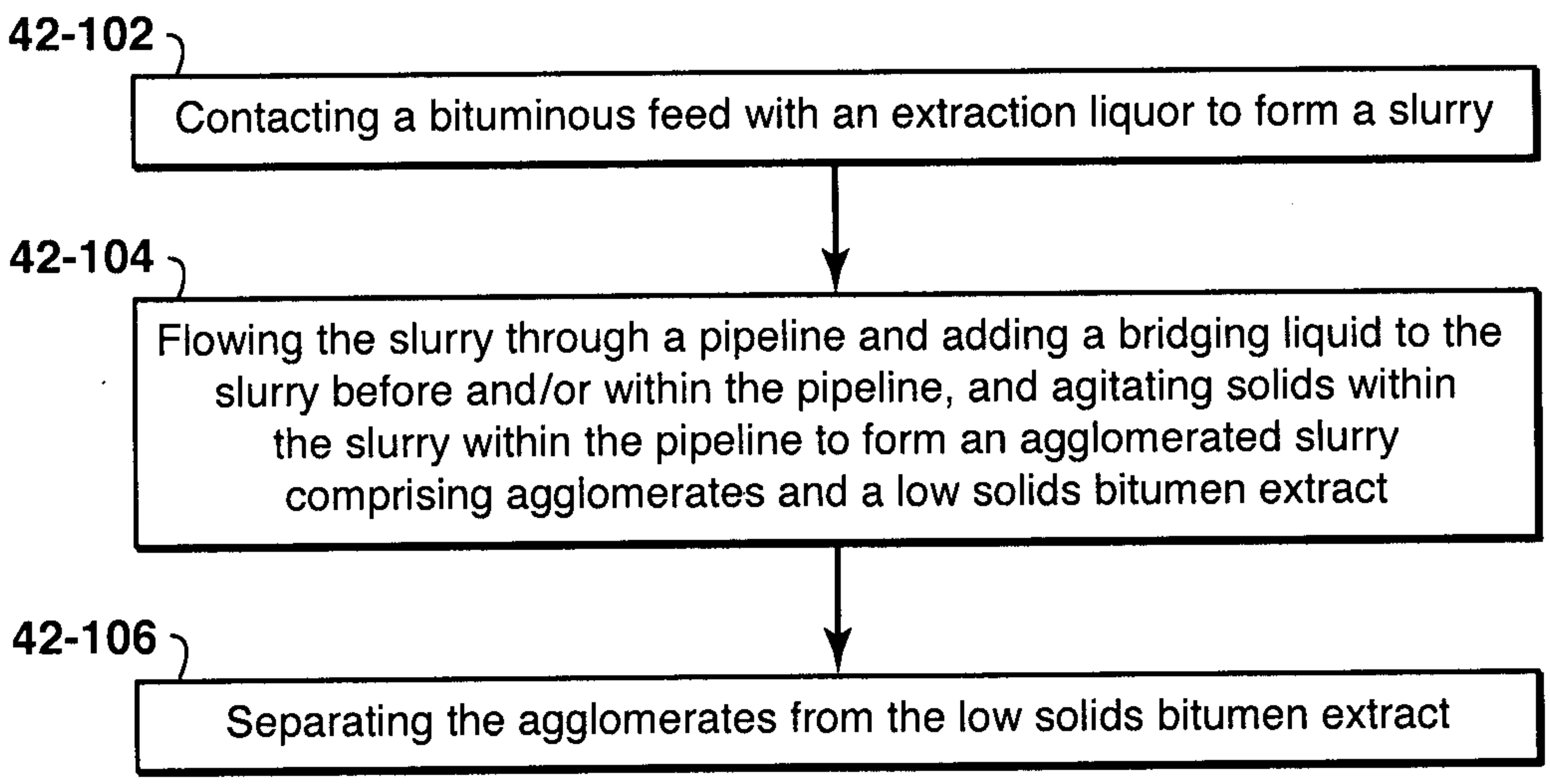

42-102
Contacting a bituminous feed with an extraction liquor to form a slurry
42-104
Flowing the slurry through a pipeline and adding a bridging liquid to the slurry before and/or within the pipeline, and agitating solids within the slurry within the pipeline to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract
42-106
Separating the agglomerates from the low solids bitumen extract

FIG. 42

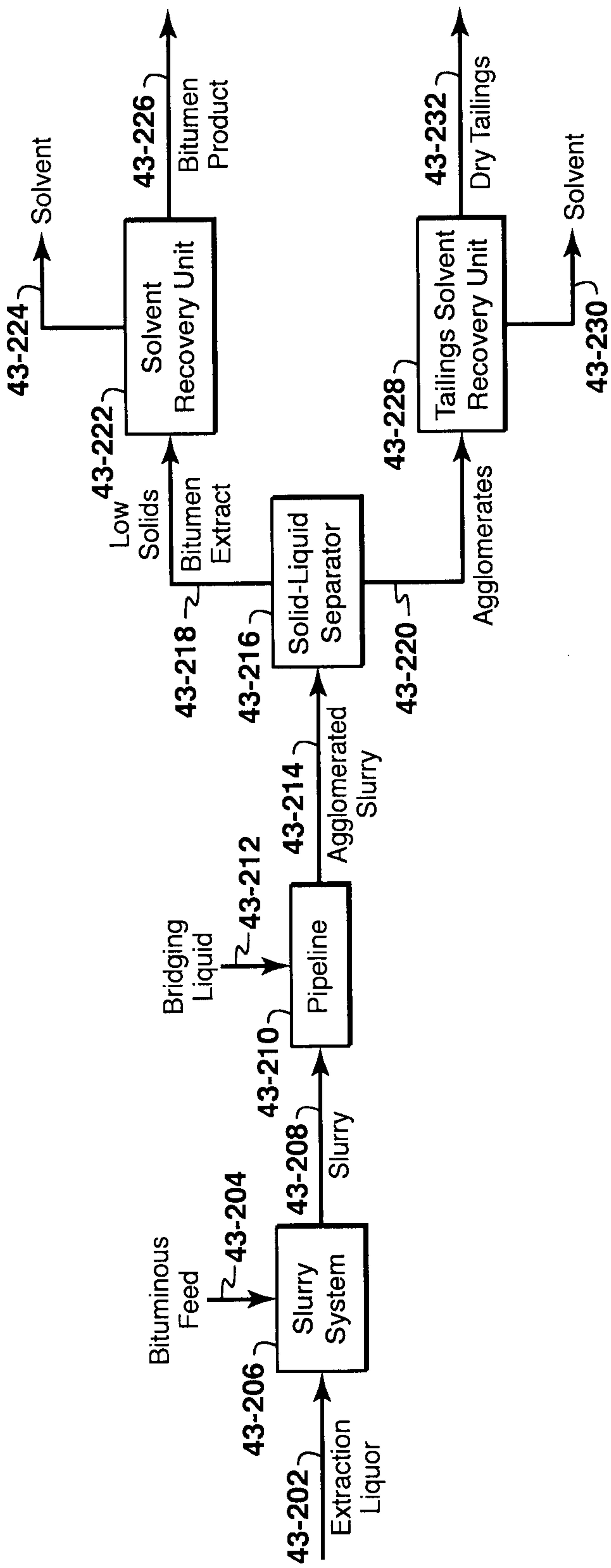

43-202
Extraction Liquor
43-206
Slurry System
Bituminous Feed
43-204
43-208
Slurry
43-210
Pipeline
Bridging Liquid
43-212
43-214
Agglomerated Slurry
43-216
Solid-Liquid Separator
43-218
Low Solids
Bitumen Extract
43-220
Agglomerates
43-222
Solvent Recovery Unit
43-224
Solvent
43-226
Bitumen Product
43-228
Tailings Solvent Recovery Unit
43-230
Solvent
43-232
Dry Tailings

FIG. 43

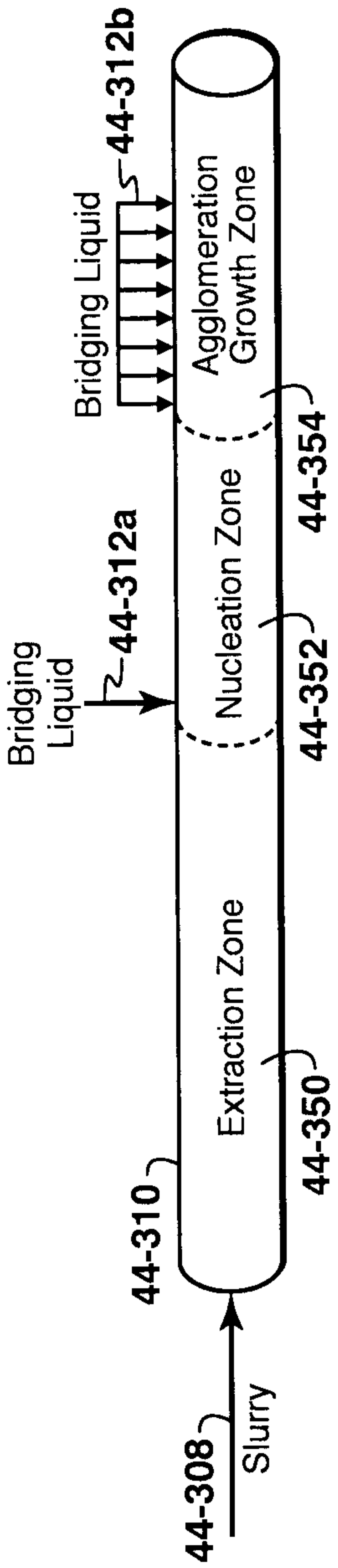

44-308
Slurry
44-310
Extraction Zone
44-350
Bridging Liquid
44-312a
Nucleation Zone
44-352
44-354
Bridging Liquid
44-312b
Agglomeration Growth Zone

FIG. 44

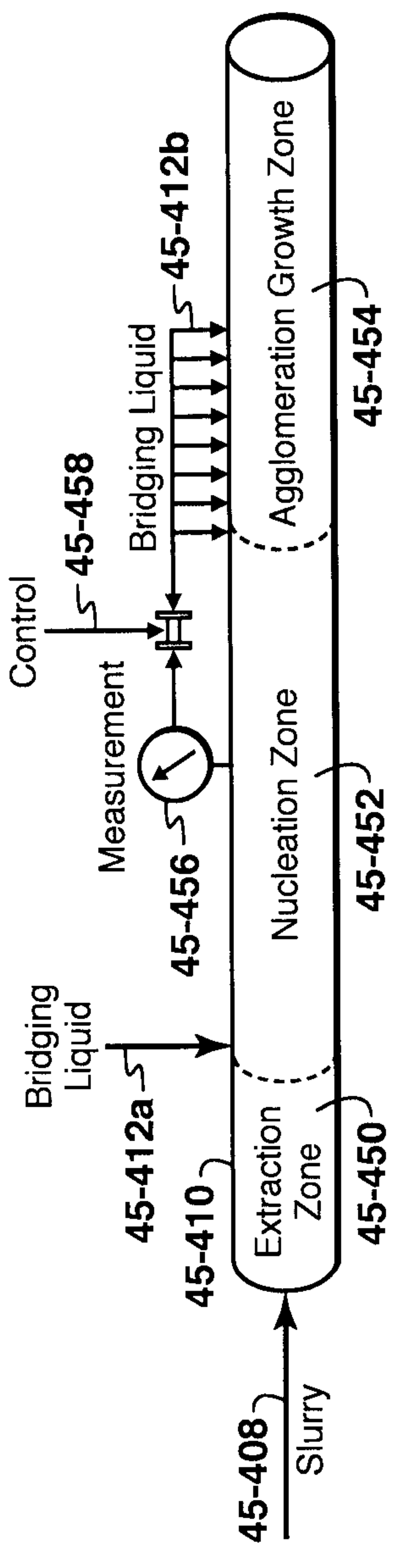

45-408
Slurry
45-410
Extraction Zone
45-450
Bridging Liquid
45-412a
Nucleation Zone
45-452
Measurement
45-456
Control
45-458
Bridging Liquid
45-412b
Agglomeration Growth Zone
45-454

FIG. 45

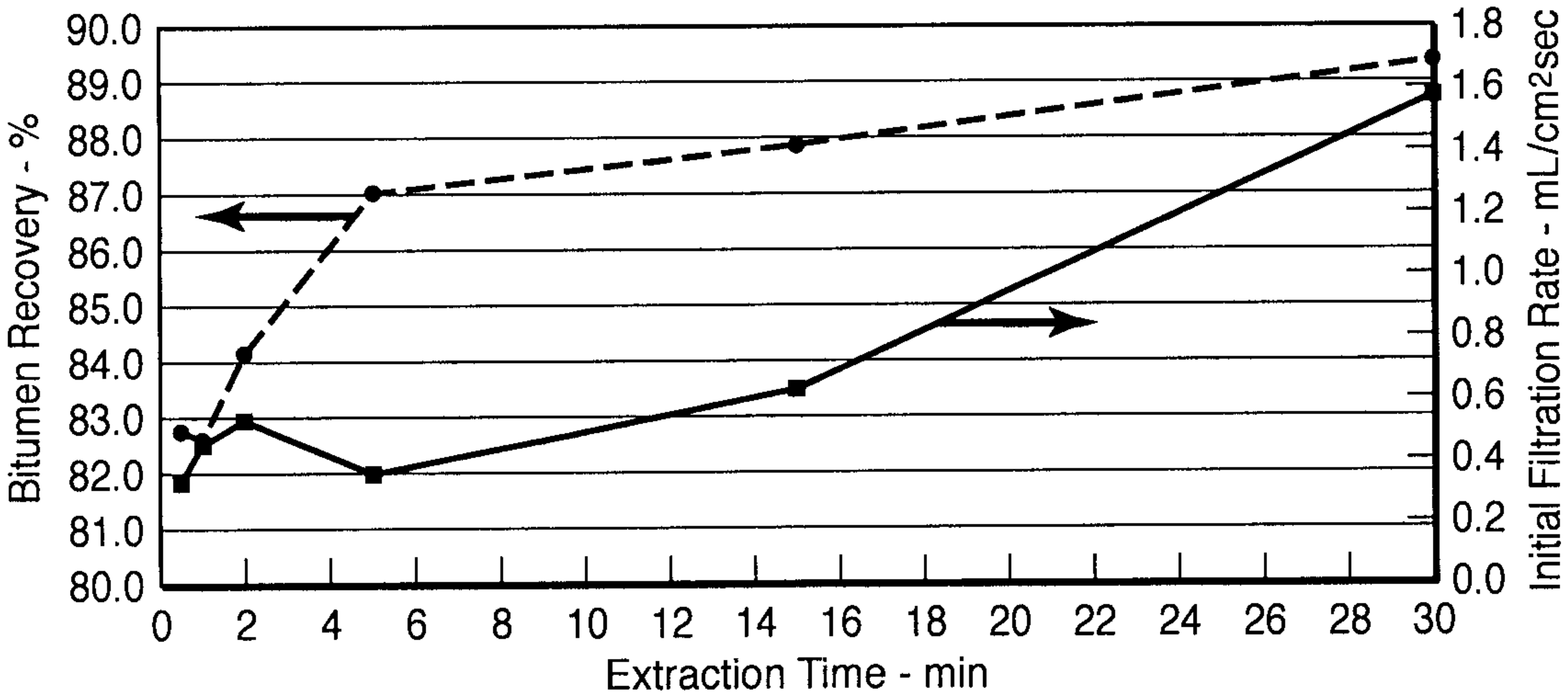

90.0
89.0
88.0
87.0
86.0
85.0
84.0
83.0
82.0
81.0
80.0
Bitumen Recovery - %
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Initial Filtration Rate - mL/cm2sec
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
Extraction Time - min

FIG. 46

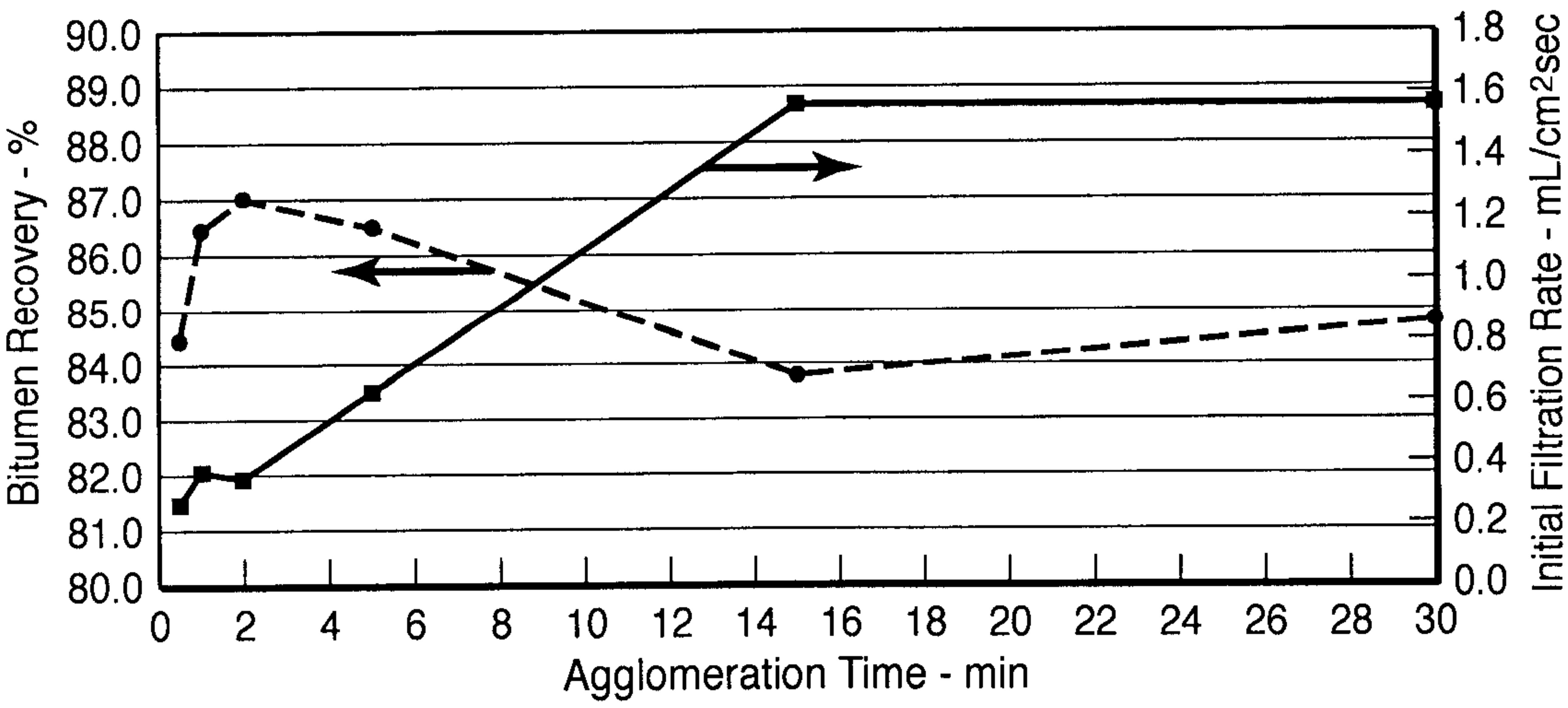

90.0
89.0
88.0
87.0
86.0
85.0
84.0
83.0
82.0
81.0
80.0
Bitumen Recovery - %
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Initial Filtration Rate - mL/cm2sec
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
Agglomeration Time - min

FIG. 47

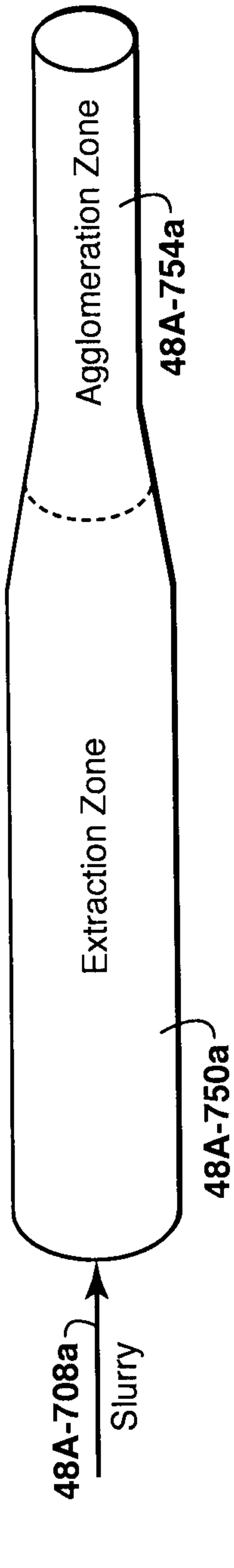


FIG. 48A

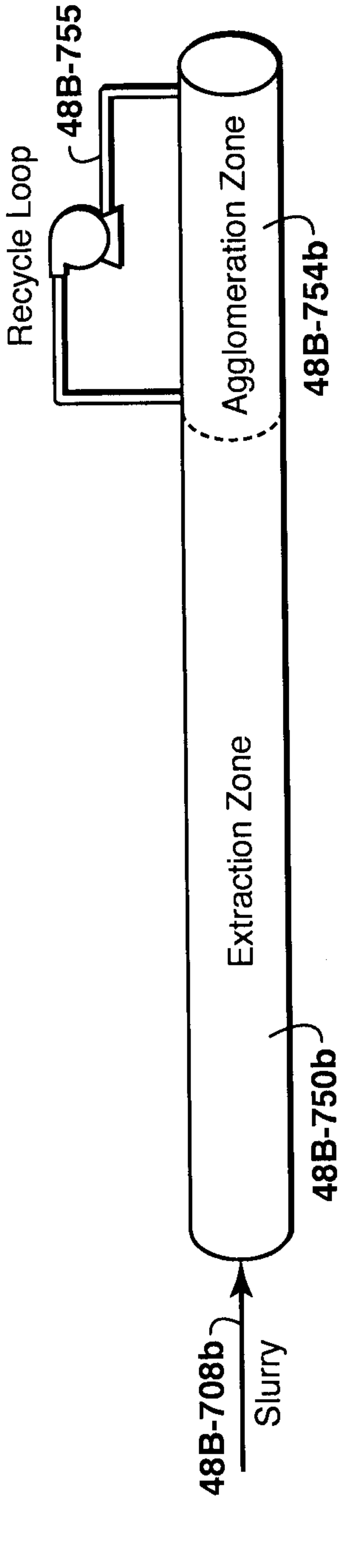


FIG. 48B

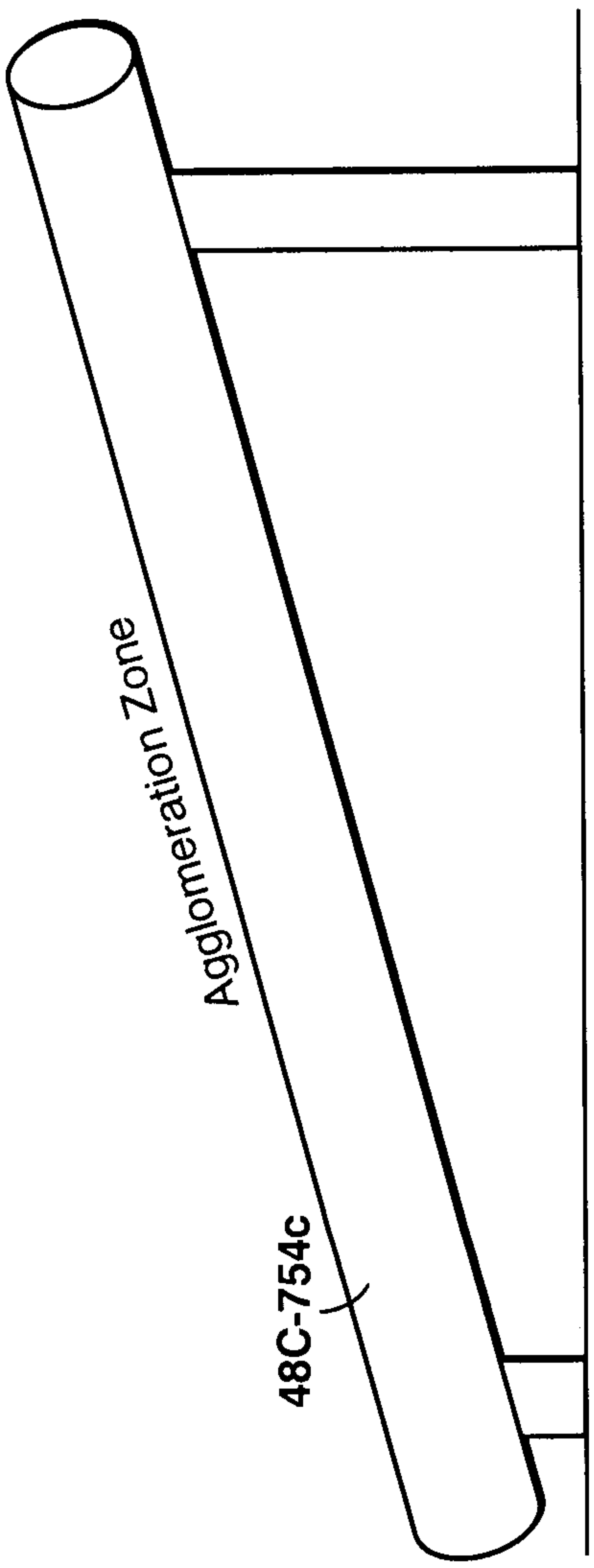


FIG. 48C

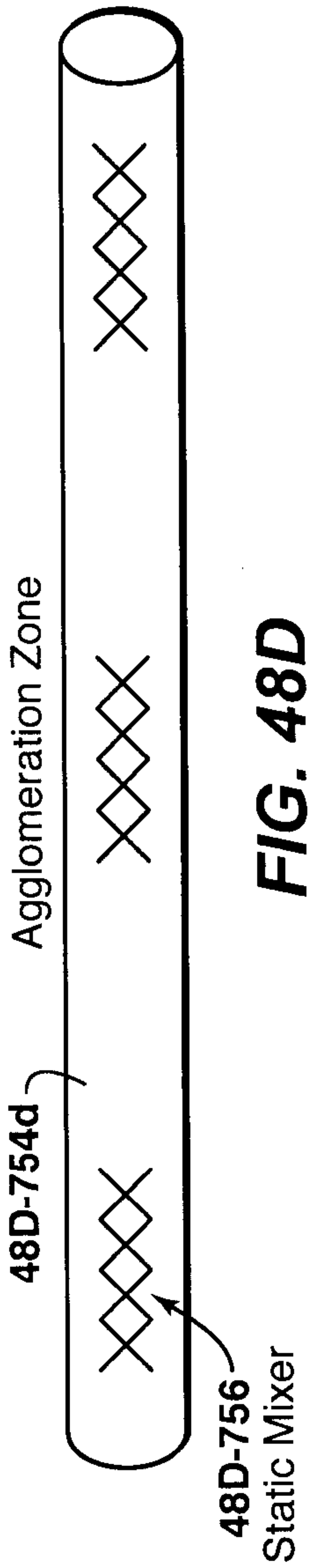


FIG. 48D

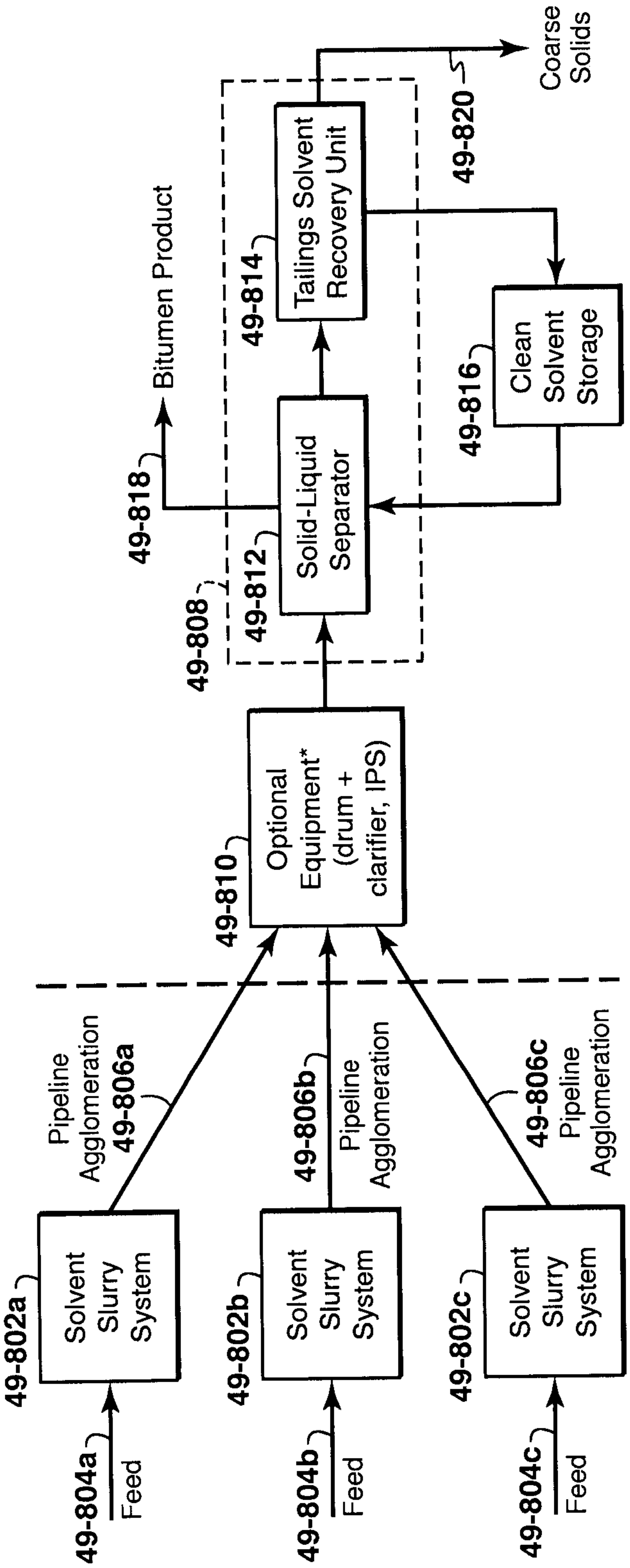

Feed
49-804a
Solvent Slurry System
49-802a
Pipeline Agglomeration
49-806a
Feed
49-804b
Solvent Slurry System
49-802b
Pipeline Agglomeration
49-806b
Feed
49-804c
Solvent Slurry System
49-802c
Pipeline Agglomeration
49-806c
Optional Equipment* (drum + clarifier, IPS)
49-810
49-808
Solid-Liquid Separator
49-812
49-818
Bitumen Product
Tailings Solvent Recovery Unit
49-814
Clean Solvent Storage
49-816
49-820
Coarse Solids

FIG. 49

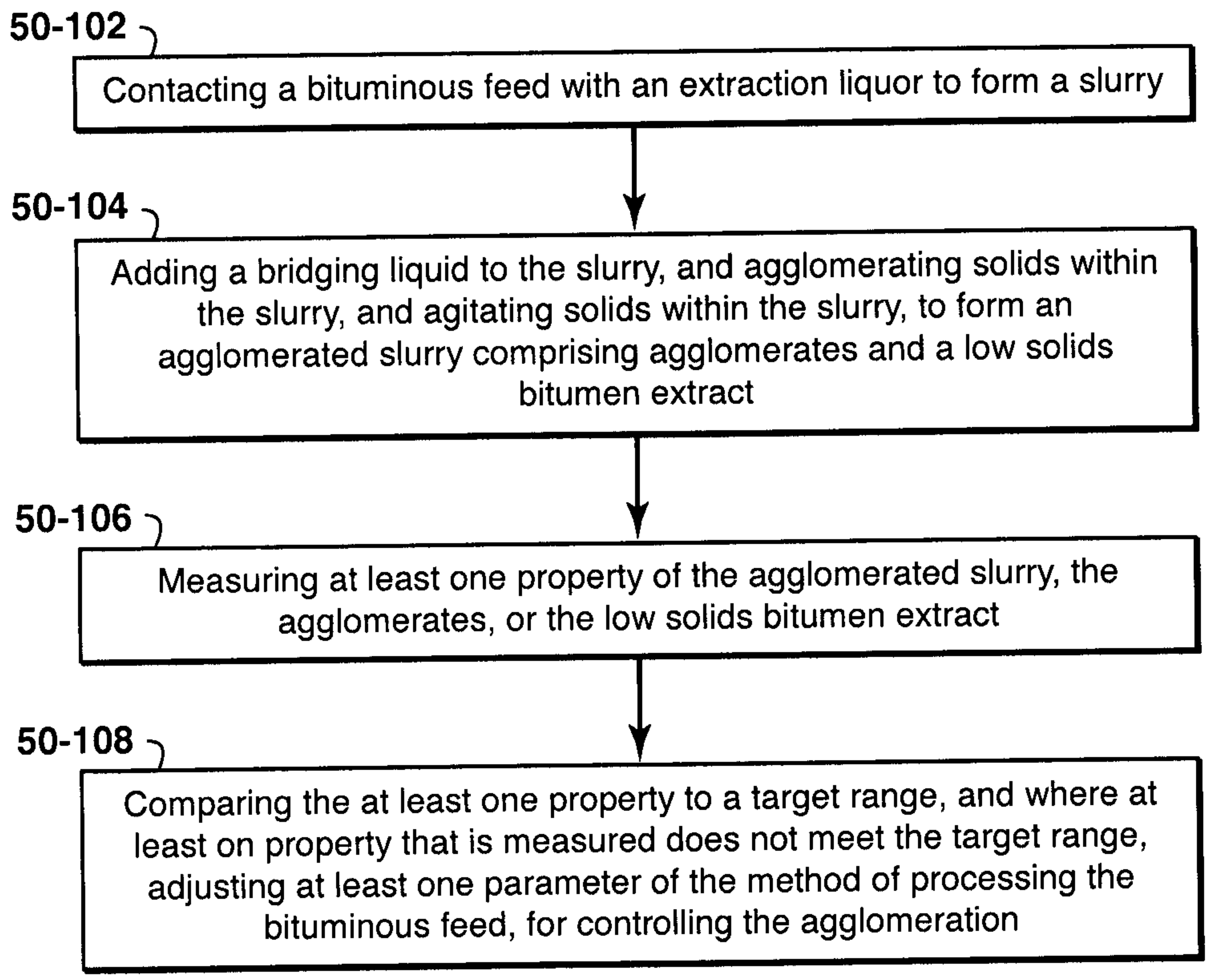

50-102
Contacting a bituminous feed with an extraction liquor to form a slurry
50-104
Adding a bridging liquid to the slurry, and agglomerating solids within the slurry, and agitating solids within the slurry, to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract
50-106
Measuring at least one property of the agglomerated slurry, the agglomerates, or the low solids bitumen extract
50-108
Comparing the at least one property to a target range, and where at least on property that is measured does not meet the target range, adjusting at least one parameter of the method of processing the bituminous feed, for controlling the agglomeration

FIG. 50

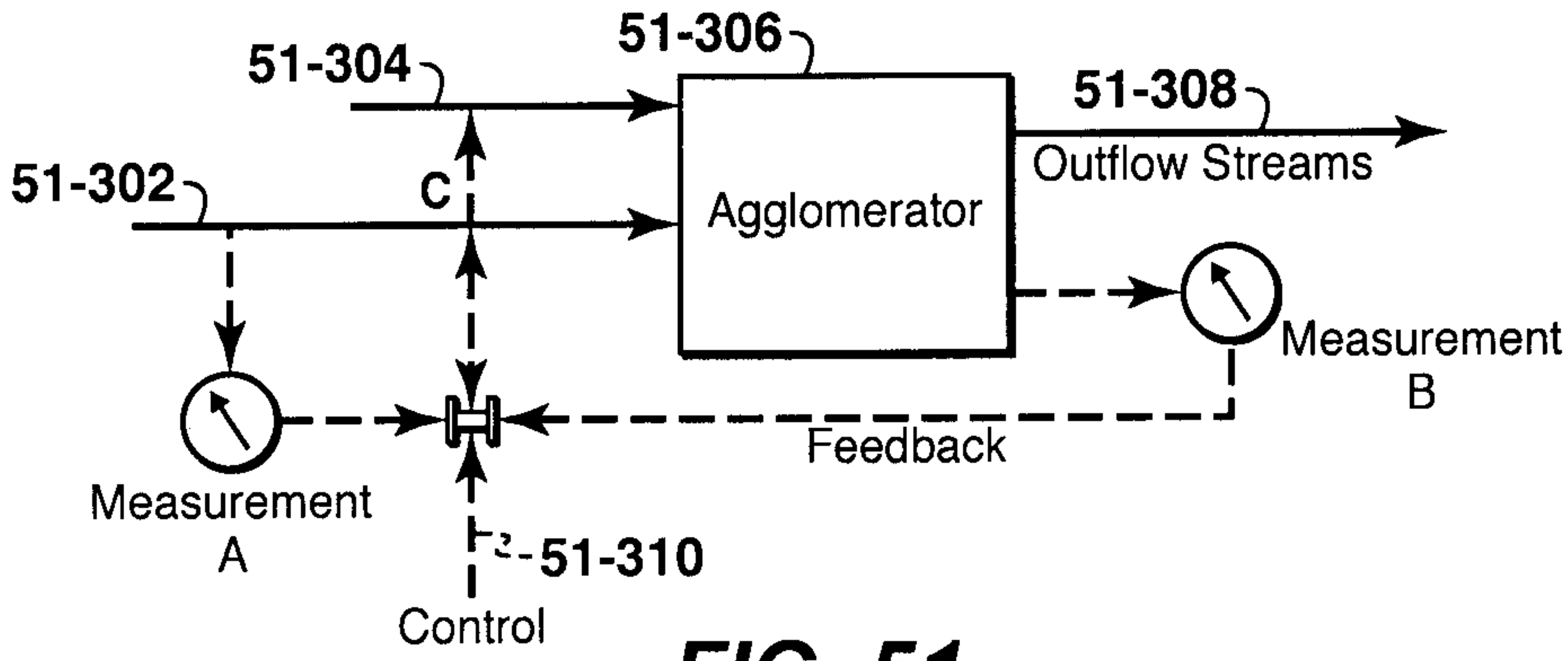


FIG. 51

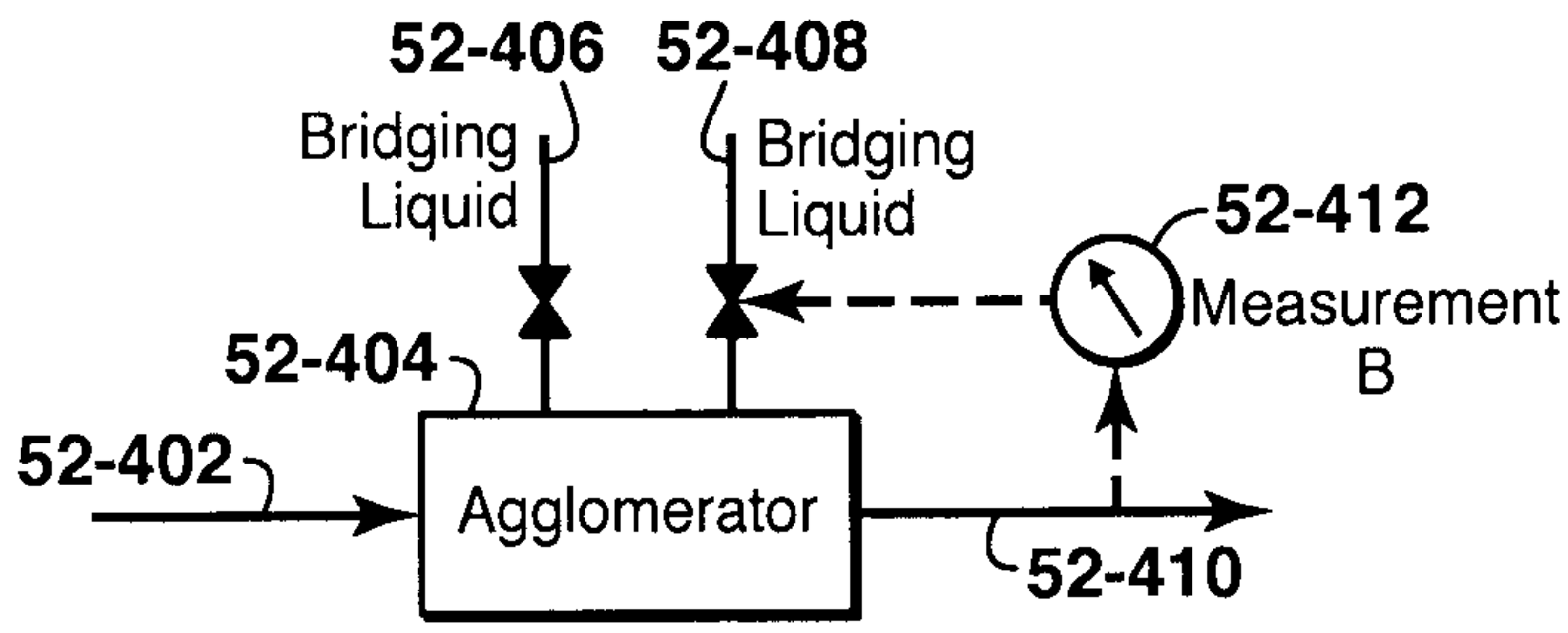


FIG. 52

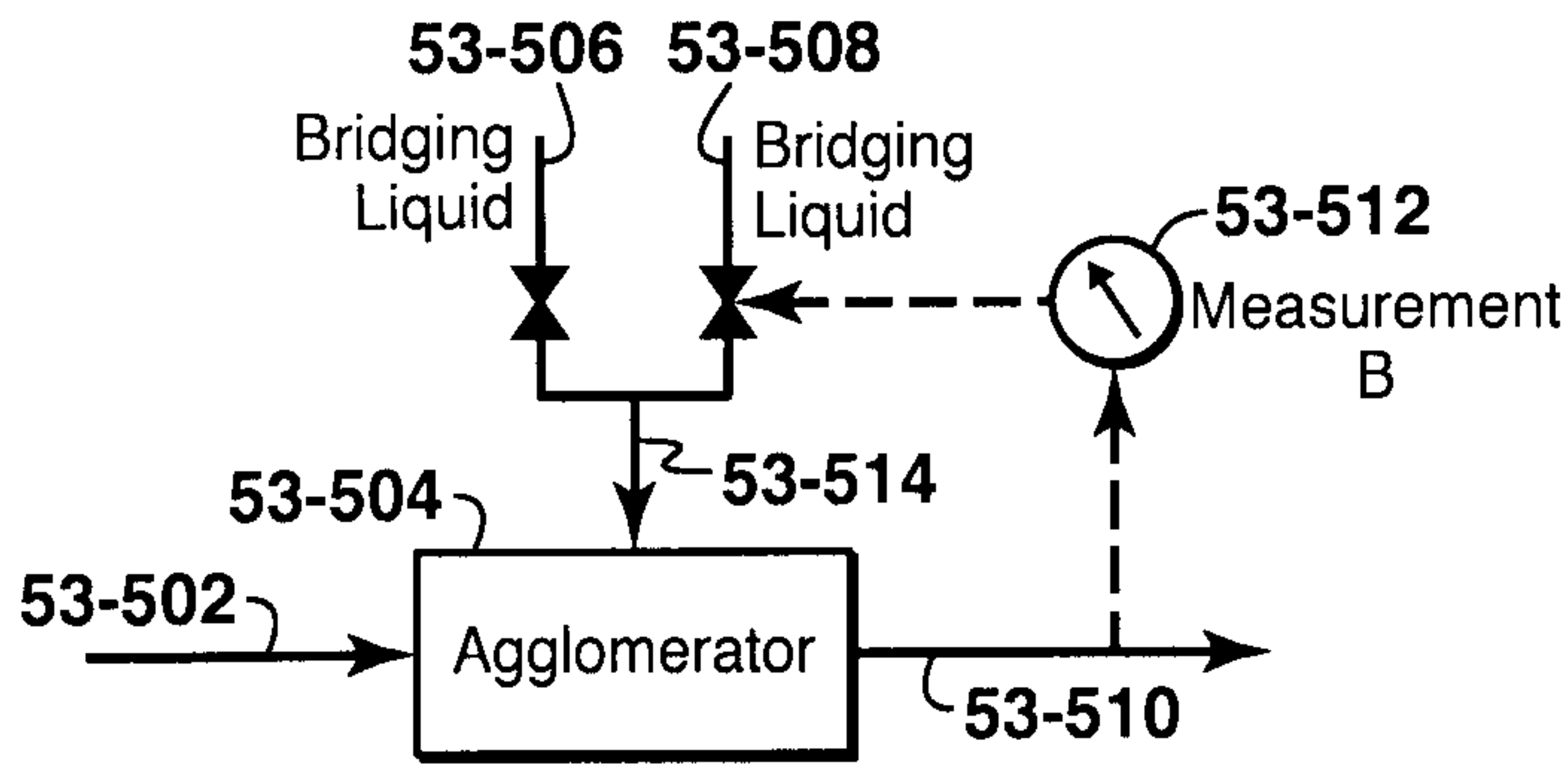


FIG. 53

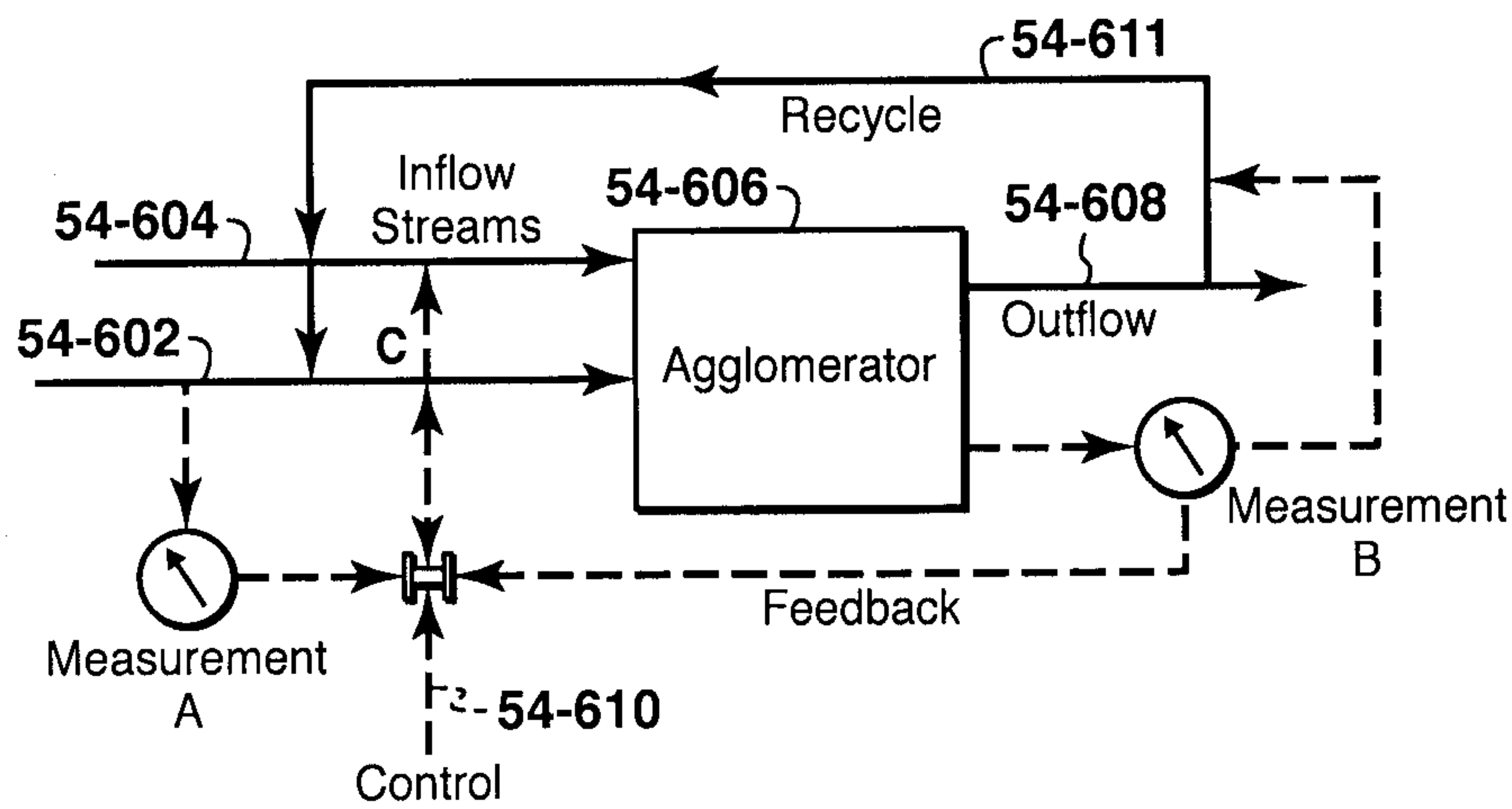
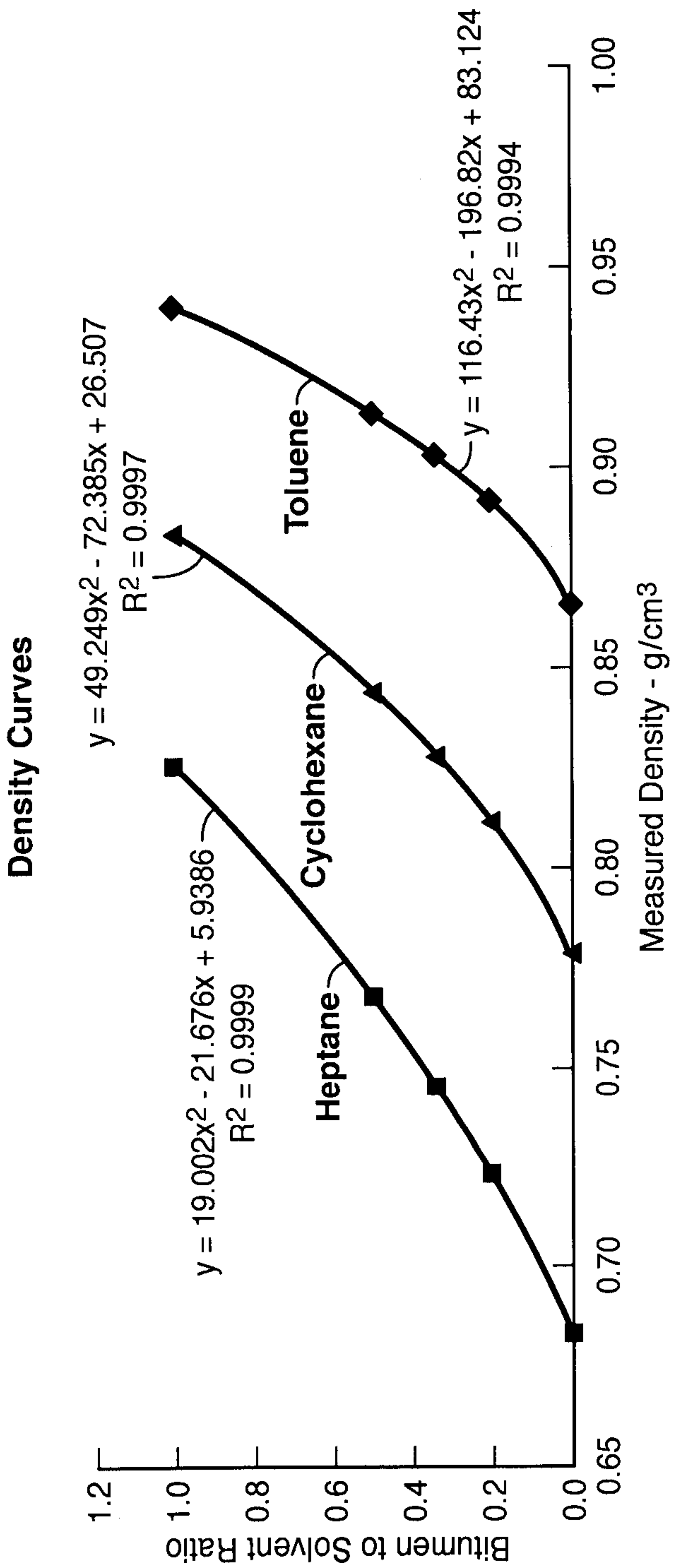

54-611
Recycle
Inflow
Streams
54-606
54-608
54-604
Outflow
54-602
C
Agglomerator
Measurement
B
Feedback
Measurement
A
54-610
Control

FIG. 54



Density Curves
Bitumen to Solvent Ratio
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.65
0.70
0.75
0.80
0.85
0.90
0.95
1.00
Measured Density - g/cm3
Heptane
$y = 19.002x^2 - 21.676x + 5.9386$
$R^2 = 0.9999$
Cyclohexane
$y = 49.249x^2 - 72.385x + 26.507$
$R^2 = 0.9997$
Toluene
$y = 116.43x^2 - 196.82x + 83.124$
$R^2 = 0.9994$

FIG. 55

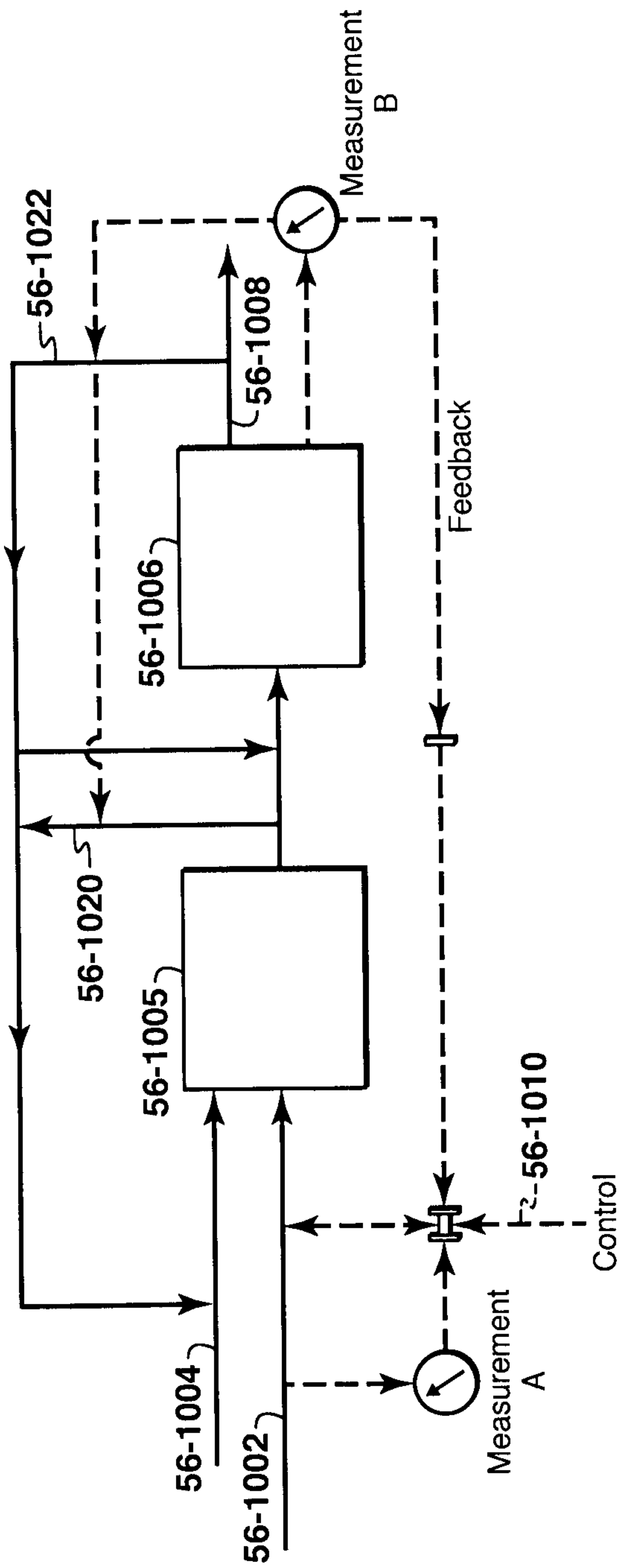

56-1022
56-1008
Measurement
B
56-1006
Feedback
56-1020
56-1005
56-1010
Control
56-1004
56-1002
Measurement
A

FIG. 56

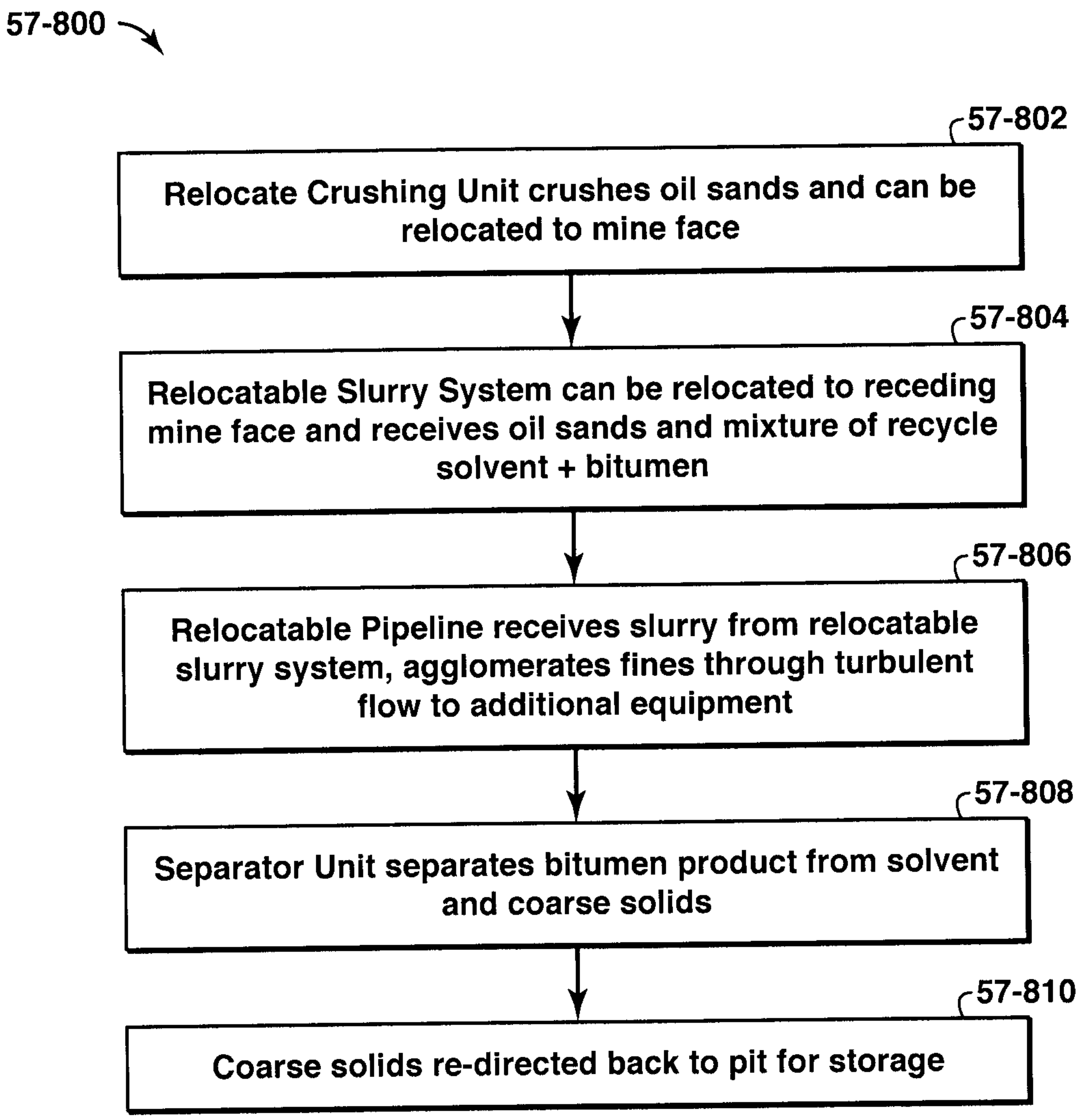

57-800
57-802
Relocate Crushing Unit crushes oil sands and can be relocated to mine face
57-804
Relocatable Slurry System can be relocated to receding mine face and receives oil sands and mixture of recycle solvent + bitumen
57-806
Relocatable Pipeline receives slurry from relocatable slurry system, agglomerates fines through turbulent flow to additional equipment
57-808
Separator Unit separates bitumen product from solvent and coarse solids
57-810
Coarse solids re-directed back to pit for storage

FIG. 57

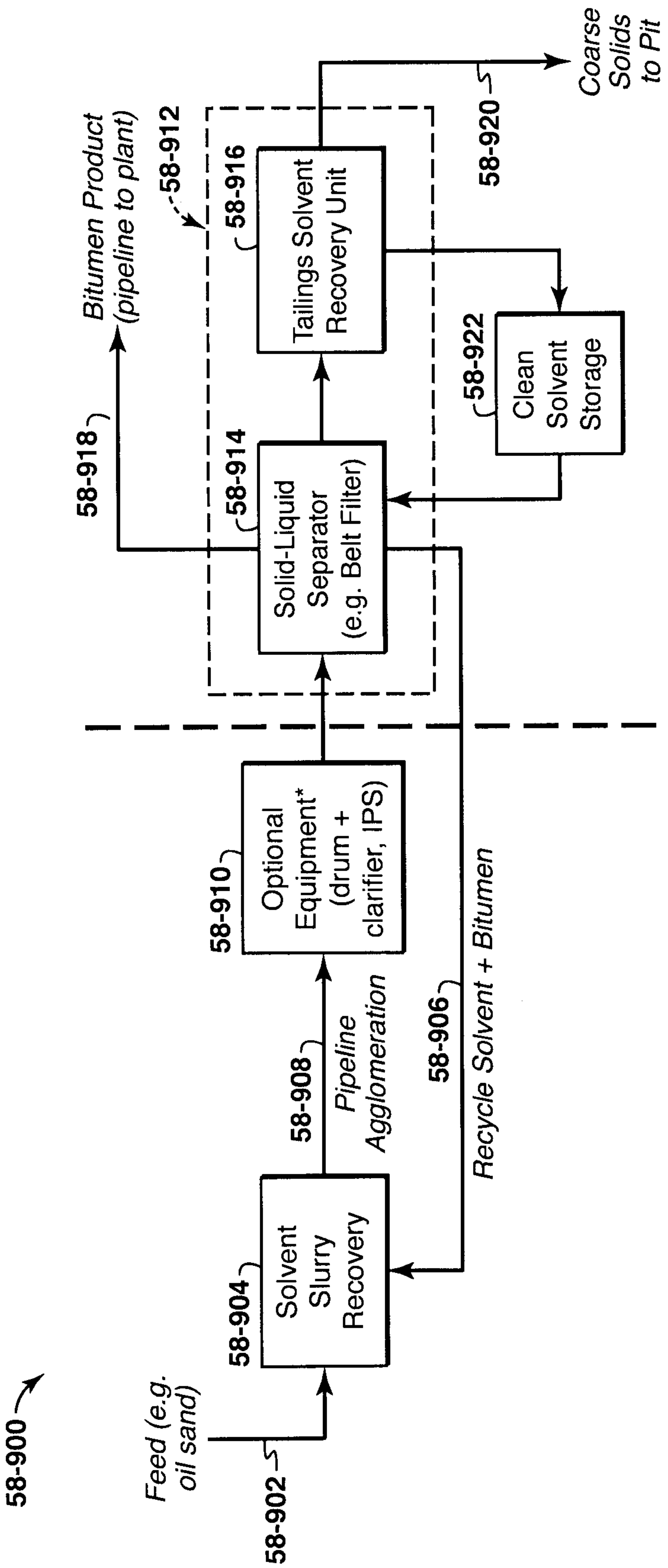

58-900
Feed (e.g. oil sand)
58-902
Solvent Slurry Recovery
58-904
58-908
Pipeline Agglomeration
Optional Equipment* (drum + clarifier, IPS)
58-910
58-906
Recycle Solvent + Bitumen
Solid-Liquid Separator (e.g. Belt Filter)
58-914
58-912
Tailings Solvent Recovery Unit
58-916
58-918
Bitumen Product (pipeline to plant)
Clean Solvent Storage
58-922
58-920
Coarse Solids to Pit

FIG. 58

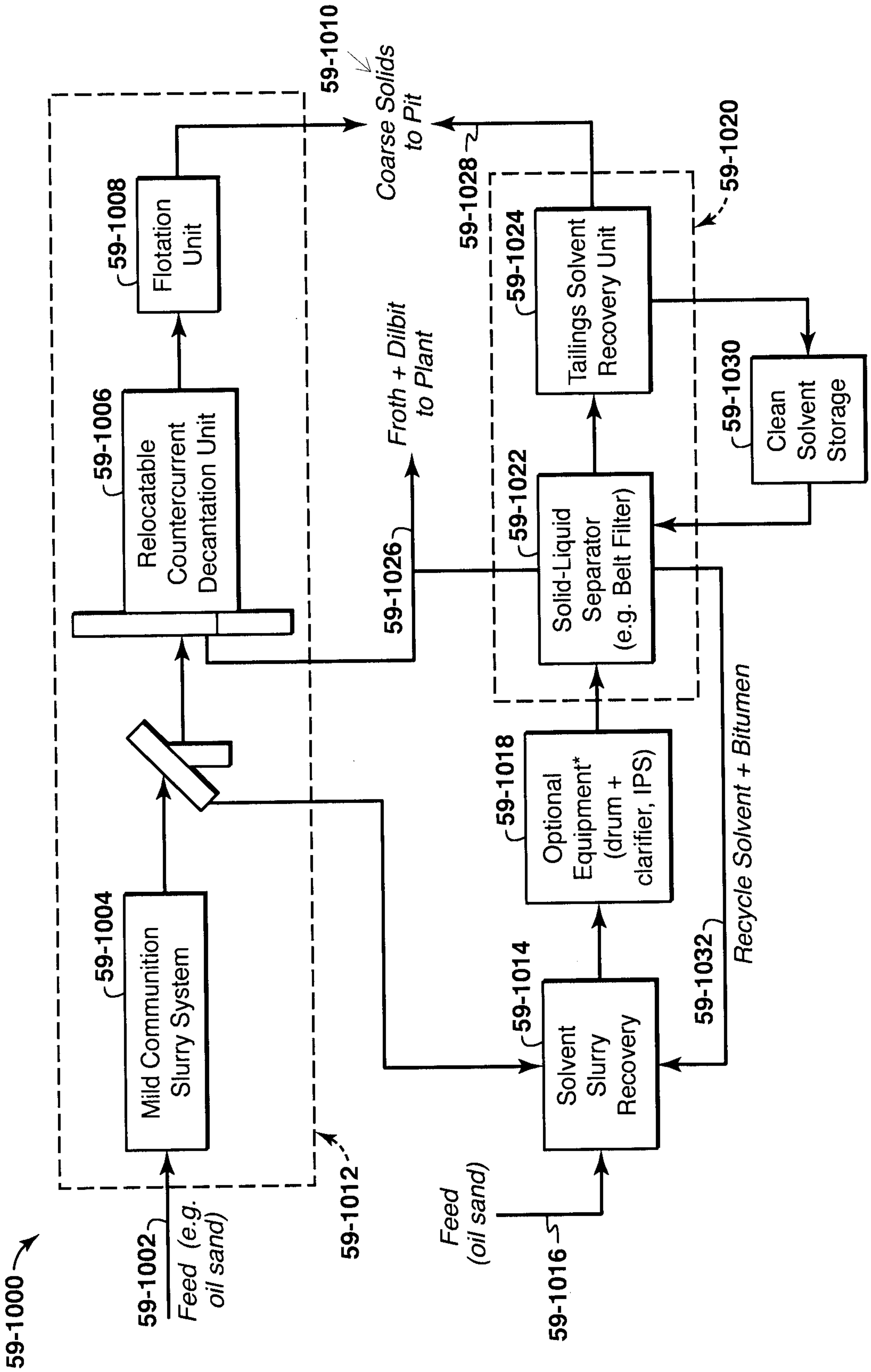

59-1000
59-1002
Feed (e.g. oil sand)
59-1004
Mild Communition Slurry System
59-1006
Relocatable Countercurrent Decantation Unit
59-1008
Flotation Unit
59-1010
Coarse Solids to Pit
59-1012
Froth + Dilbit to Plant
59-1026
59-1028
59-1014
Solvent Slurry Recovery
59-1016
Feed (oil sand)
59-1018
Optional Equipment* (drum + clarifier, IPS)
59-1022
Solid-Liquid Separator (e.g. Belt Filter)
59-1024
Tailings Solvent Recovery Unit
59-1020
59-1030
Clean Solvent Storage
59-1032
Recycle Solvent + Bitumen

FIG. 59

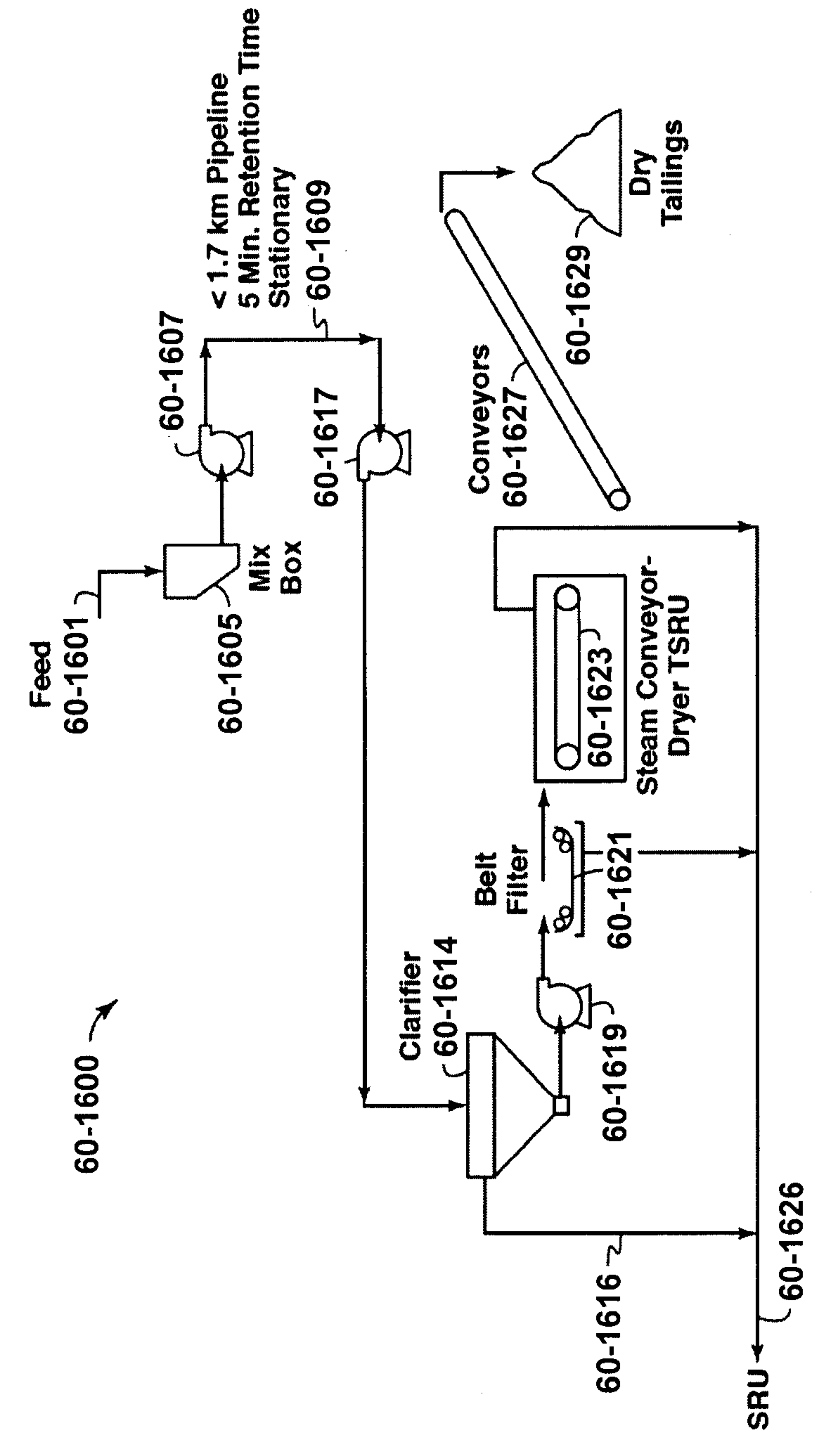

60-1600
Feed
60-1601
60-1605
Mix
Box
60-1607
< 1.7 km Pipeline
5 Min. Retention Time
Stationary
60-1609
60-1617
Clarifier
60-1614
60-1619
Belt
Filter
60-1621
60-1623
Steam Conveyor-
Dryer TSRU
Conveyors
60-1627
60-1629
Dry
Tailings
60-1616
60-1626
SRU

FIG. 60

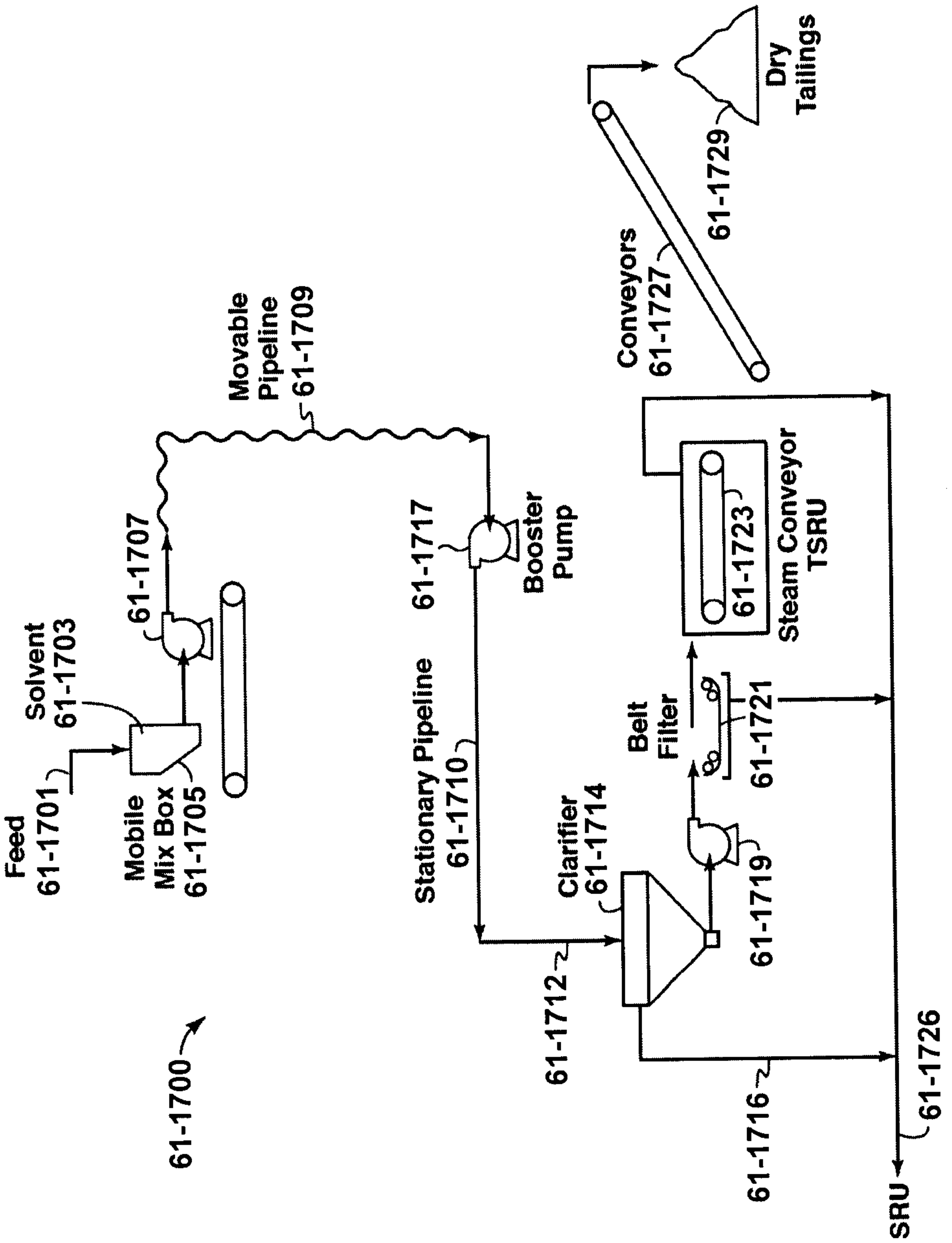

61-1700
Feed
61-1701
Solvent
61-1703
Mobile
Mix Box
61-1705
61-1707
Movable
Pipeline
61-1709
61-1717
Booster
Pump
Stationary Pipeline
61-1710
61-1712
Clarifier
61-1714
61-1719
Belt
Filter
61-1721
61-1723
Steam Conveyor
TSRU
Conveyors
61-1727
61-1729
Dry
Tailings
61-1716
61-1726
SRU

FIG. 61

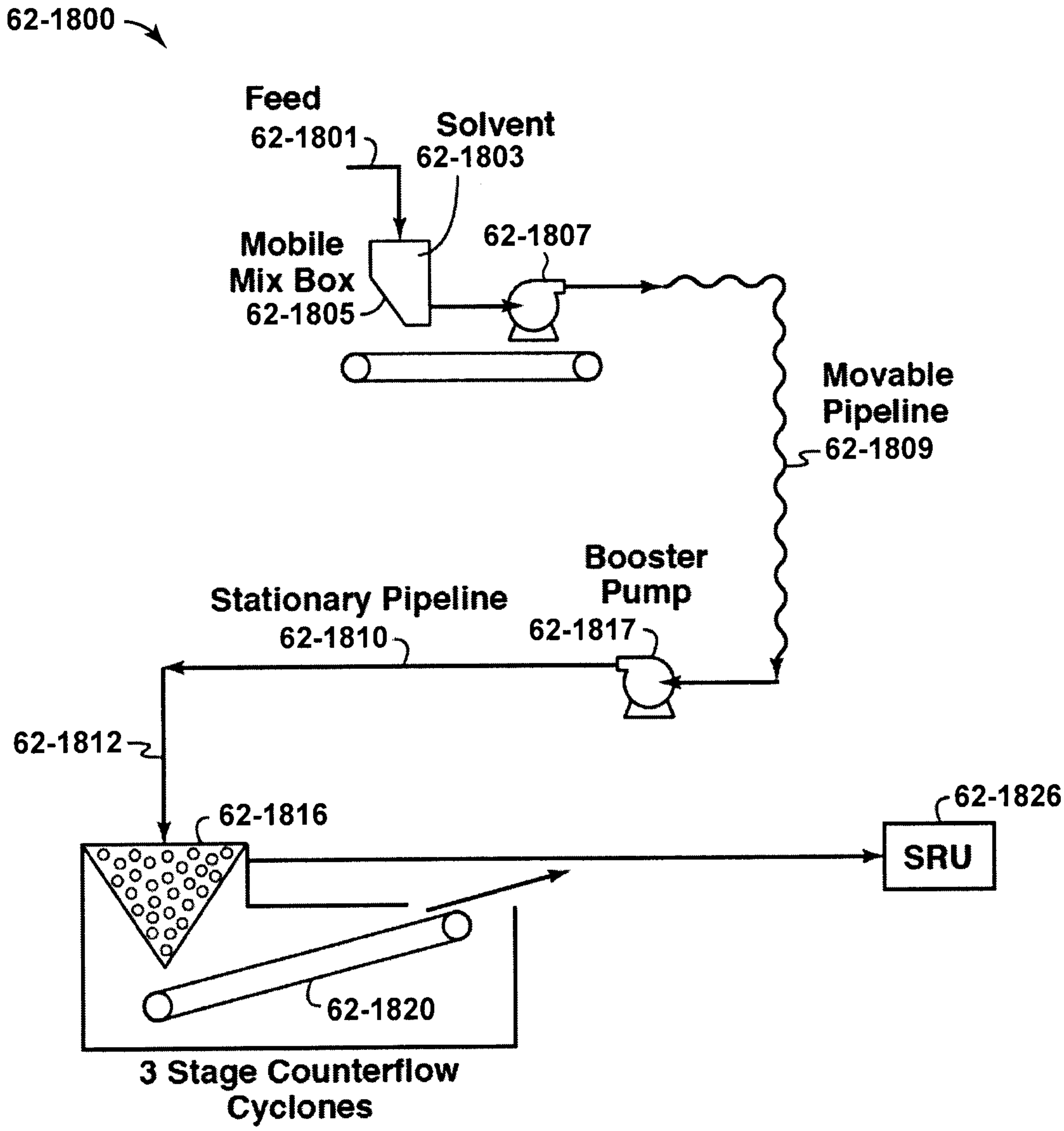

62-1800
Feed
62-1801
Solvent
62-1803
Mobile
Mix Box
62-1805
62-1807
Movable
Pipeline
62-1809
Booster
Pump
62-1817
Stationary Pipeline
62-1810
62-1812
62-1816
62-1826
SRU
62-1820
3 Stage Counterflow
Cyclones

FIG. 62

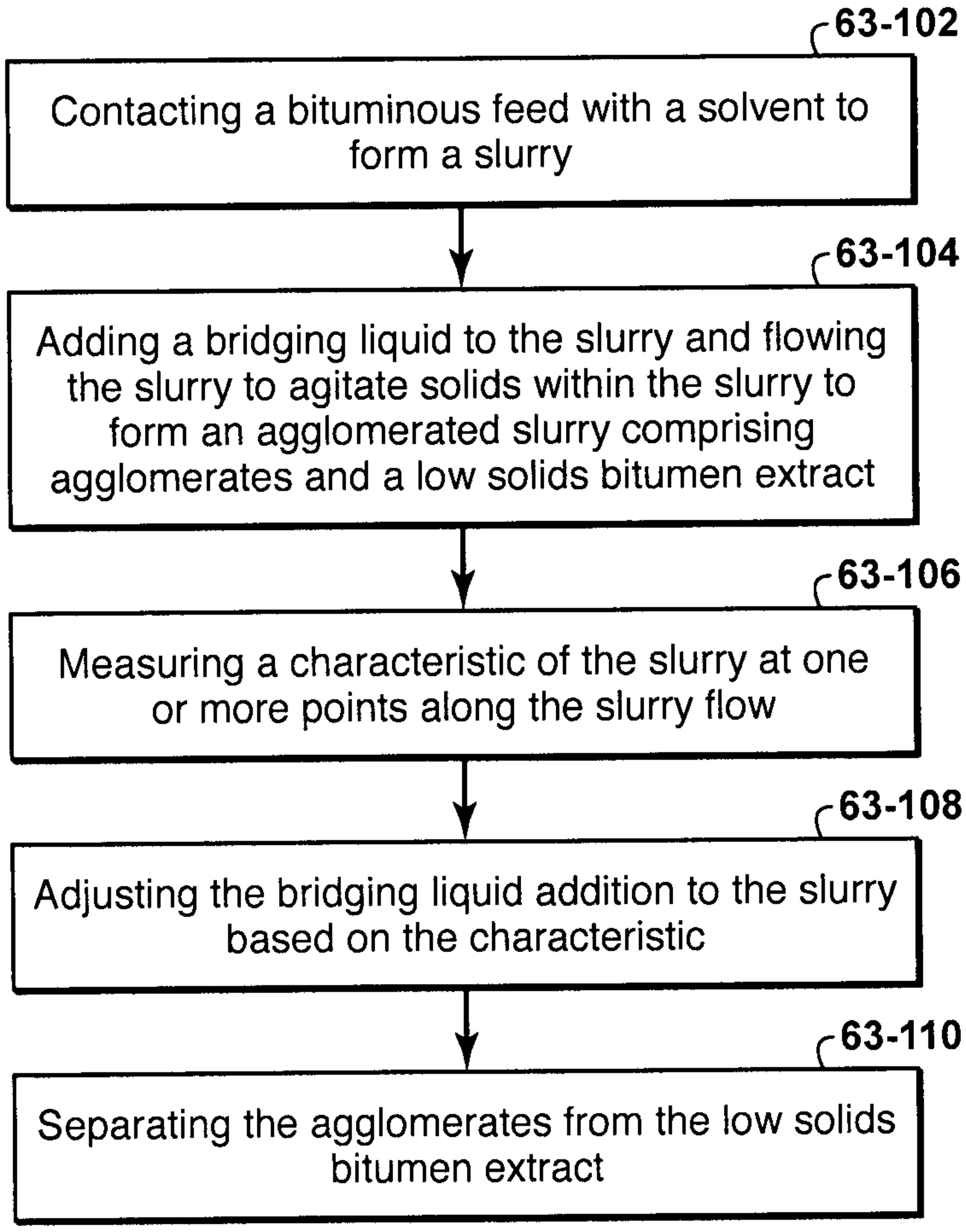
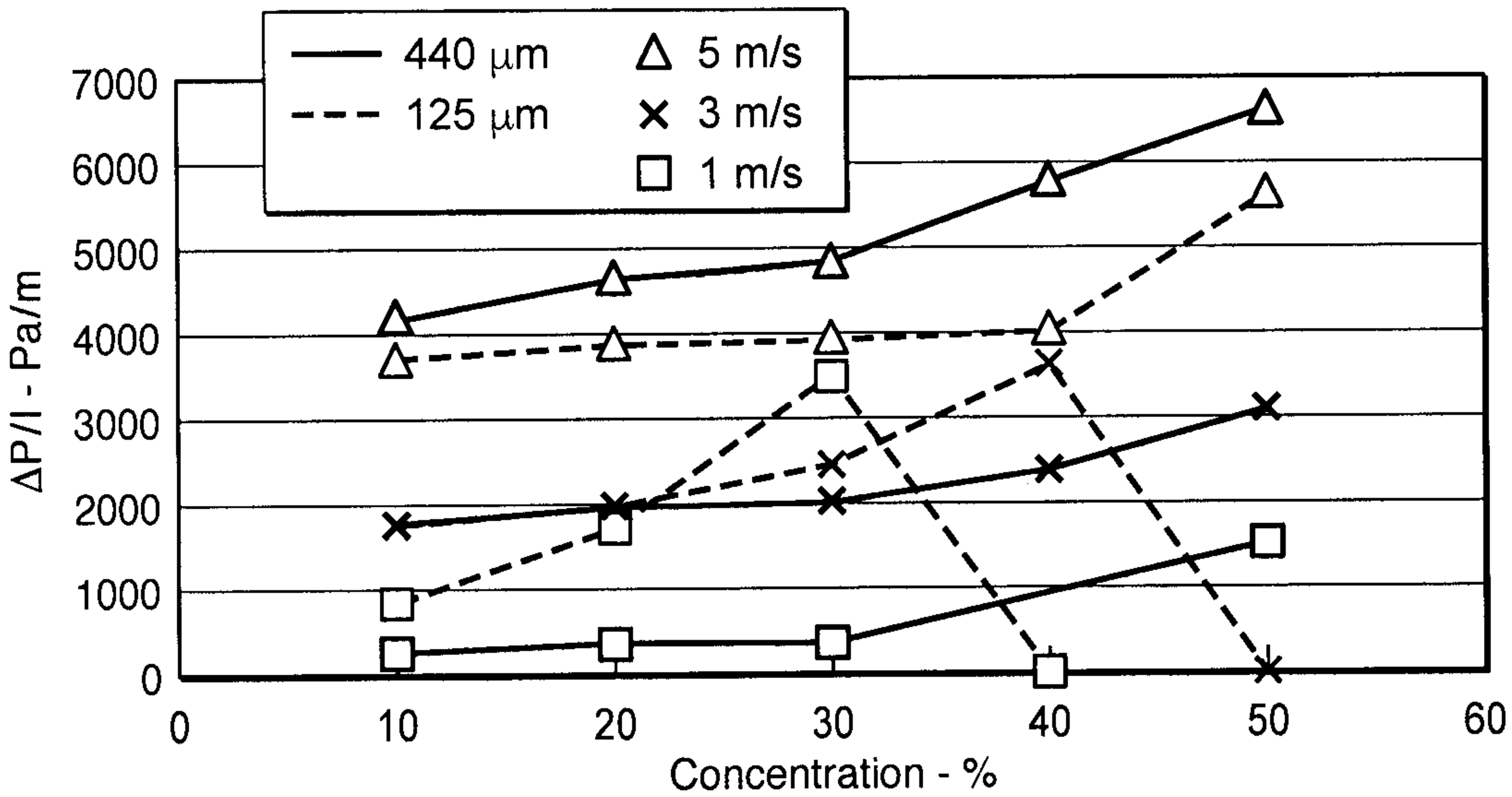
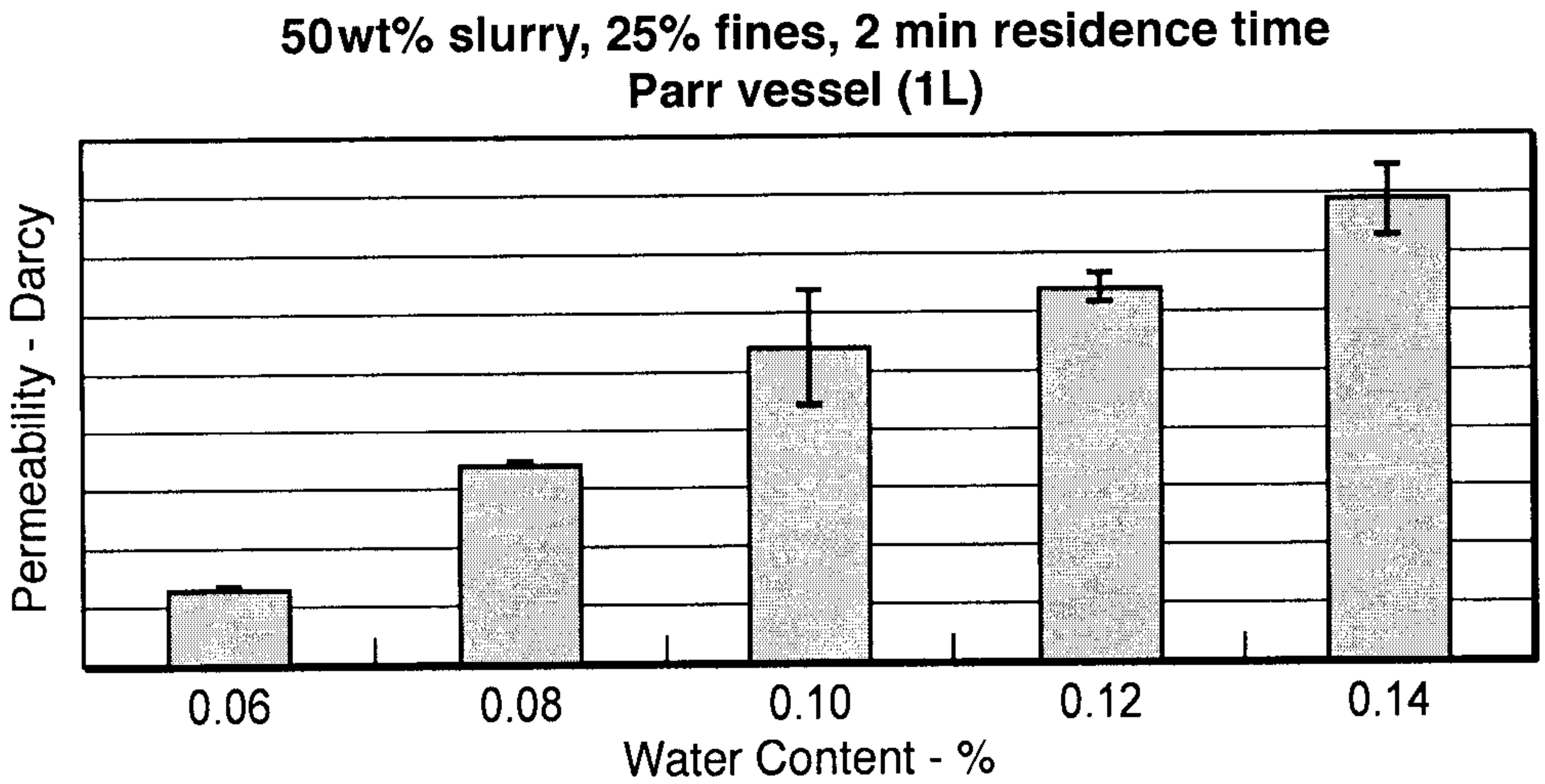

63-102
Contacting a bituminous feed with a solvent to form a slurry
63-104
Adding a bridging liquid to the slurry and flowing the slurry to agitate solids within the slurry to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract
63-106
Measuring a characteristic of the slurry at one or more points along the slurry flow
63-108
Adjusting the bridging liquid addition to the slurry based on the characteristic
63-110
Separating the agglomerates from the low solids bitumen extract

FIG. 63



440 μm
125 μm
5 m/s
3 m/s
1 m/s
7000
6000
5000
4000
3000
2000
1000
0
ΔP/l - Pa/m
0
10
20
30
40
50
60
Concentration - %

FIG. 64



50wt% slurry, 25% fines, 2 min residence time
Parr vessel (1L)
Permeability - Darcy
0.06
0.08
0.10
0.12
0.14
Water Content - %

FIG. 65

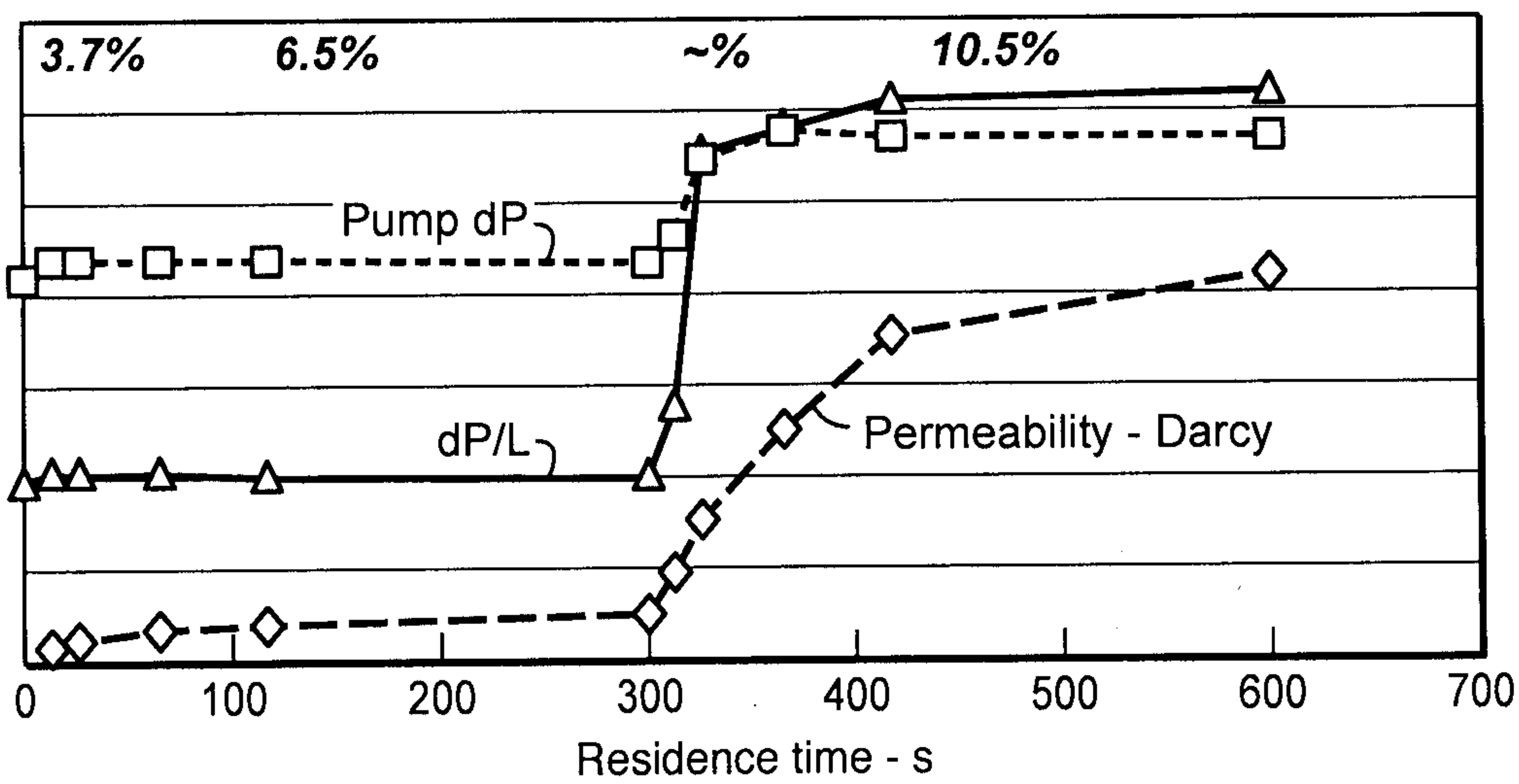

3.7%
6.5%
~%
10.5%
Pump dP
dP/L
Permeability - Darcy
0
100
200
300
400
500
600
700
Residence time - s

FIG. 66

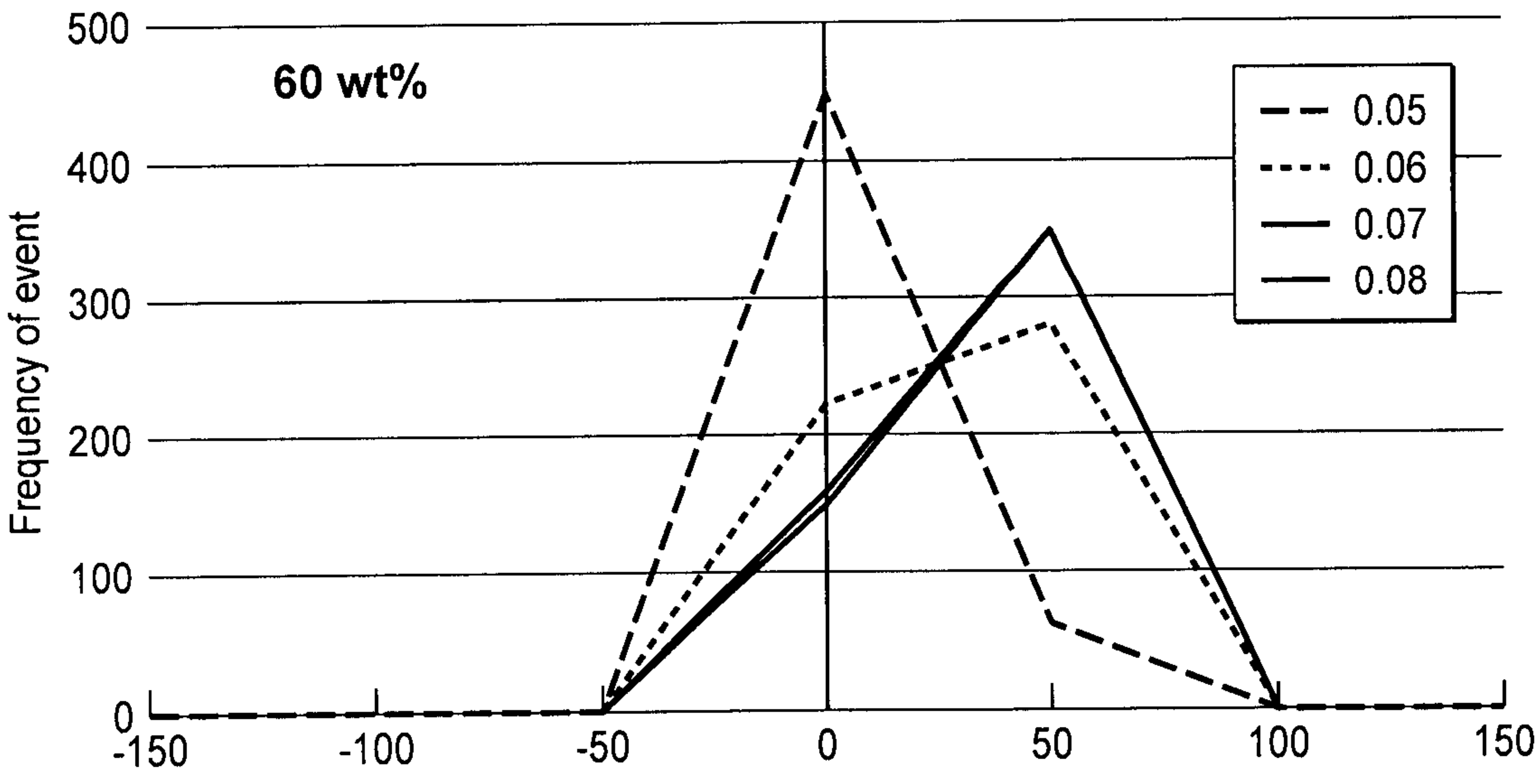

500
400
300
200
100
0
60 wt%
0.05
0.06
0.07
0.08
Frequency of event
-150
-100
-50
0
50
100
150

FIG. 67

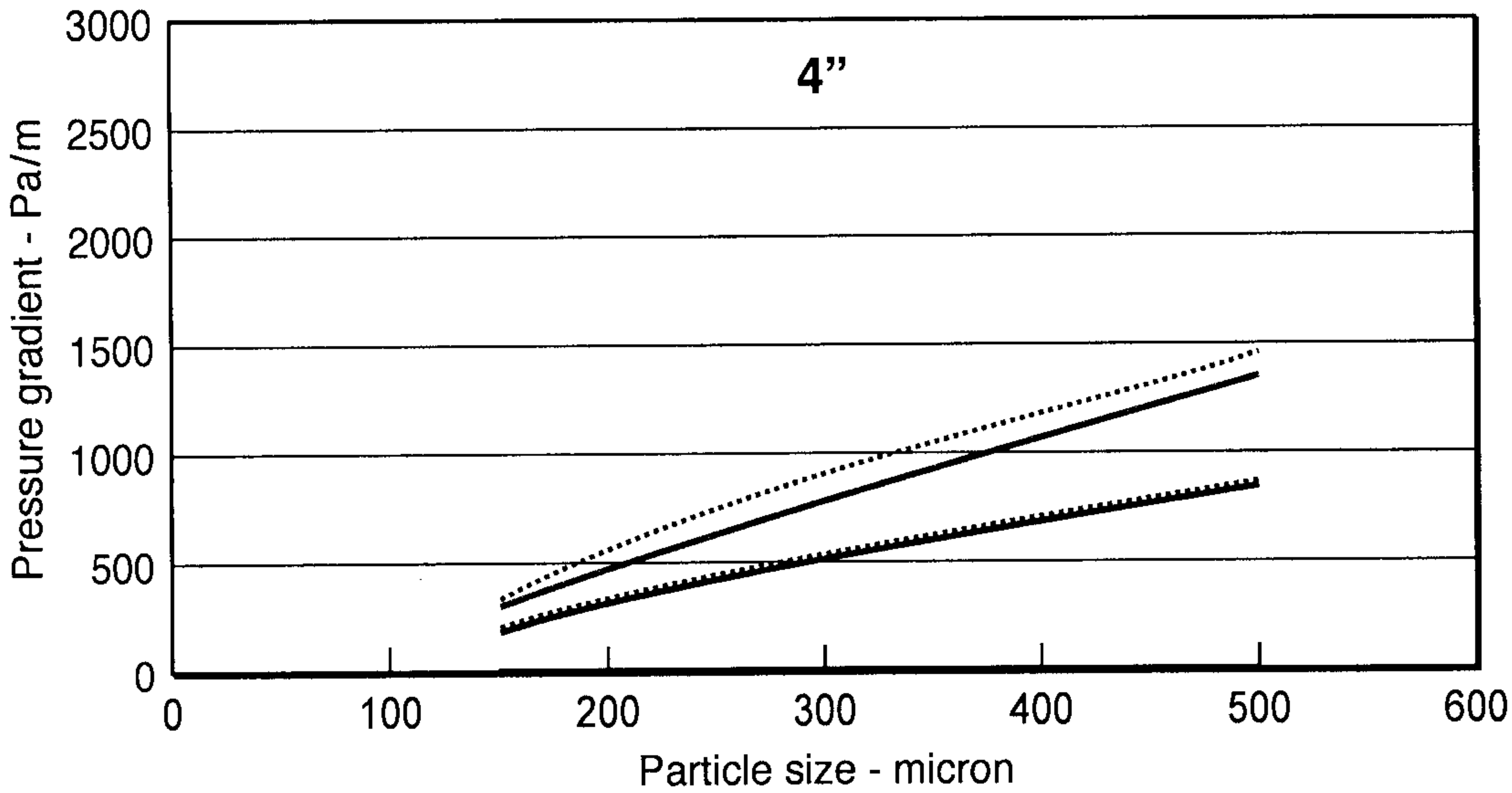


FIG. 68A

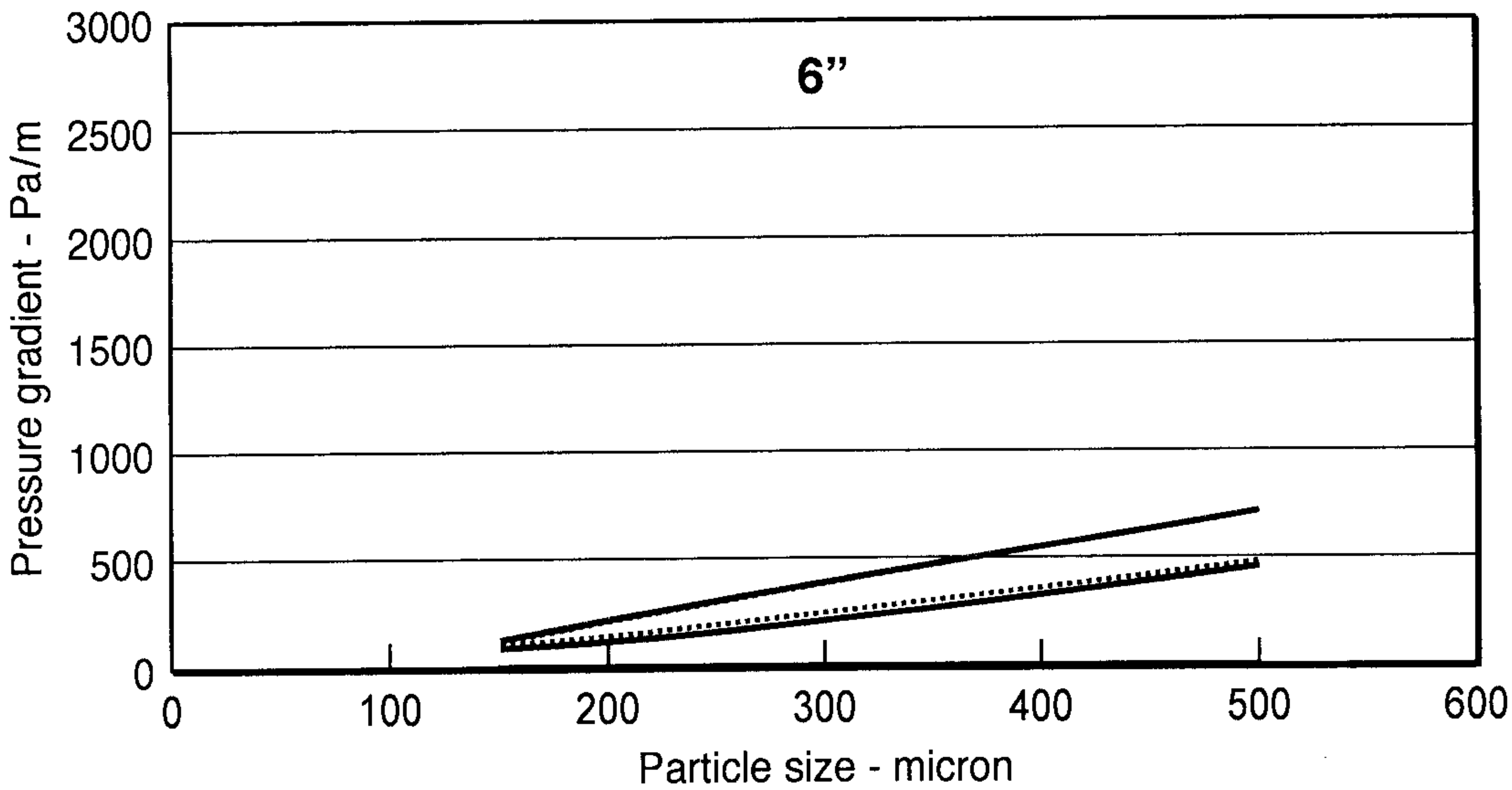


FIG. 68B

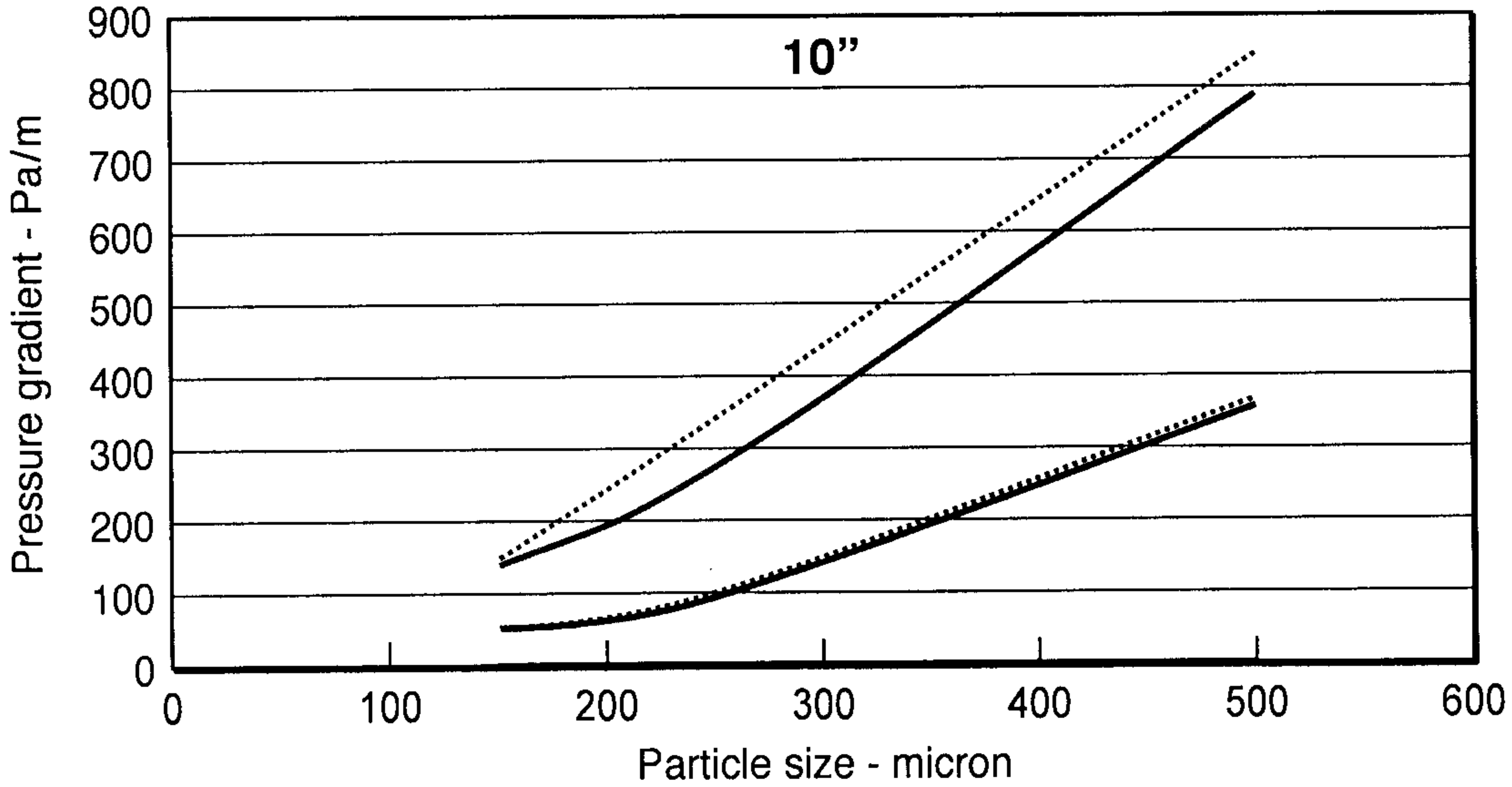

10"
900
800
700
600
500
400
300
200
100
0
Pressure gradient - Pa/m
0
100
200
300
400
500
600
Particle size - micron

FIG. 68C

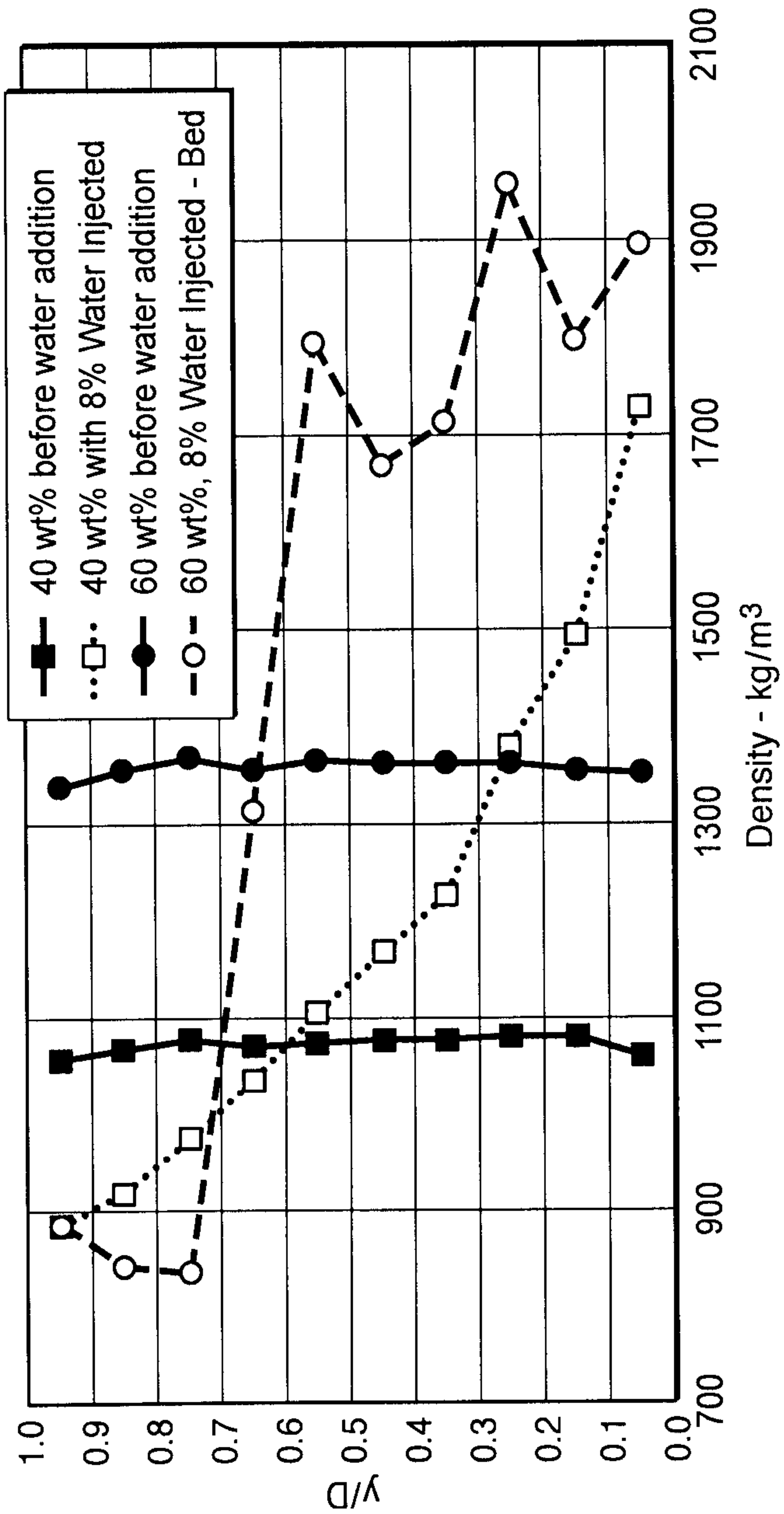

40 wt% before water addition
40 wt% with 8% Water Injected
60 wt% before water addition
60 wt%, 8% Water Injected - Bed
y/D
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
700
900
1100
1300
1500
1700
1900
2100
Density - kg/m3

FIG. 69

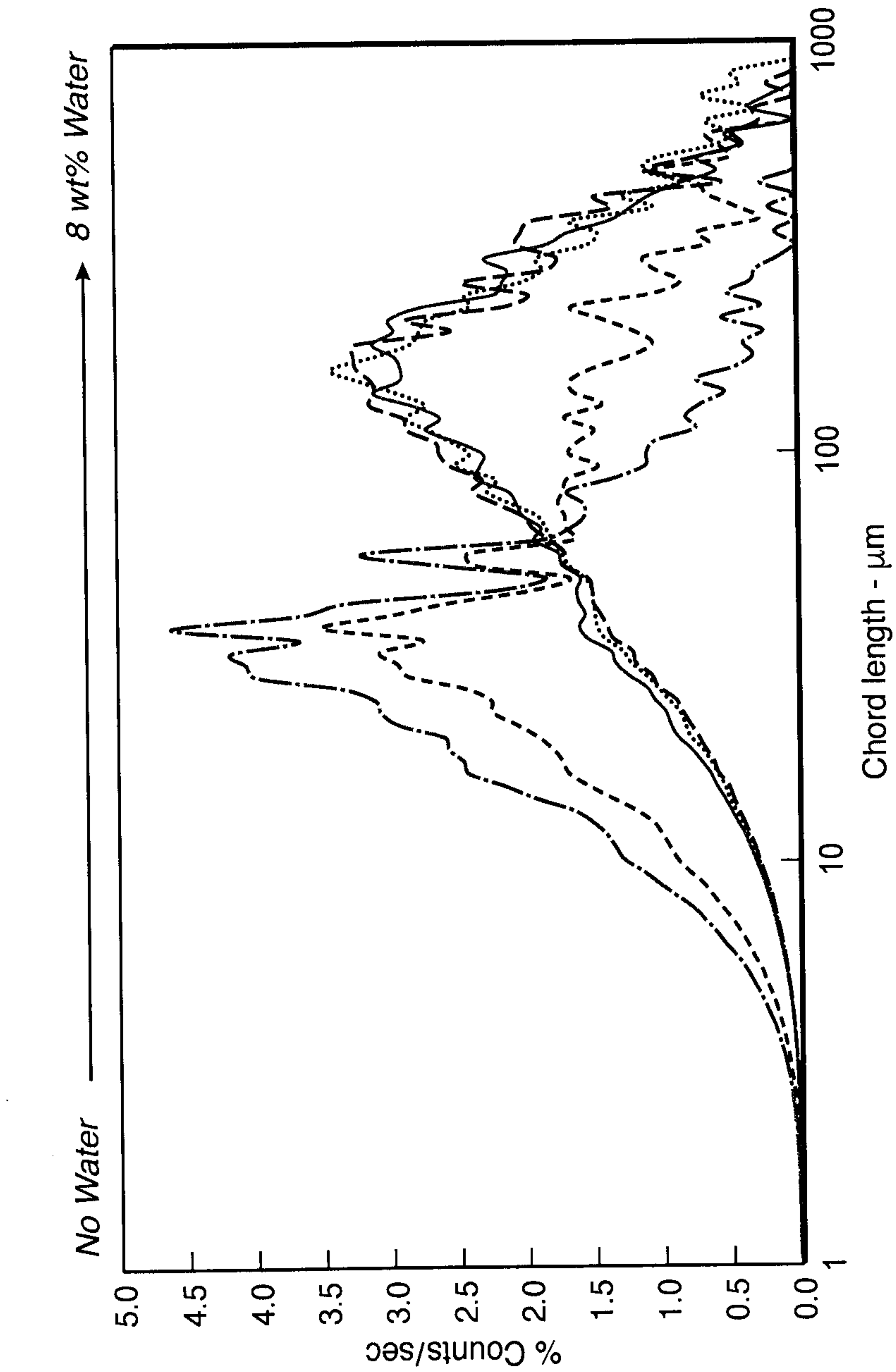

No Water
8 wt% Water
% Counts/sec
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1
10
100
1000
Chord length - μm

FIG. 70

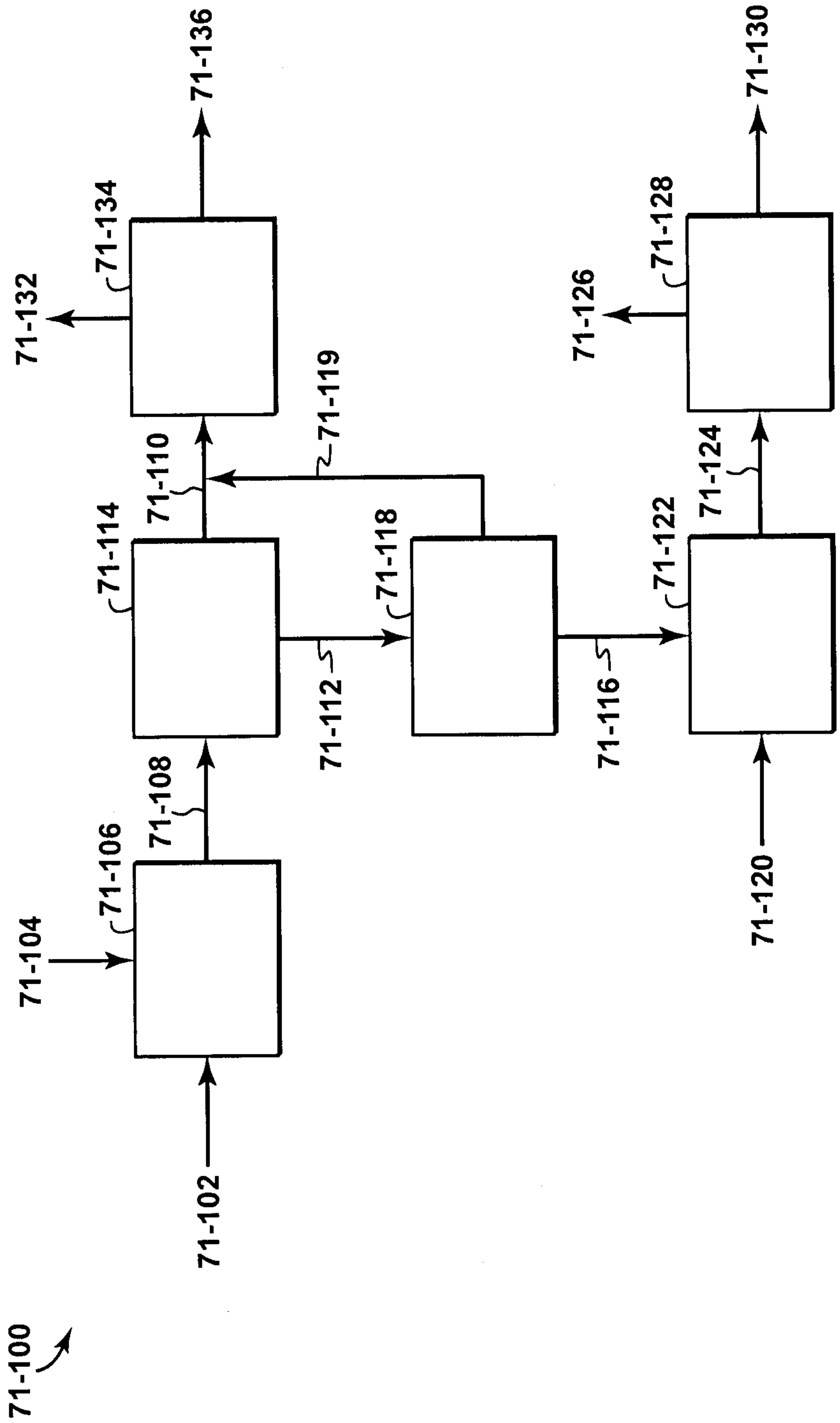

71-100
71-102
71-104
71-106
71-108
71-110
71-112
71-114
71-116
71-118
71-119
71-120
71-122
71-124
71-126
71-128
71-130
71-132
71-134
71-136

FIG. 71

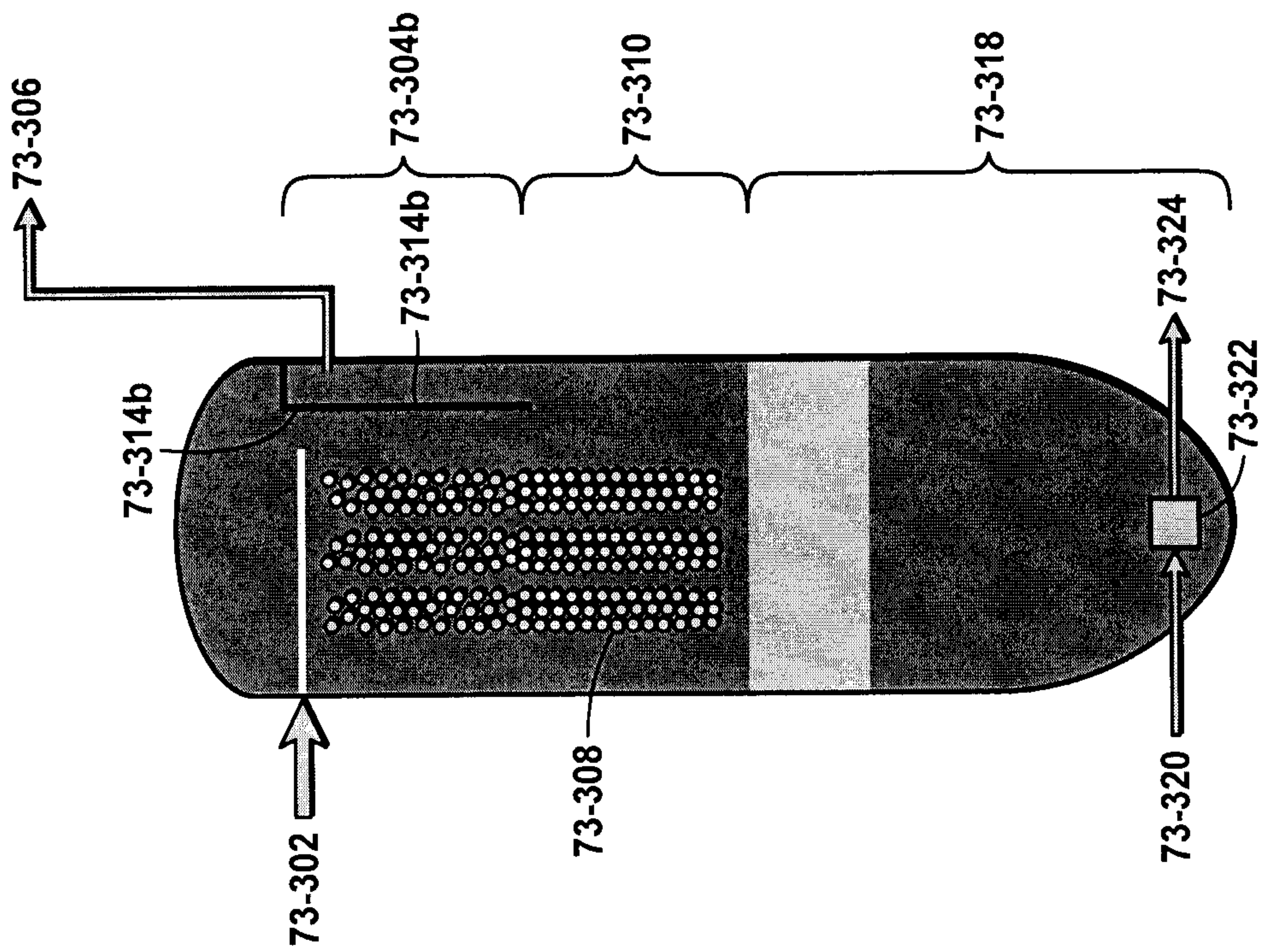

73-302
73-306
73-304b
73-314b
73-314b
73-308
73-310
73-318
73-320
73-322
73-324

FIG. 73

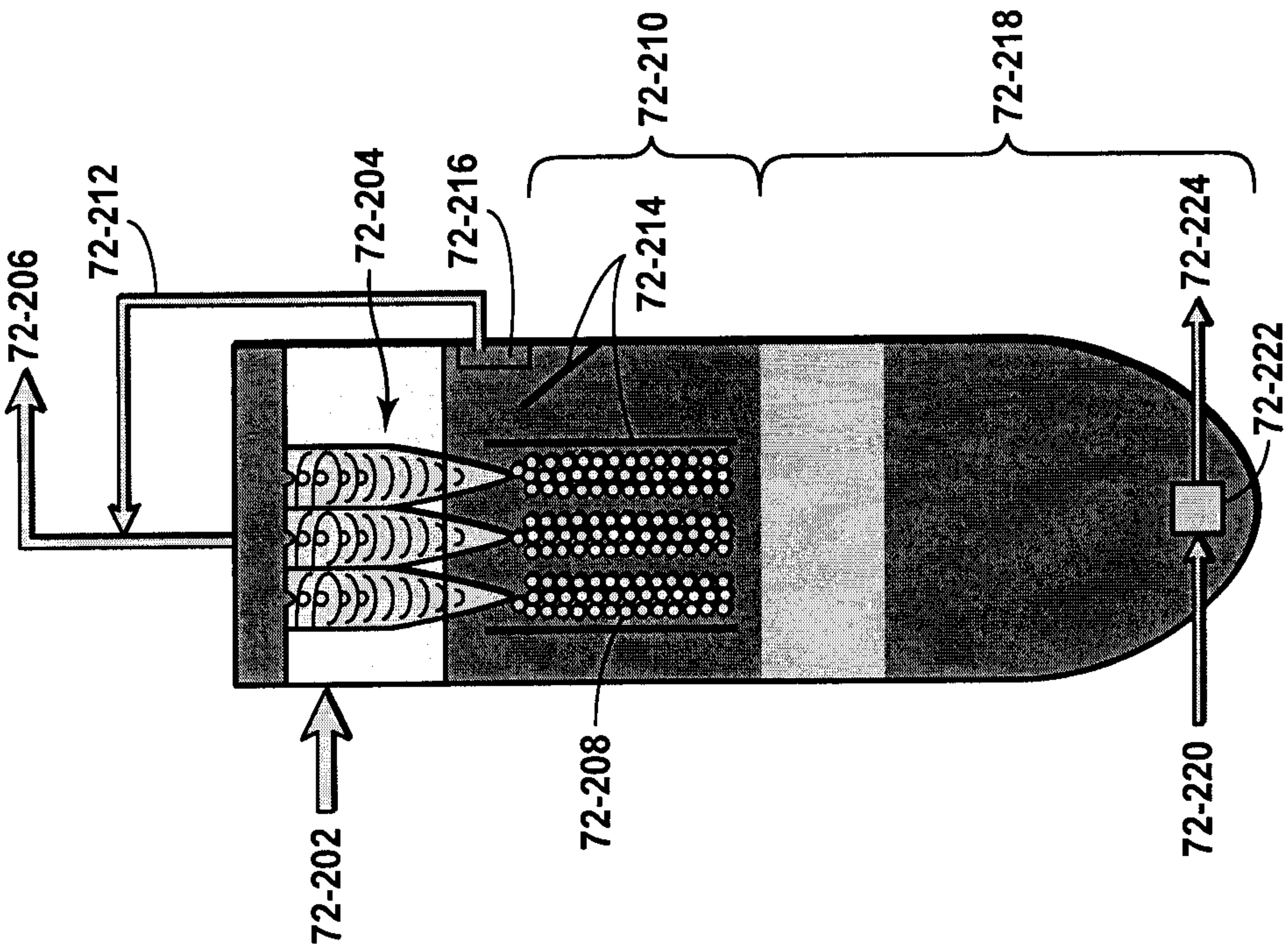
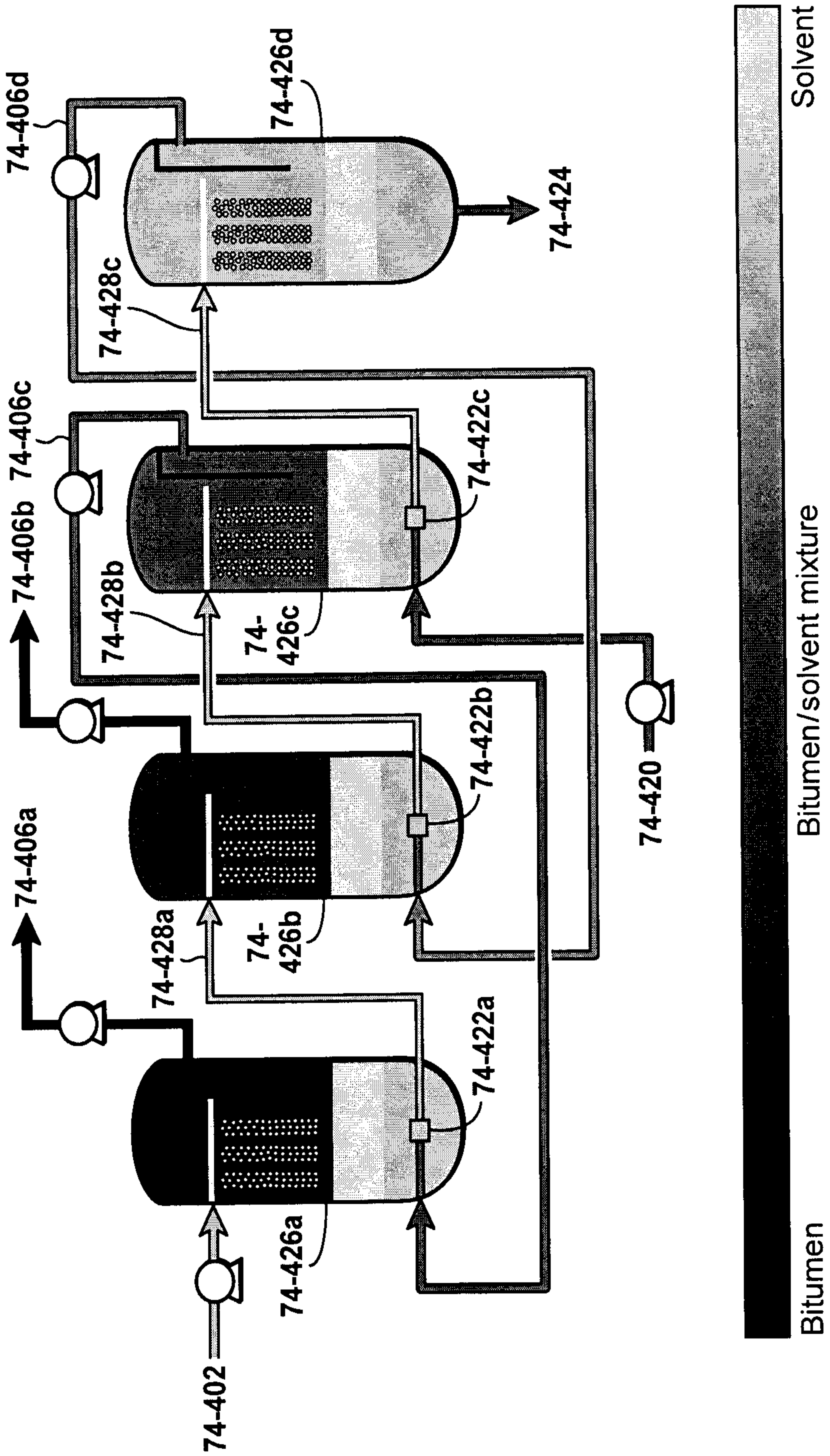

72-202
72-206
72-212
72-204
72-216
72-214
72-208
72-210
72-218
72-220
72-222
72-224

FIG. 72



74-402
74-426a
74-406a
74-428a
74-422a
74-426b
74-406b
74-428b
74-422b
74-426c
74-406c
74-422c
74-420
74-406d
74-428c
74-426d
74-424
Bitumen
Bitumen/solvent mixture
Solvent

FIG. 74

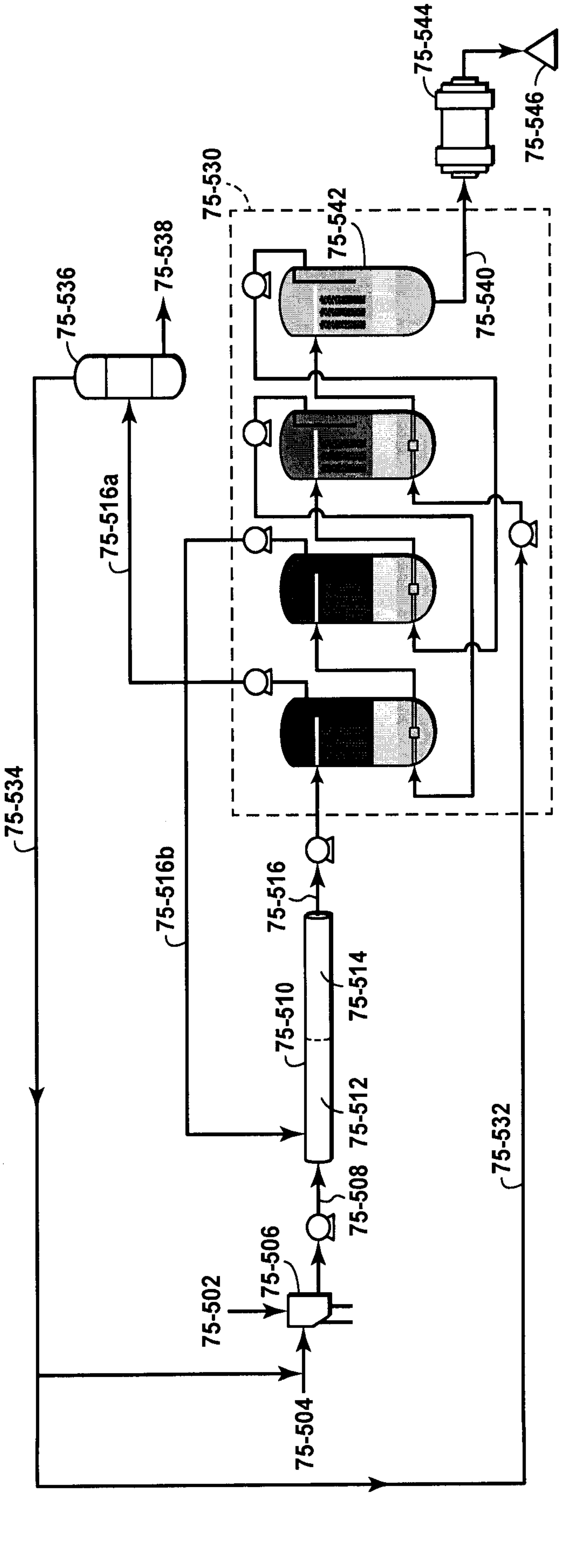

75-502
75-504
75-506
75-508
75-510
75-512
75-514
75-516
75-516a
75-516b
75-530
75-532
75-534
75-536
75-538
75-540
75-542
75-544
75-546

FIG. 75

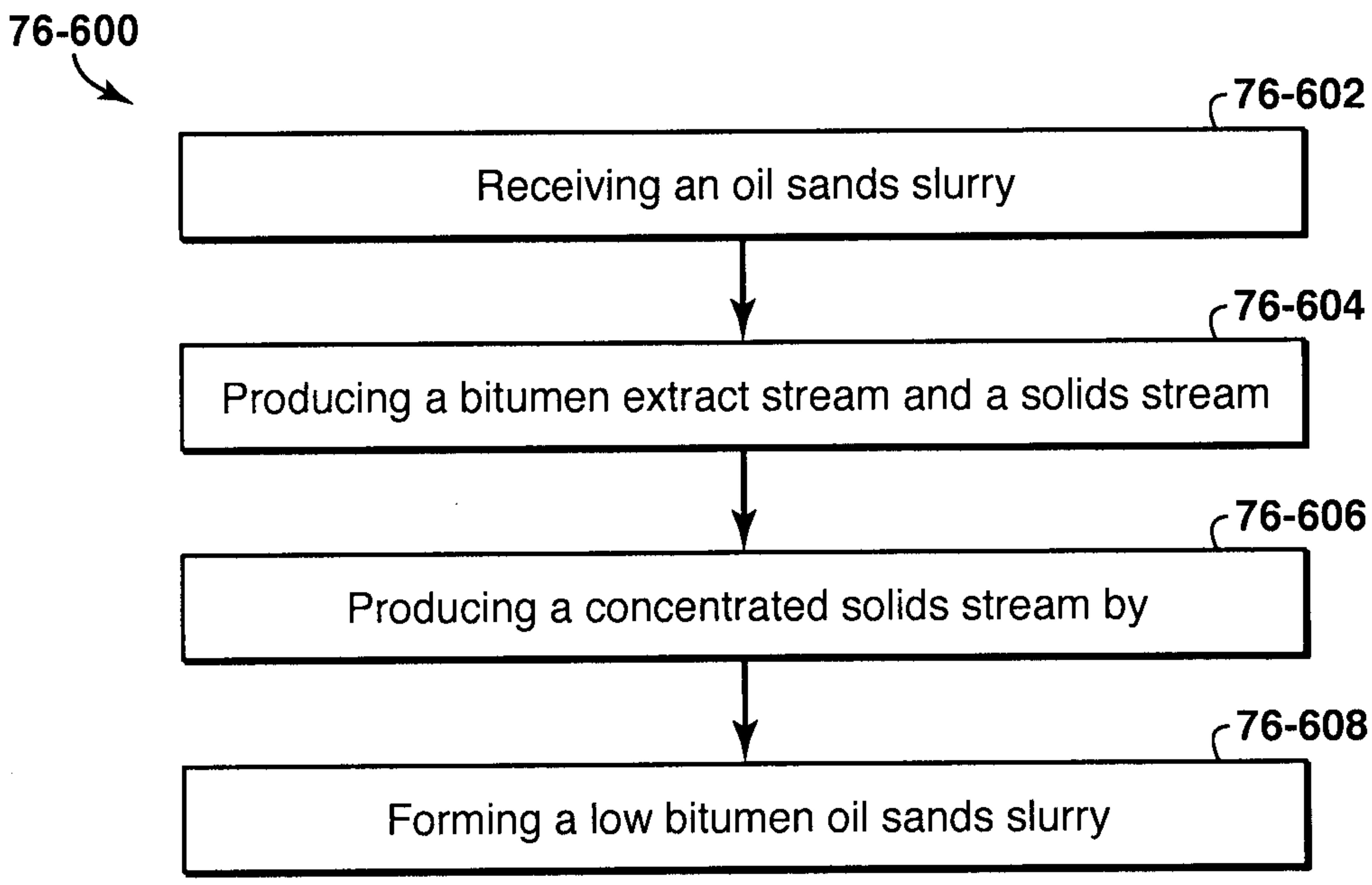

76-600
76-602
Receiving an oil sands slurry
76-604
Producing a bitumen extract stream and a solids stream
76-606
Producing a concentrated solids stream by
76-608
Forming a low bitumen oil sands slurry

FIG. 76

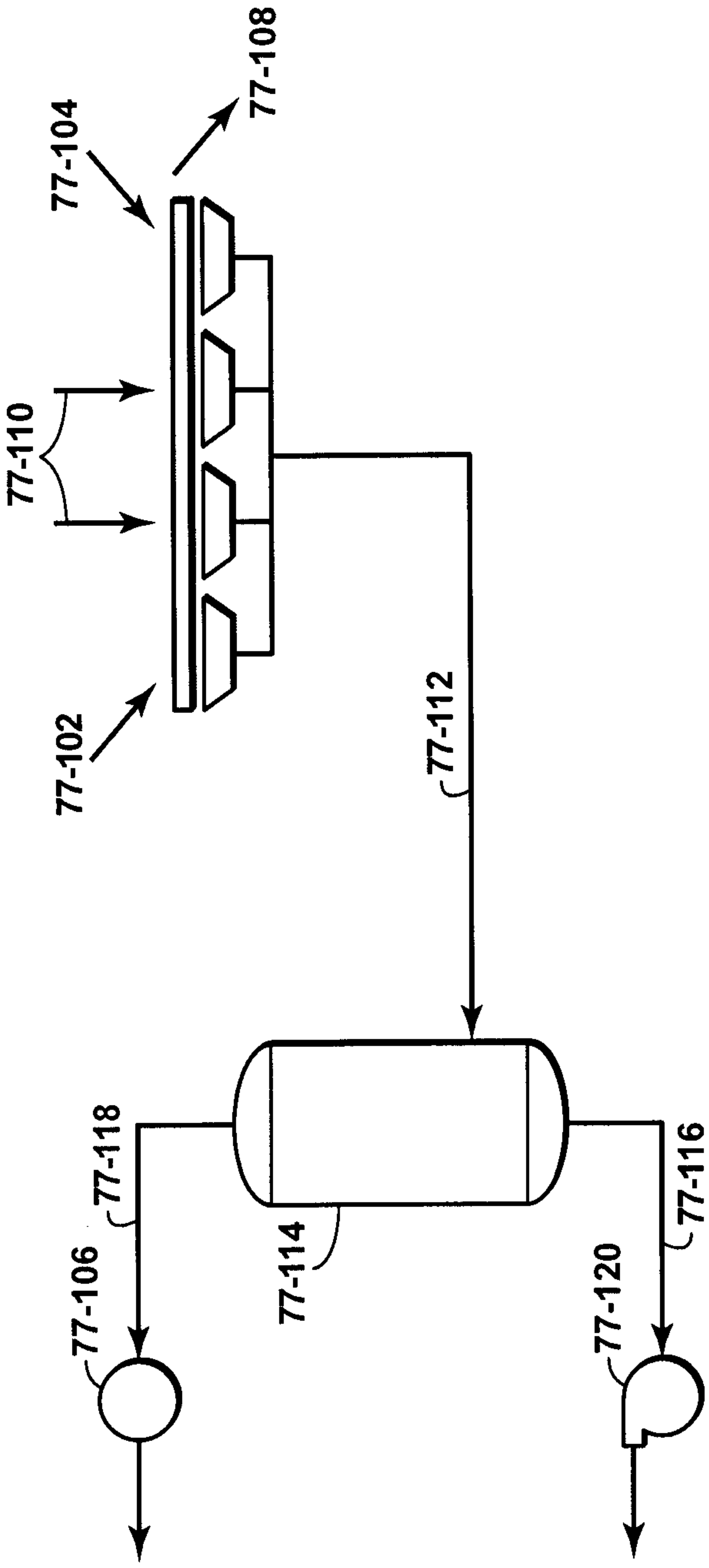


FIG. 77
(Prior Art)

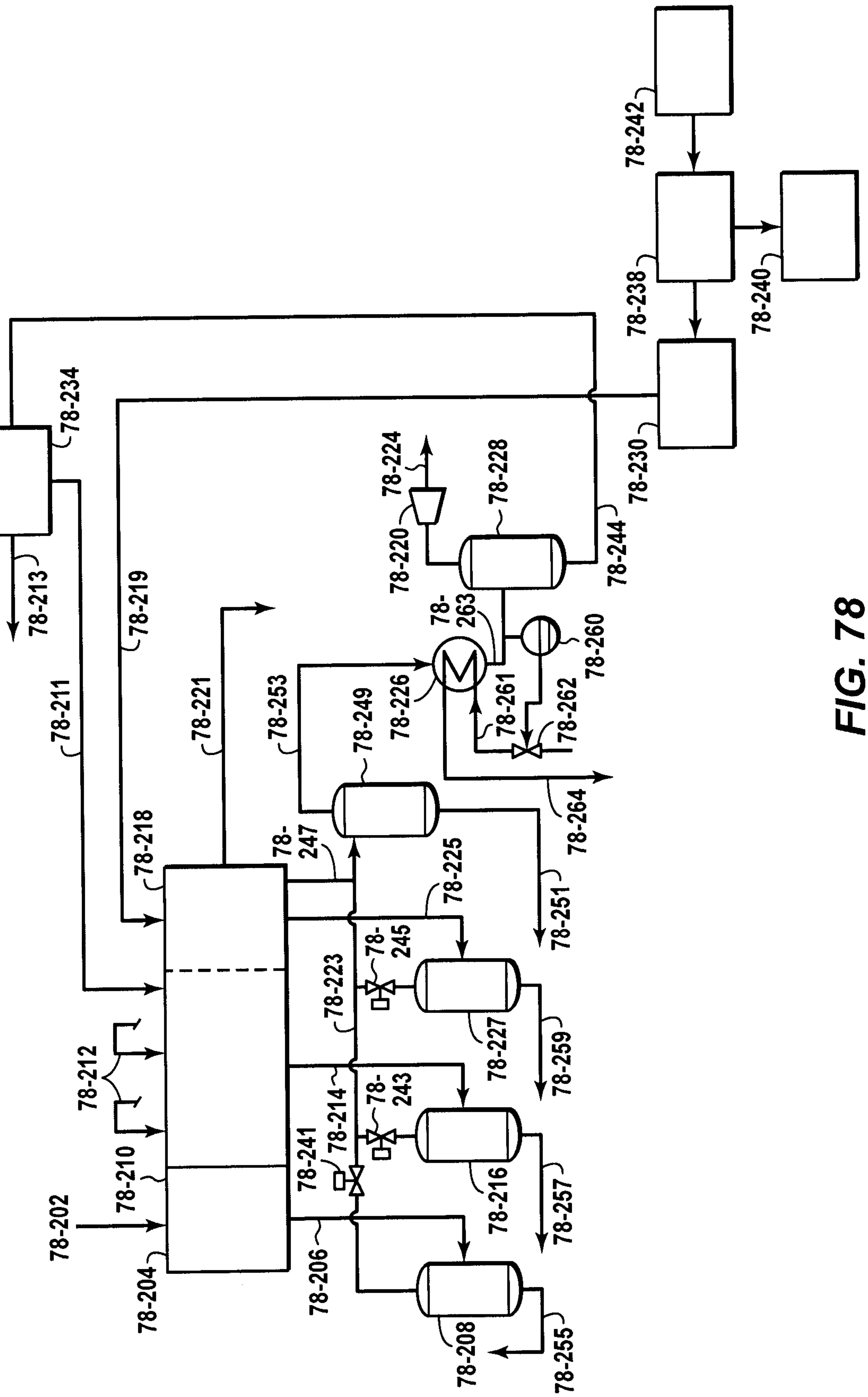

78-242
78-238
78-240
78-230
78-234
78-213
78-211
78-219
78-244
78-228
78-224
78-220
78-263
78-260
78-261
78-262
78-226
78-253
78-249
78-221
78-264
78-218
78-247
78-225
78-251
78-245
78-223
78-227
78-259
78-212
78-243
78-214
78-241
78-216
78-257
78-210
78-202
78-204
78-206
78-208
78-255

FIG. 78

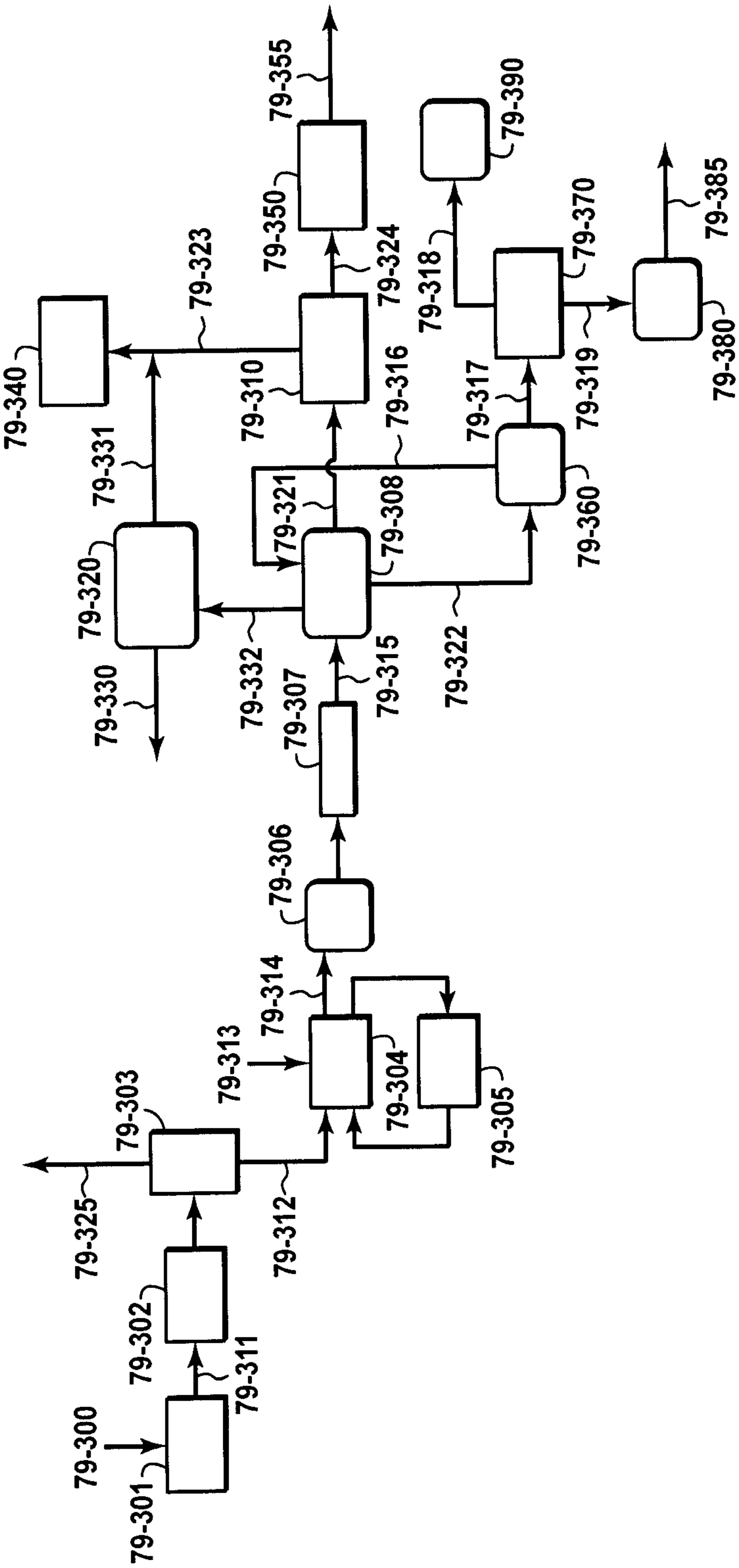

79-300
79-301
79-311
79-302
79-303
79-325
79-312
79-313
79-304
79-305
79-314
79-306
79-307
79-315
79-332
79-330
79-320
79-331
79-340
79-323
79-310
79-316
79-321
79-308
79-322
79-324
79-350
79-355
79-360
79-317
79-318
79-370
79-319
79-380
79-385
79-390

FIG. 79

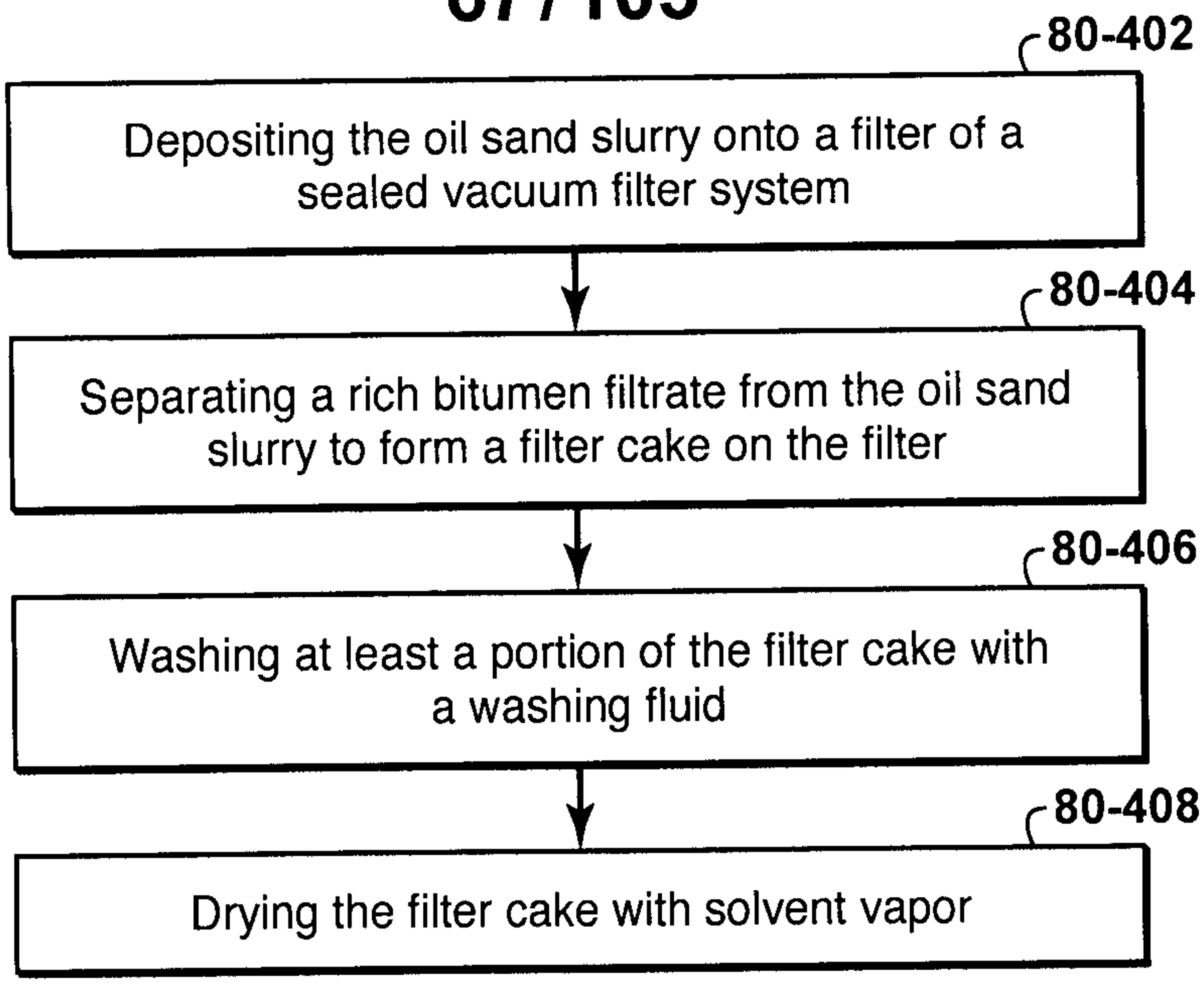

80-402
Depositing the oil sand slurry onto a filter of a sealed vacuum filter system
80-404
Separating a rich bitumen filtrate from the oil sand slurry to form a filter cake on the filter
80-406
Washing at least a portion of the filter cake with a washing fluid
80-408
Drying the filter cake with solvent vapor

FIG. 80

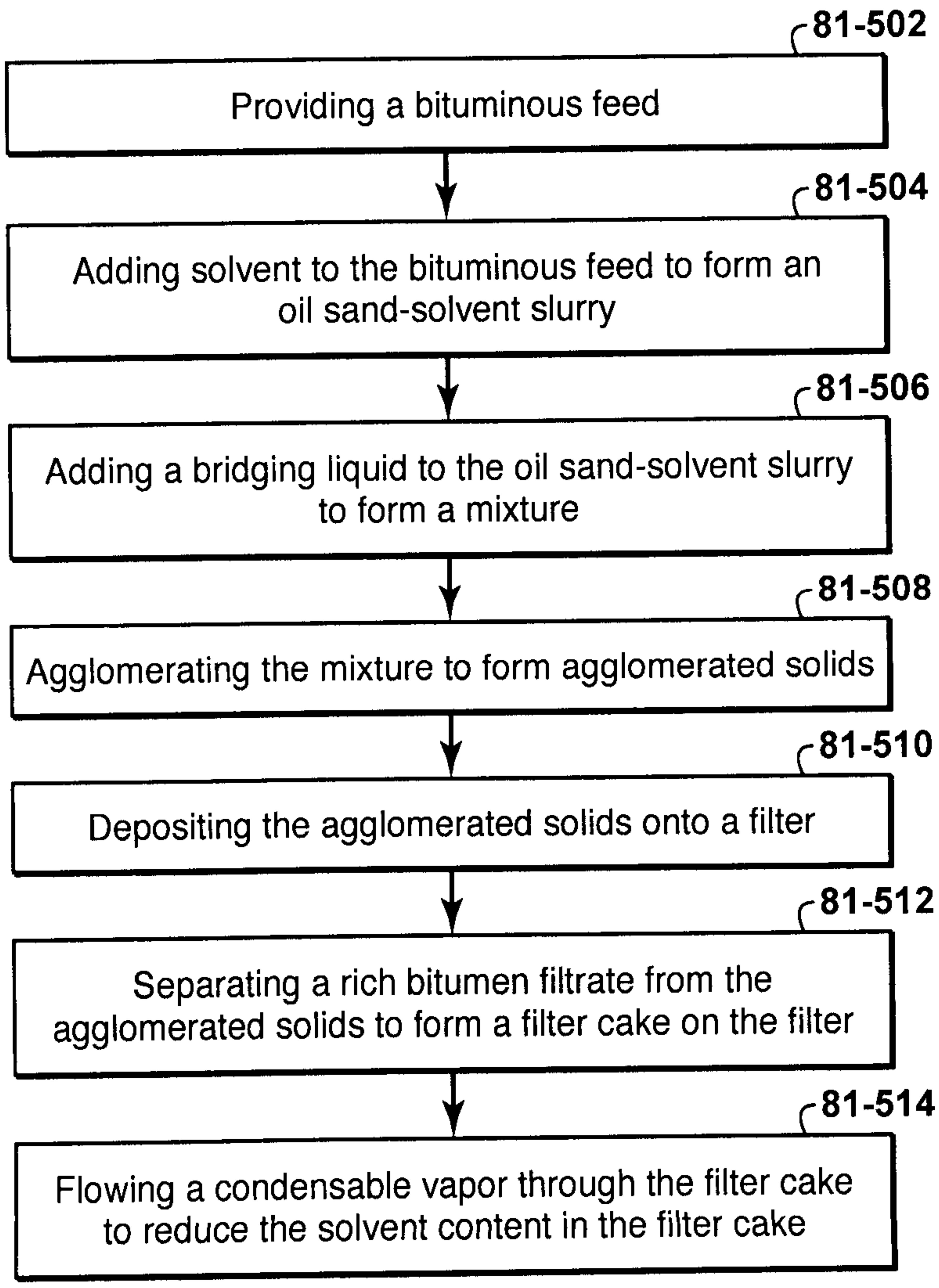

81-502
Providing a bituminous feed
81-504
Adding solvent to the bituminous feed to form an oil sand-solvent slurry
81-506
Adding a bridging liquid to the oil sand-solvent slurry to form a mixture
81-508
Agglomerating the mixture to form agglomerated solids
81-510
Depositing the agglomerated solids onto a filter
81-512
Separating a rich bitumen filtrate from the agglomerated solids to form a filter cake on the filter
81-514
Flowing a condensable vapor through the filter cake to reduce the solvent content in the filter cake

FIG. 81

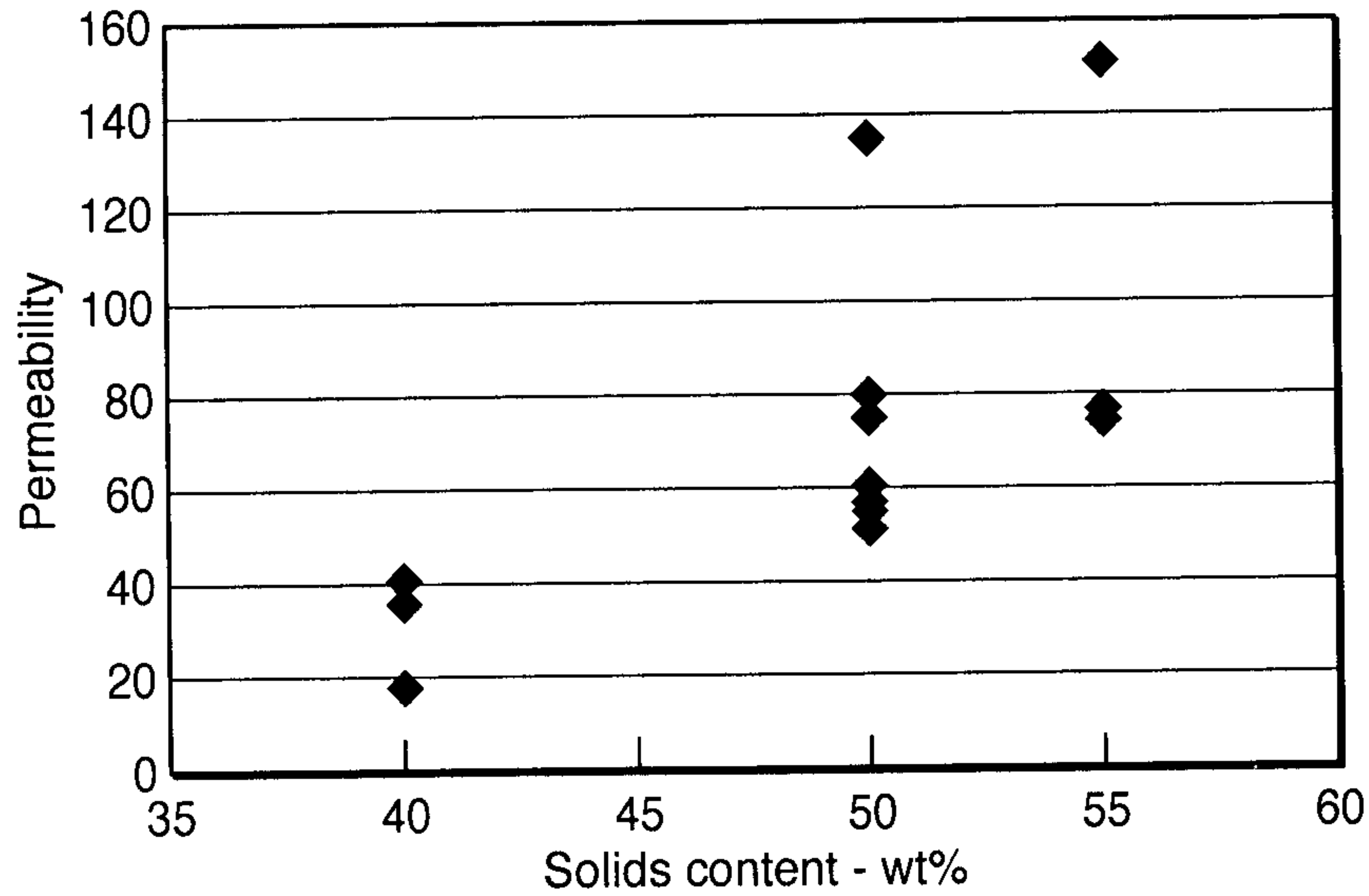

160
140
120
100
80
60
40
20
0
Permeability
35
40
45
50
55
60
Solids content - wt%

FIG. 82

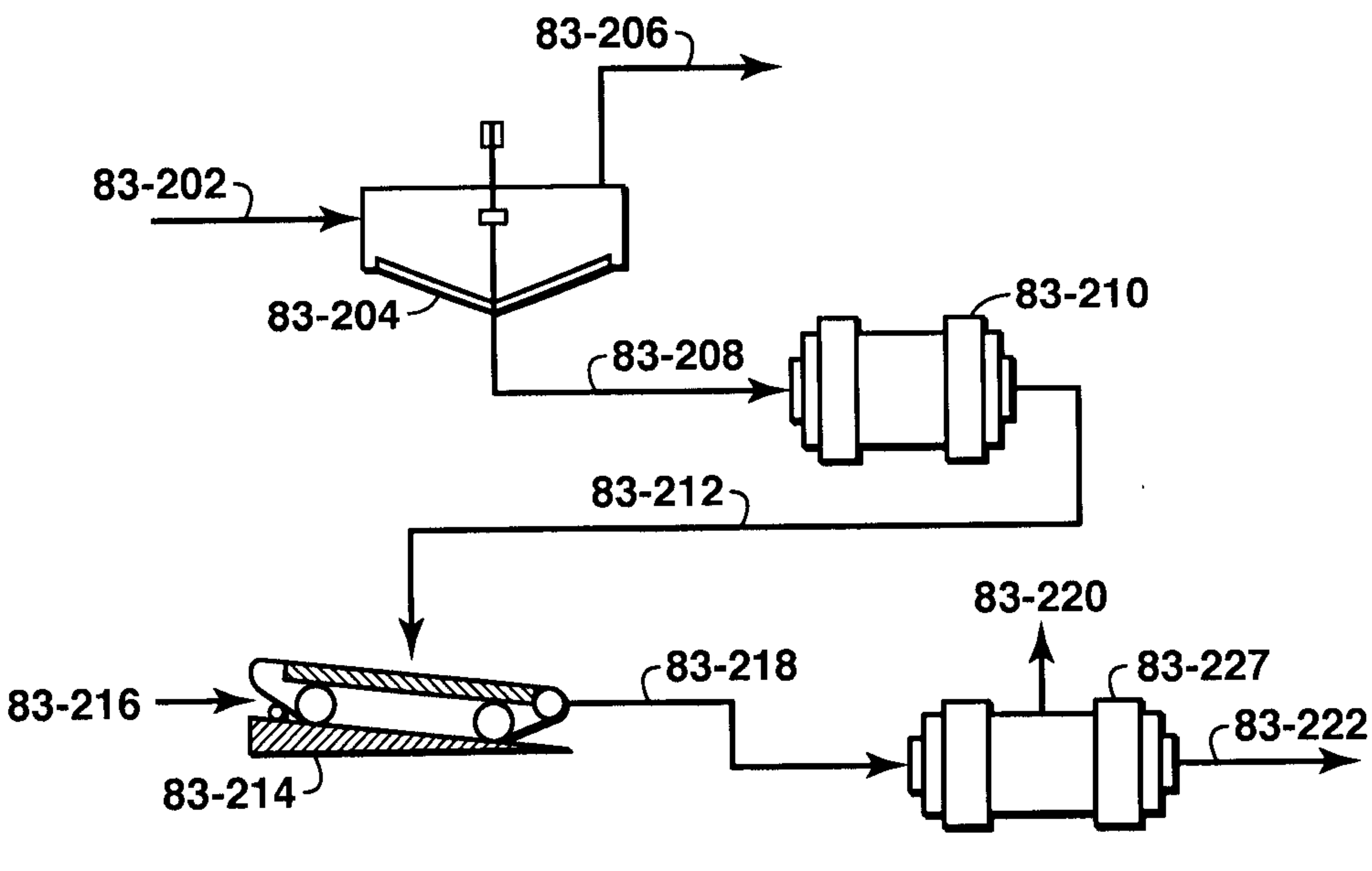

83-206
83-202
83-204
83-210
83-208
83-212
83-220
83-218
83-227
83-216
83-222
83-214

FIG. 83

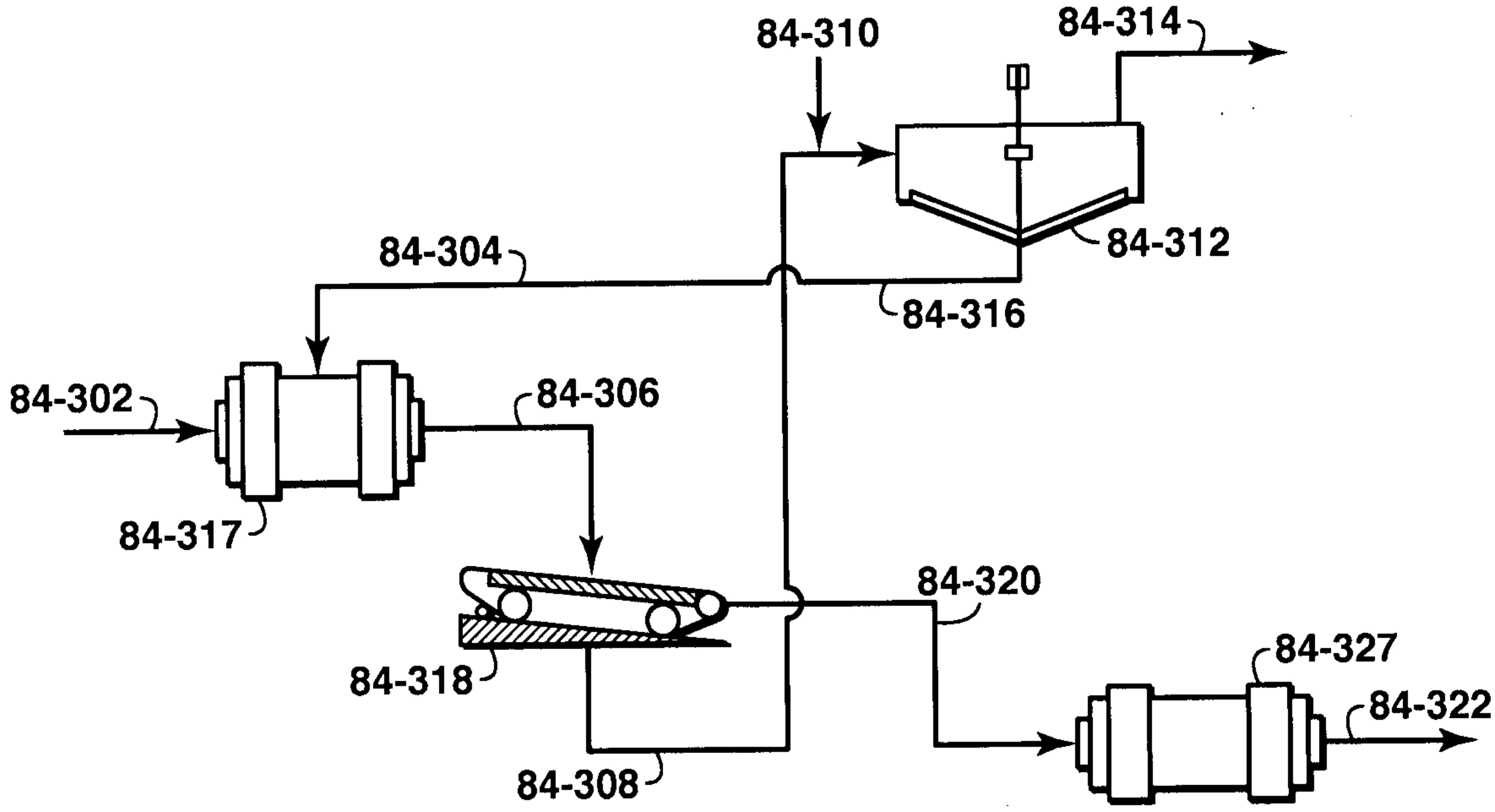

84-310
84-314
84-304
84-312
84-316
84-302
84-306
84-317
84-320
84-327
84-318
84-322
84-308

FIG. 84

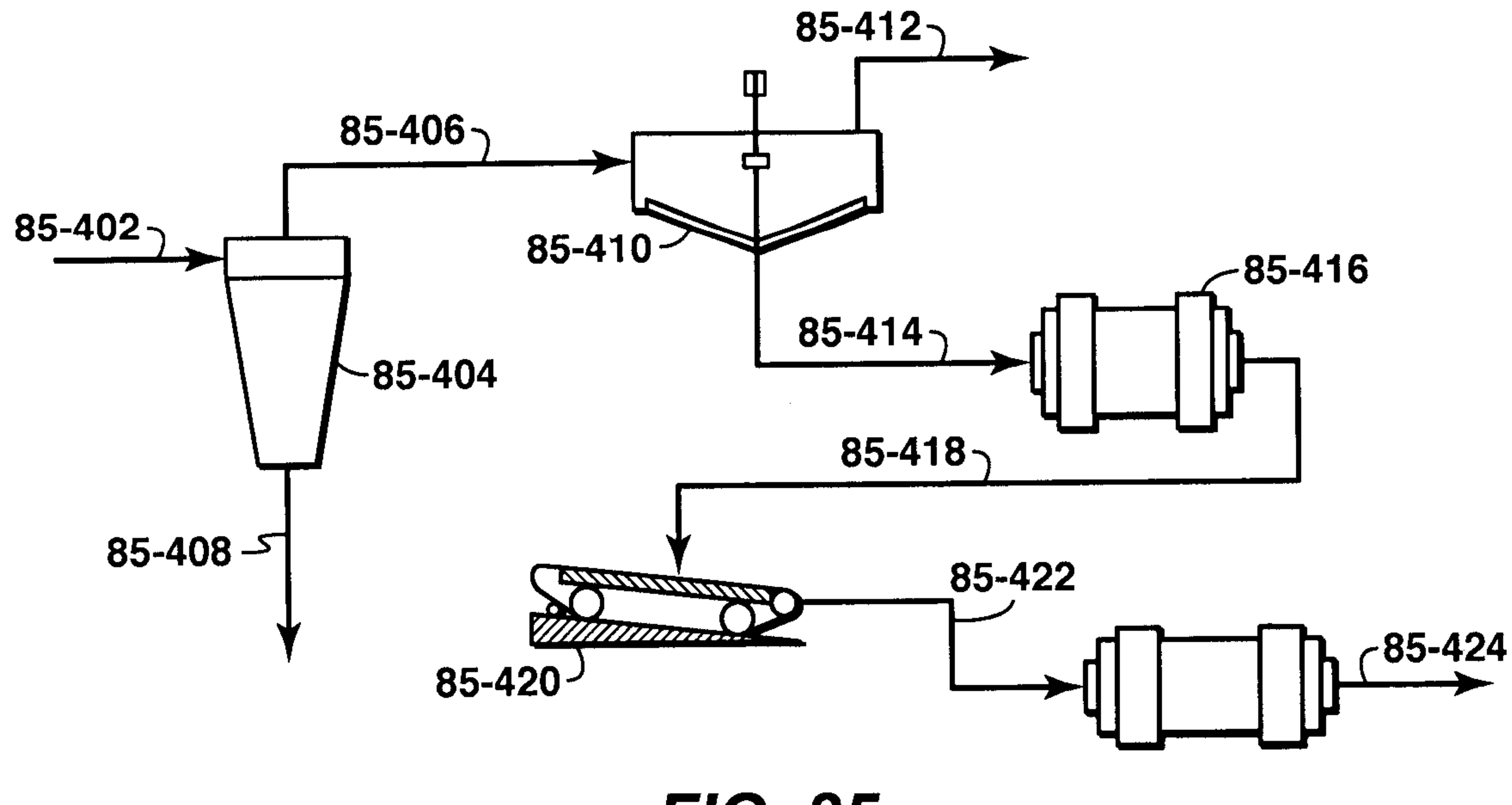

85-412
85-406
85-402
85-410
85-416
85-414
85-404
85-418
85-408
85-422
85-420
85-424

FIG. 85

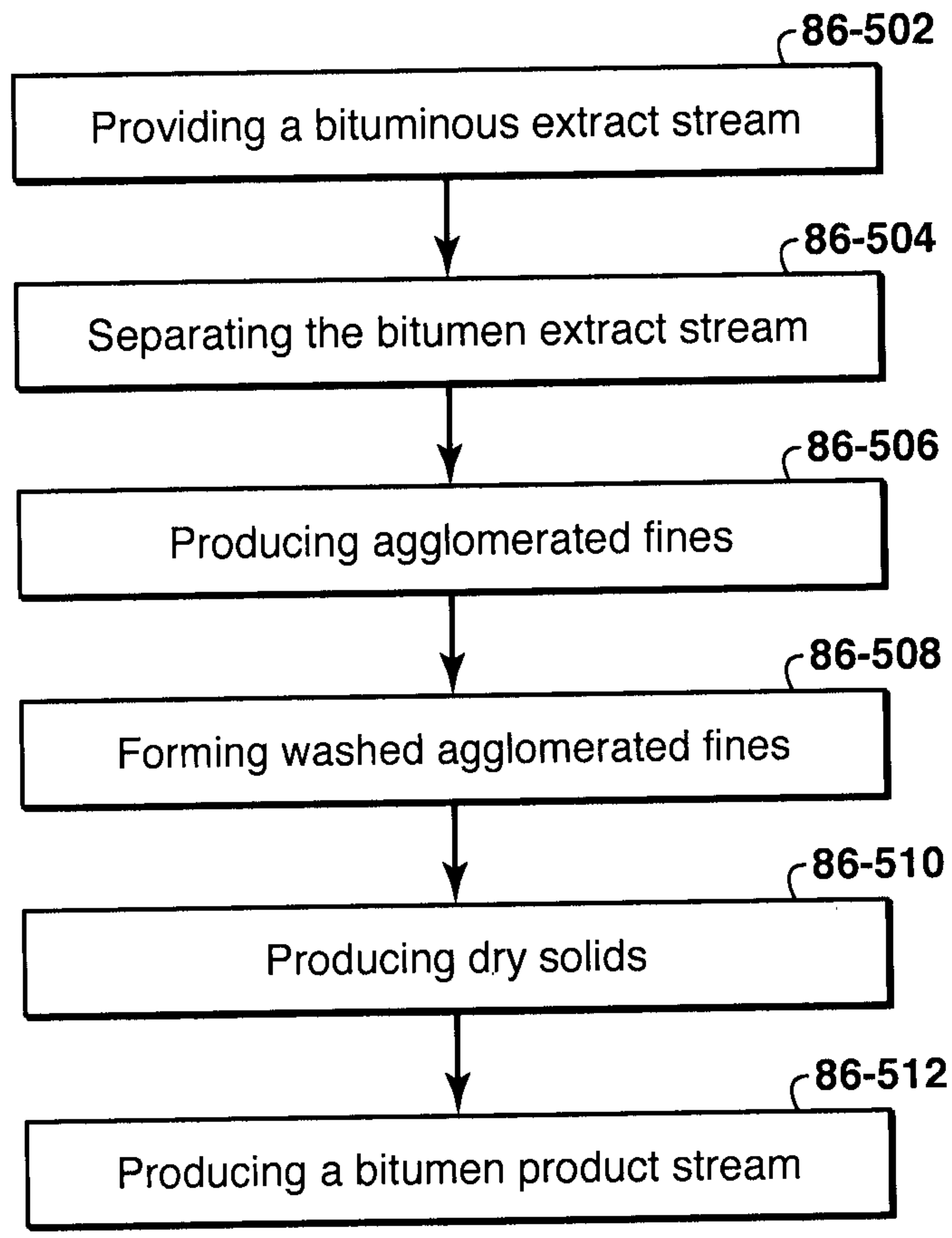

86-502
Providing a bituminous extract stream
86-504
Separating the bitumen extract stream
86-506
Producing agglomerated fines
86-508
Forming washed agglomerated fines
86-510
Producing dry solids
86-512
Producing a bitumen product stream

FIG. 86

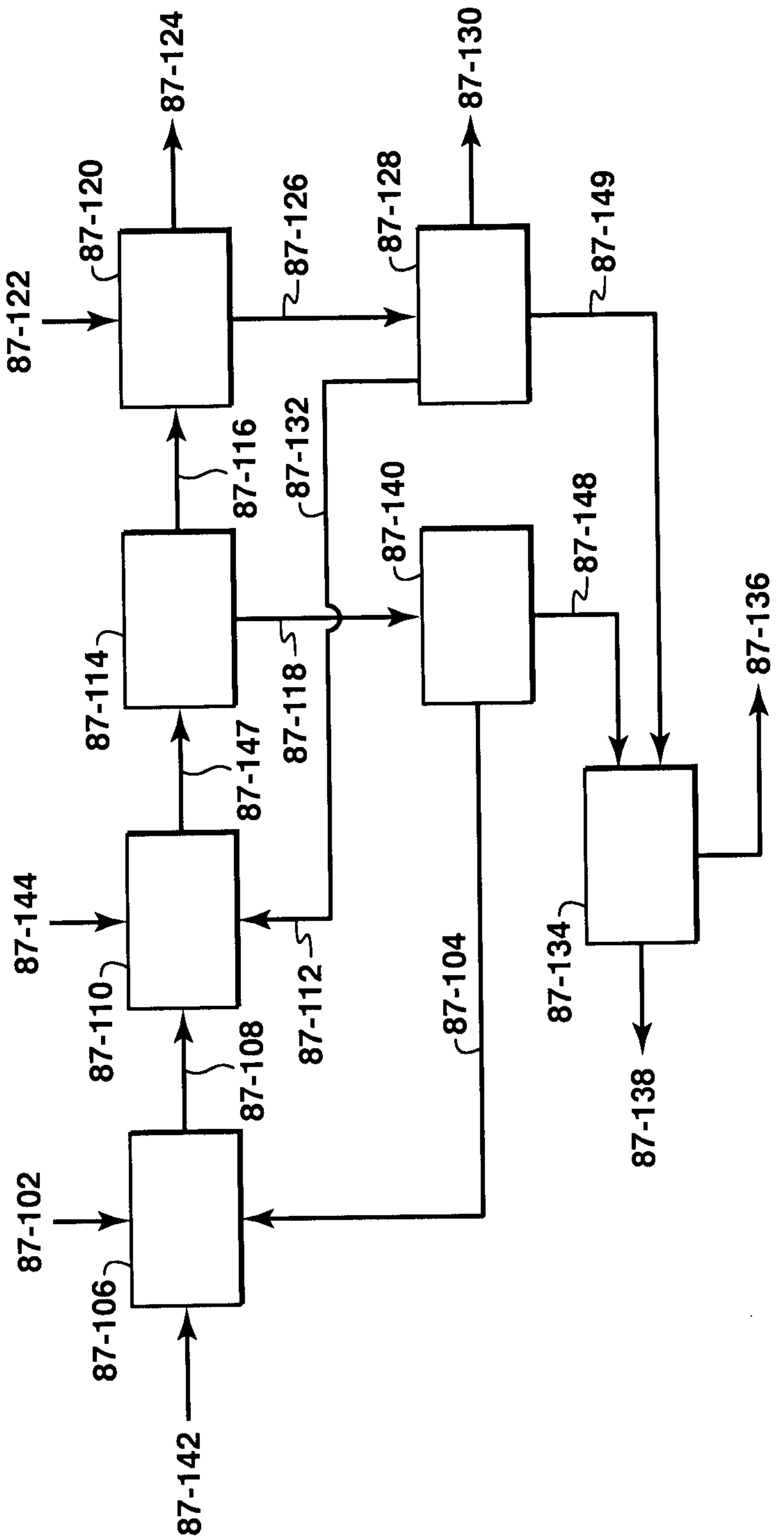

87-102
87-104
87-106
87-108
87-110
87-112
87-114
87-116
87-118
87-120
87-122
87-124
87-126
87-128
87-130
87-132
87-134
87-136
87-138
87-140
87-142
87-144
87-147
87-148
87-149

FIG. 87

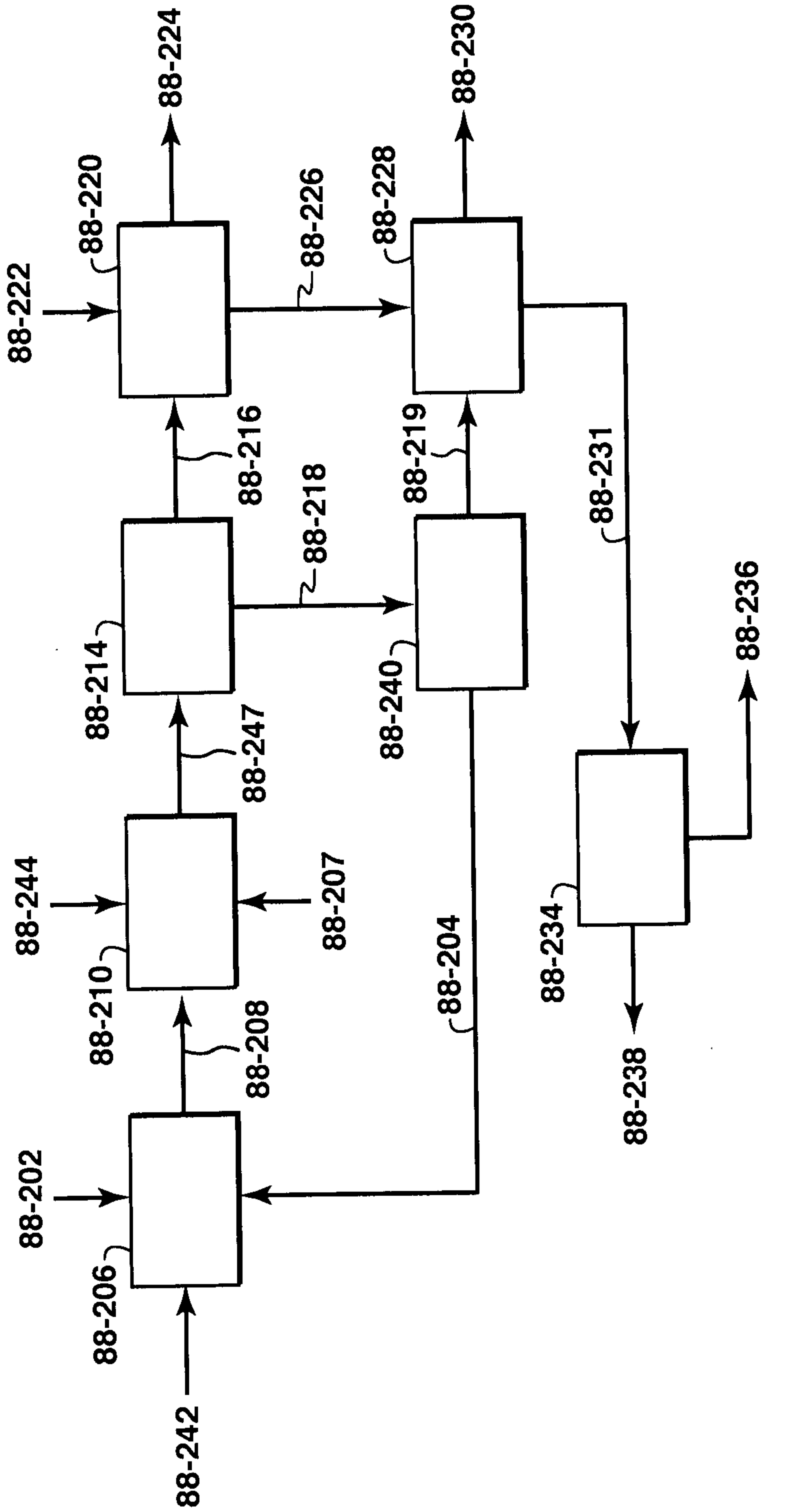

88-224
88-230
88-220
88-226
88-228
88-222
88-216
88-218
88-219
88-231
88-214
88-240
88-236
88-247
88-244
88-207
88-210
88-204
88-234
88-208
88-238
88-202
88-206
88-242

FIG. 88

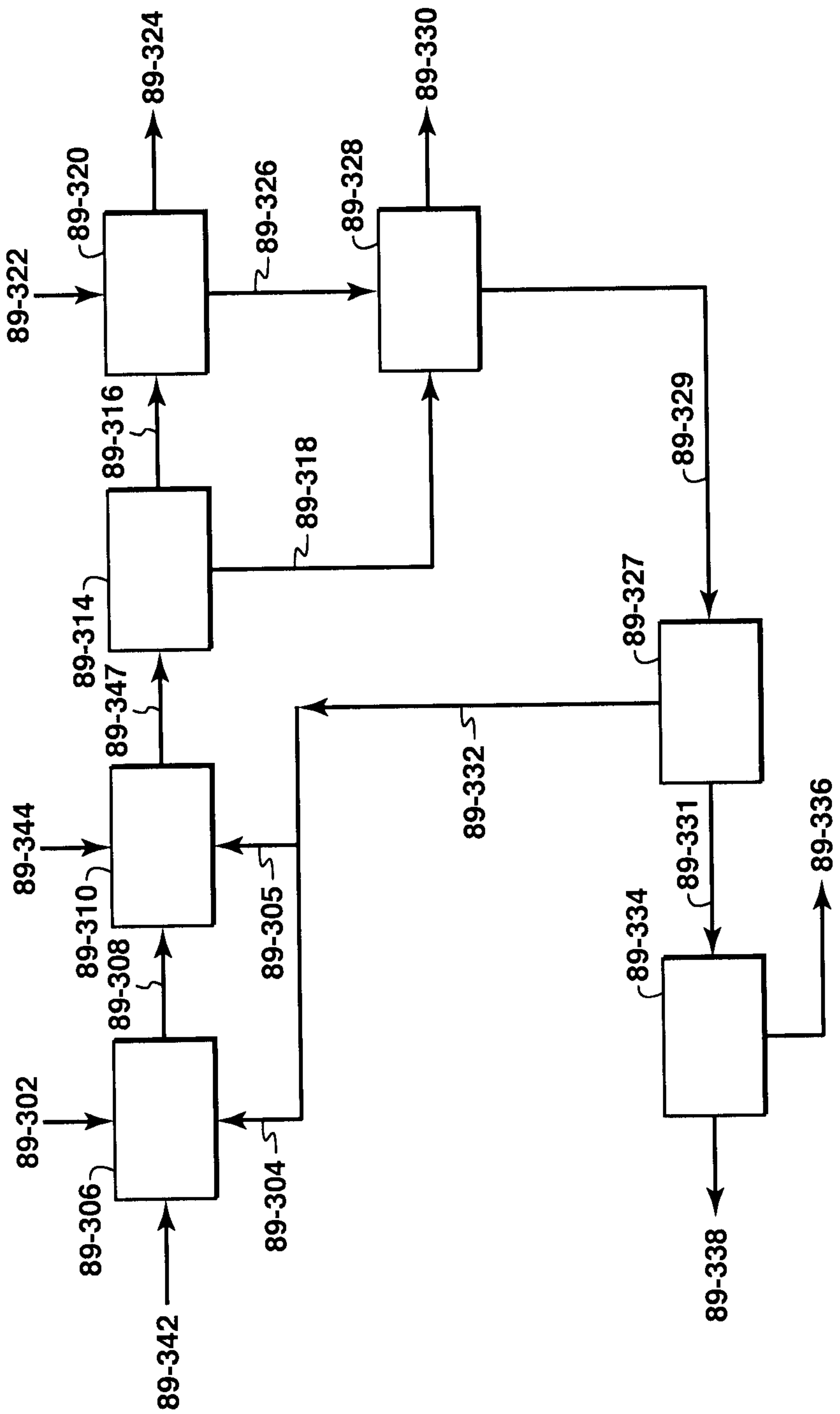

89-342
89-306
89-302
89-304
89-308
89-310
89-344
89-305
89-347
89-314
89-332
89-316
89-318
89-322
89-320
89-324
89-326
89-328
89-330
89-329
89-327
89-331
89-334
89-336
89-338

FIG. 89

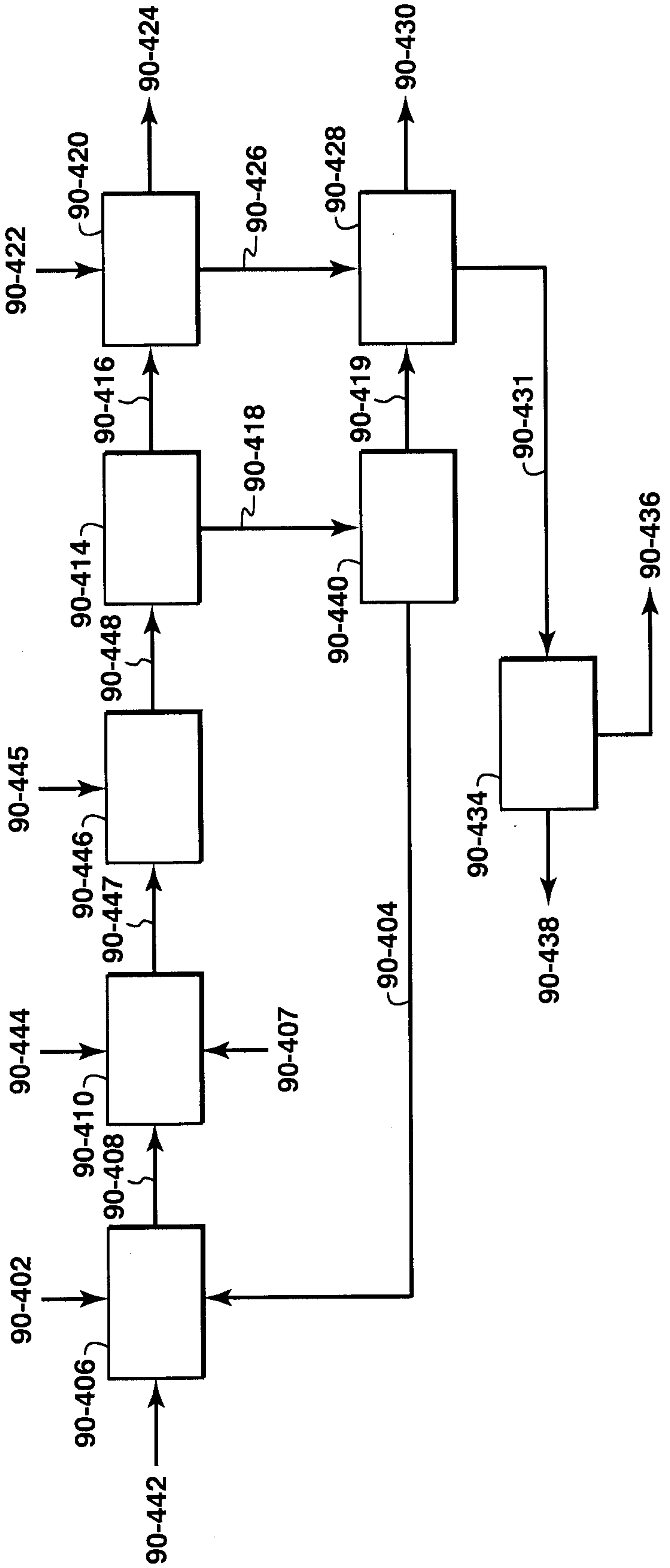

90-424
90-430
90-420
90-426
90-428
90-422
90-416
90-418
90-419
90-431
90-414
90-440
90-436
90-448
90-445
90-446
90-434
90-447
90-404
90-438
90-444
90-407
90-410
90-408
90-402
90-406
90-442

FIG. 90

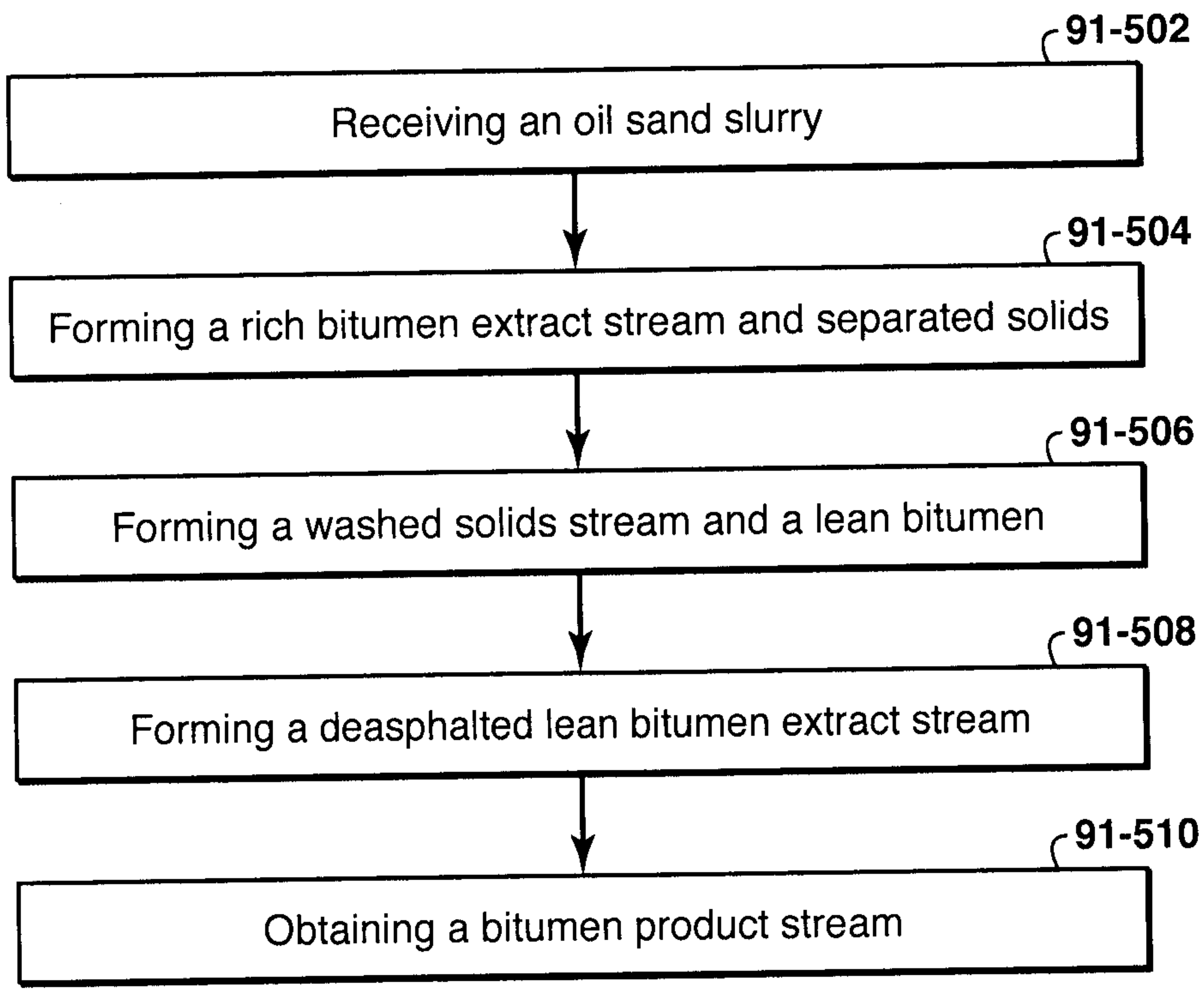

91-502
Receiving an oil sand slurry
91-504
Forming a rich bitumen extract stream and separated solids
91-506
Forming a washed solids stream and a lean bitumen
91-508
Forming a deasphalted lean bitumen extract stream
91-510
Obtaining a bitumen product stream

FIG. 91

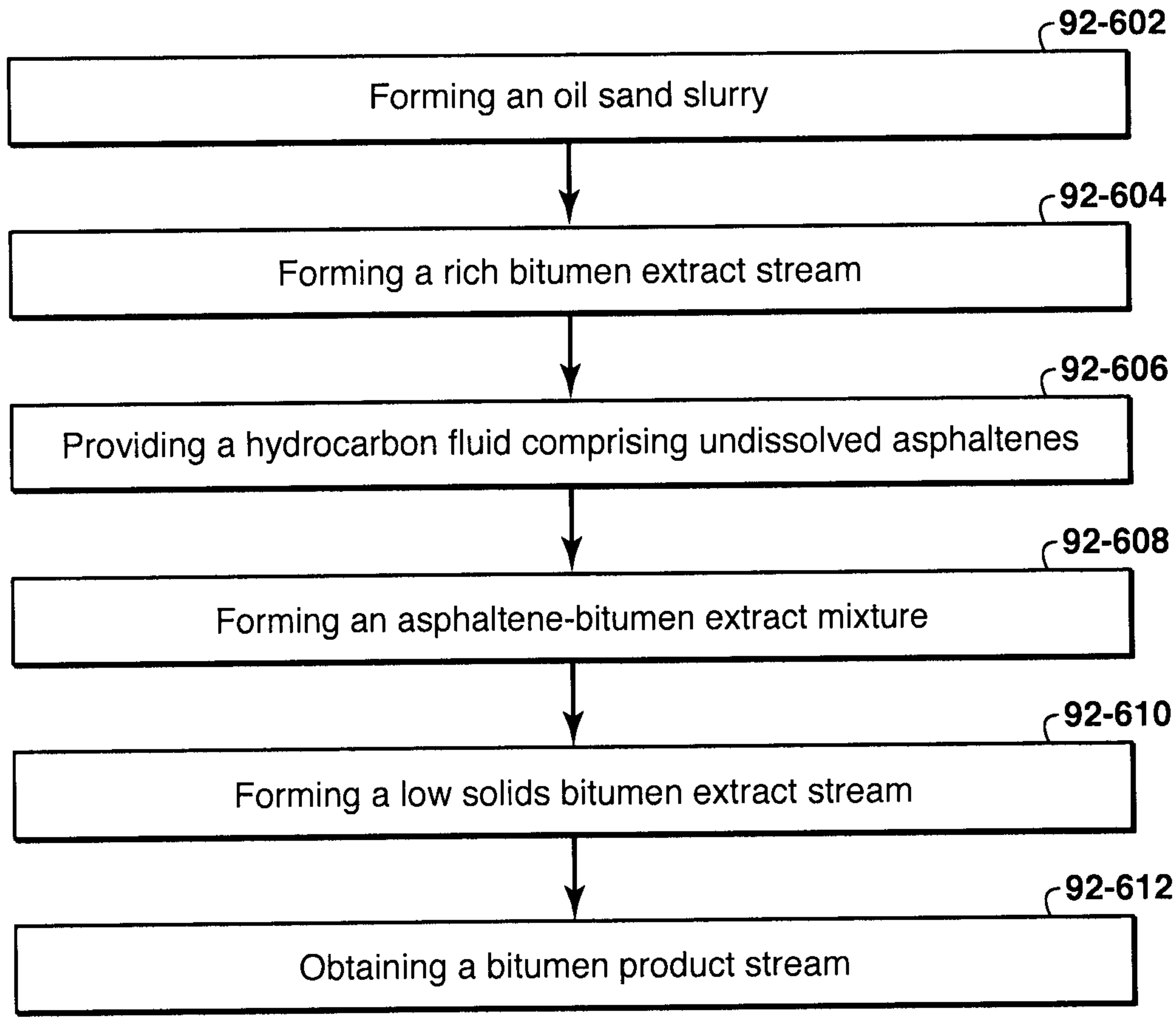

92-602
Forming an oil sand slurry
92-604
Forming a rich bitumen extract stream
92-606
Providing a hydrocarbon fluid comprising undissolved asphaltenes
92-608
Forming an asphaltene-bitumen extract mixture
92-610
Forming a low solids bitumen extract stream
92-612
Obtaining a bitumen product stream

FIG. 92

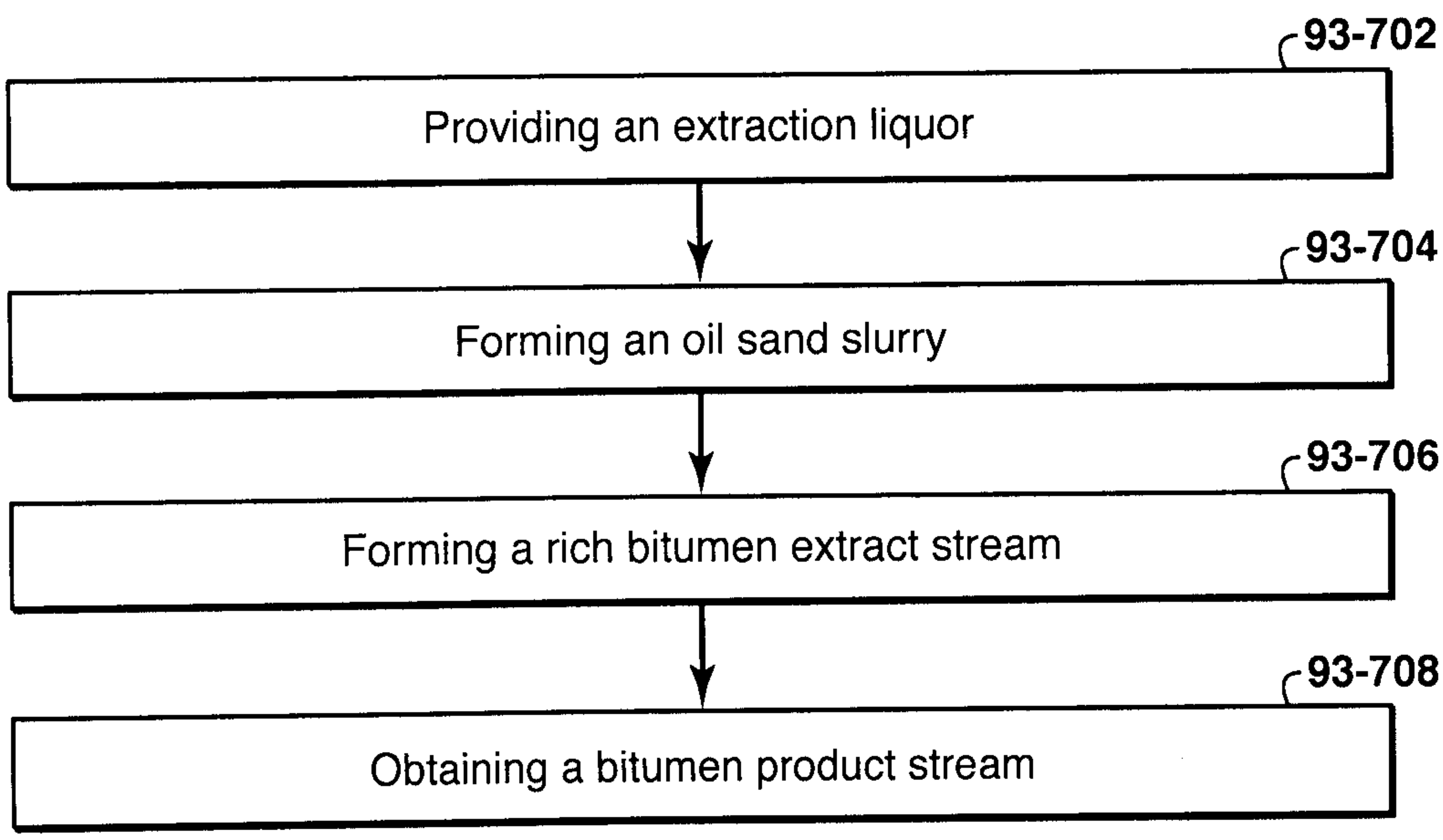

93-702
Providing an extraction liquor
93-704
Forming an oil sand slurry
93-706
Forming a rich bitumen extract stream
93-708
Obtaining a bitumen product stream

FIG. 93

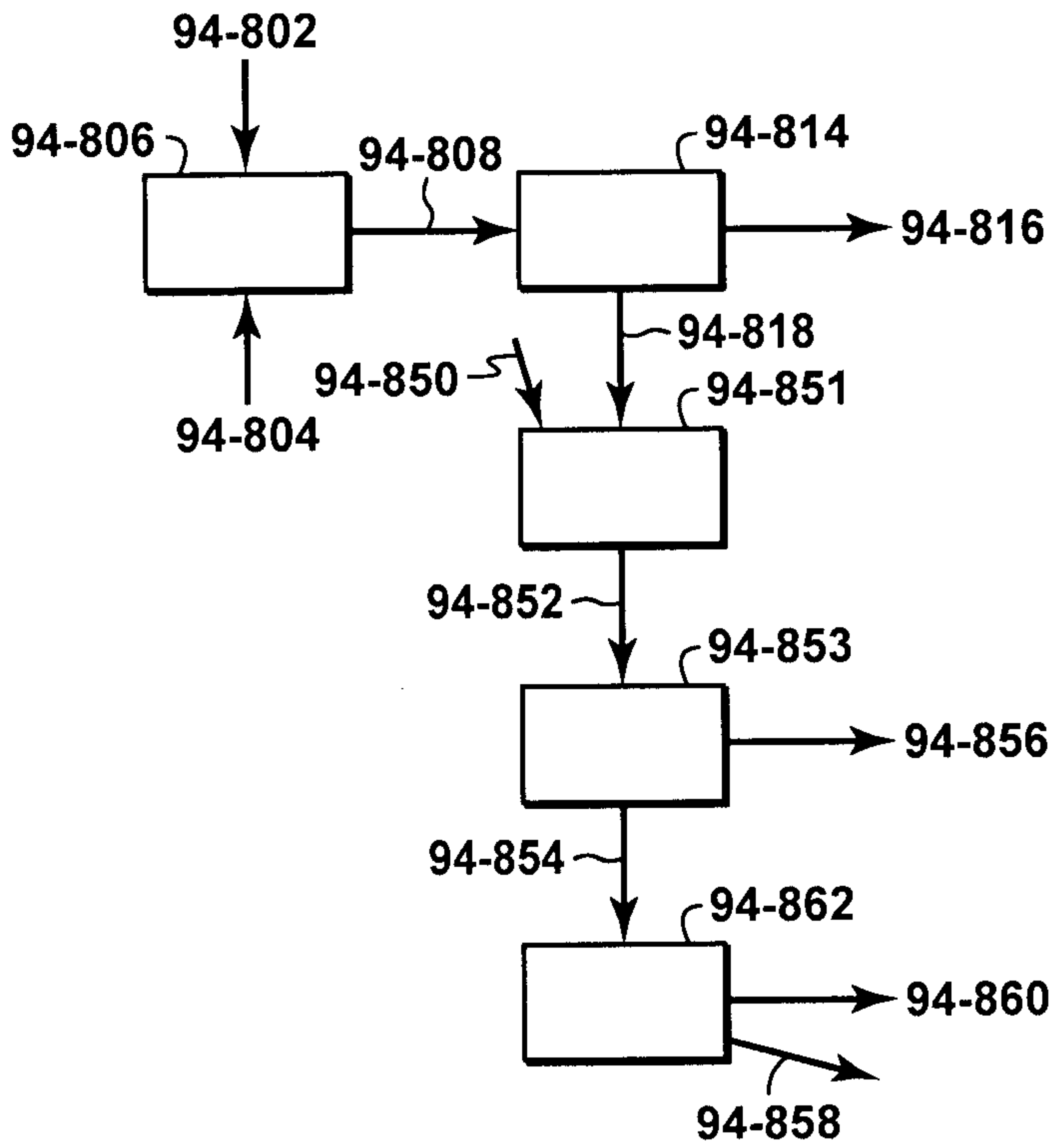

94-802
94-806
94-808
94-814
94-816
94-818
94-850
94-851
94-804
94-852
94-853
94-856
94-854
94-862
94-860
94-858

FIG. 94

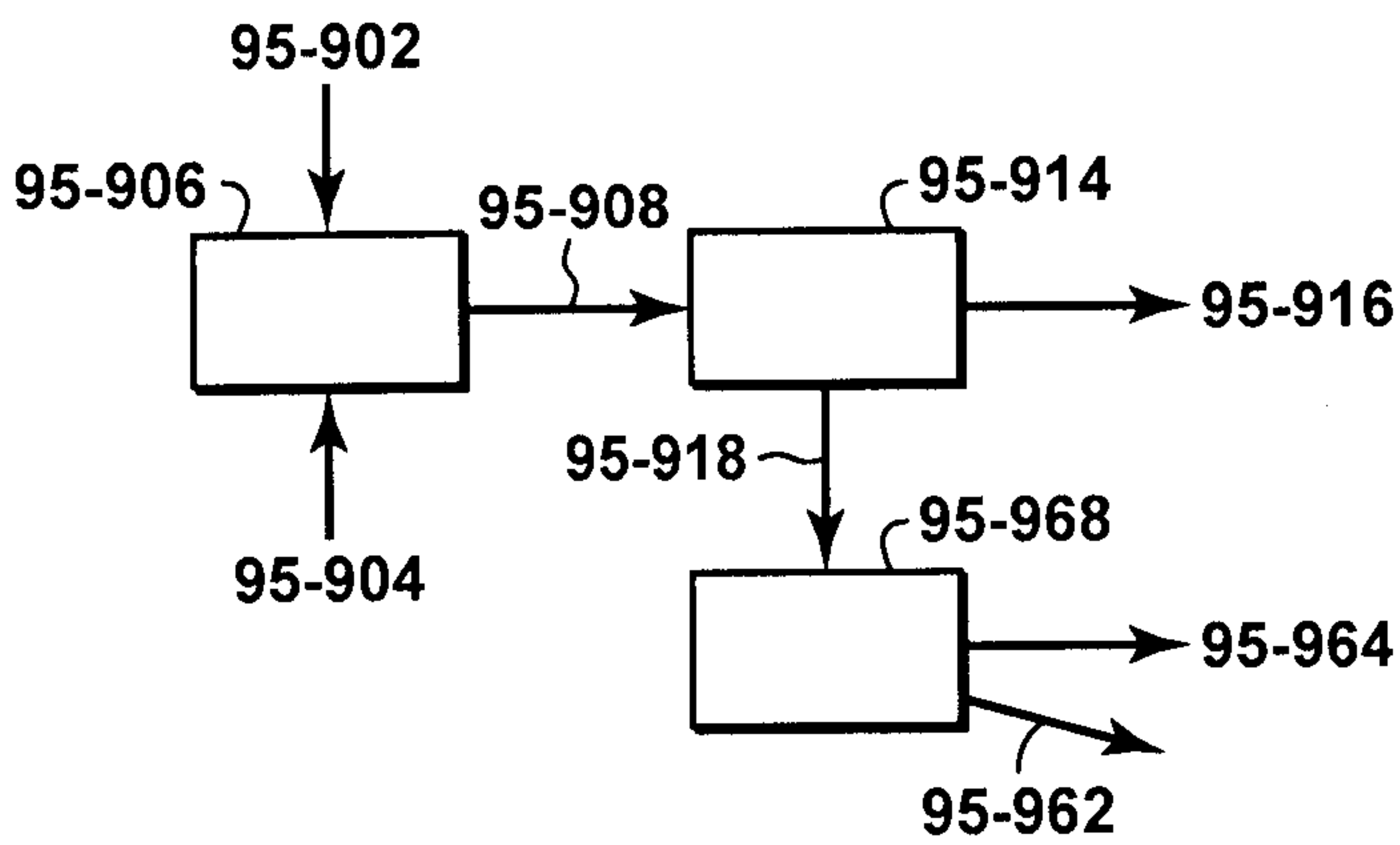

95-902
95-906
95-908
95-914
95-916
95-918
95-968
95-904
95-964
95-962

FIG. 95

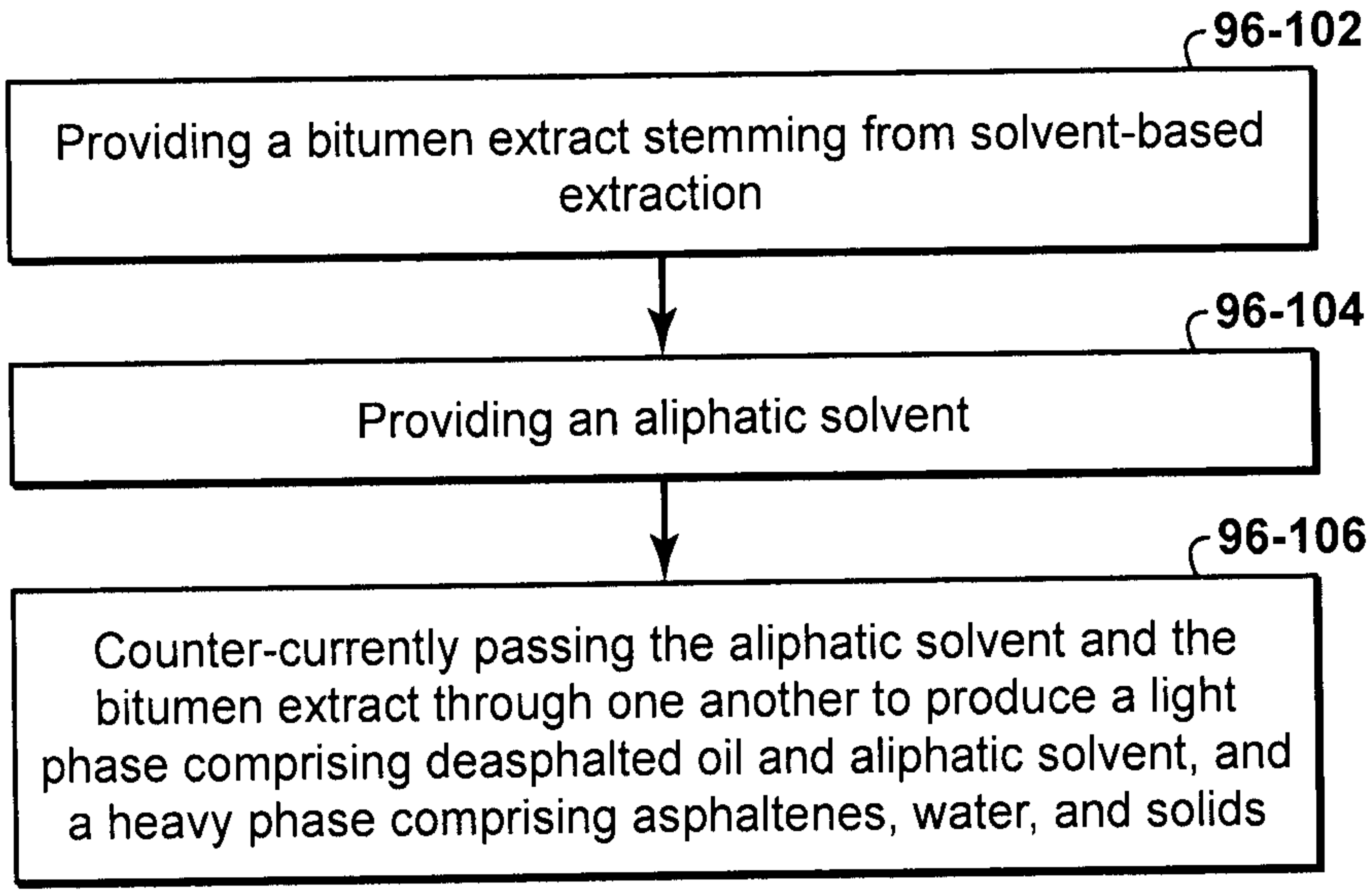

96-102
Providing a bitumen extract stemming from solvent-based extraction
96-104
Providing an aliphatic solvent
96-106
Counter-currently passing the aliphatic solvent and the bitumen extract through one another to produce a light phase comprising deasphalted oil and aliphatic solvent, and a heavy phase comprising asphaltenes, water, and solids

FIG. 96

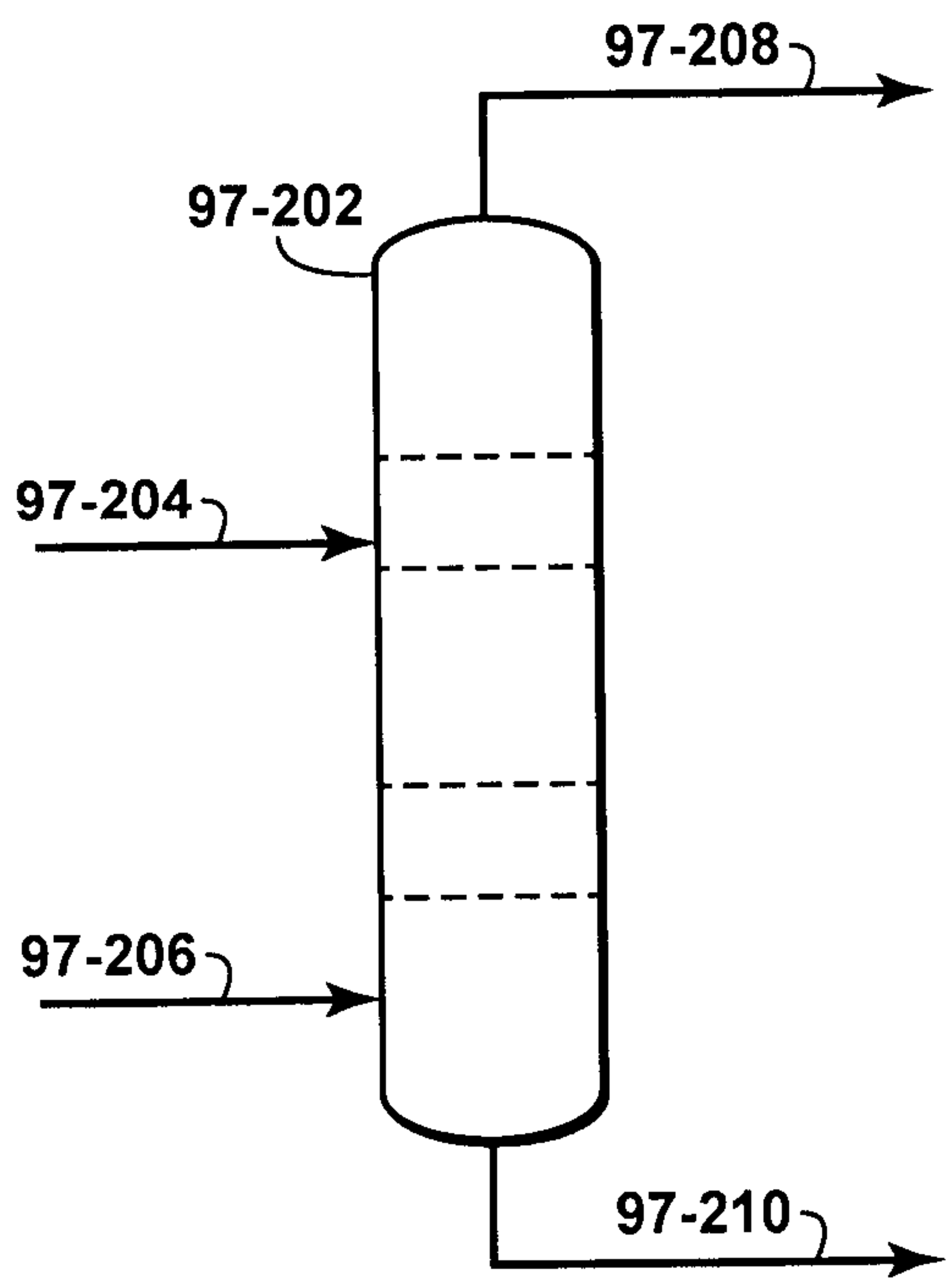

97-208
97-202
97-204
97-206
97-210

FIG. 97

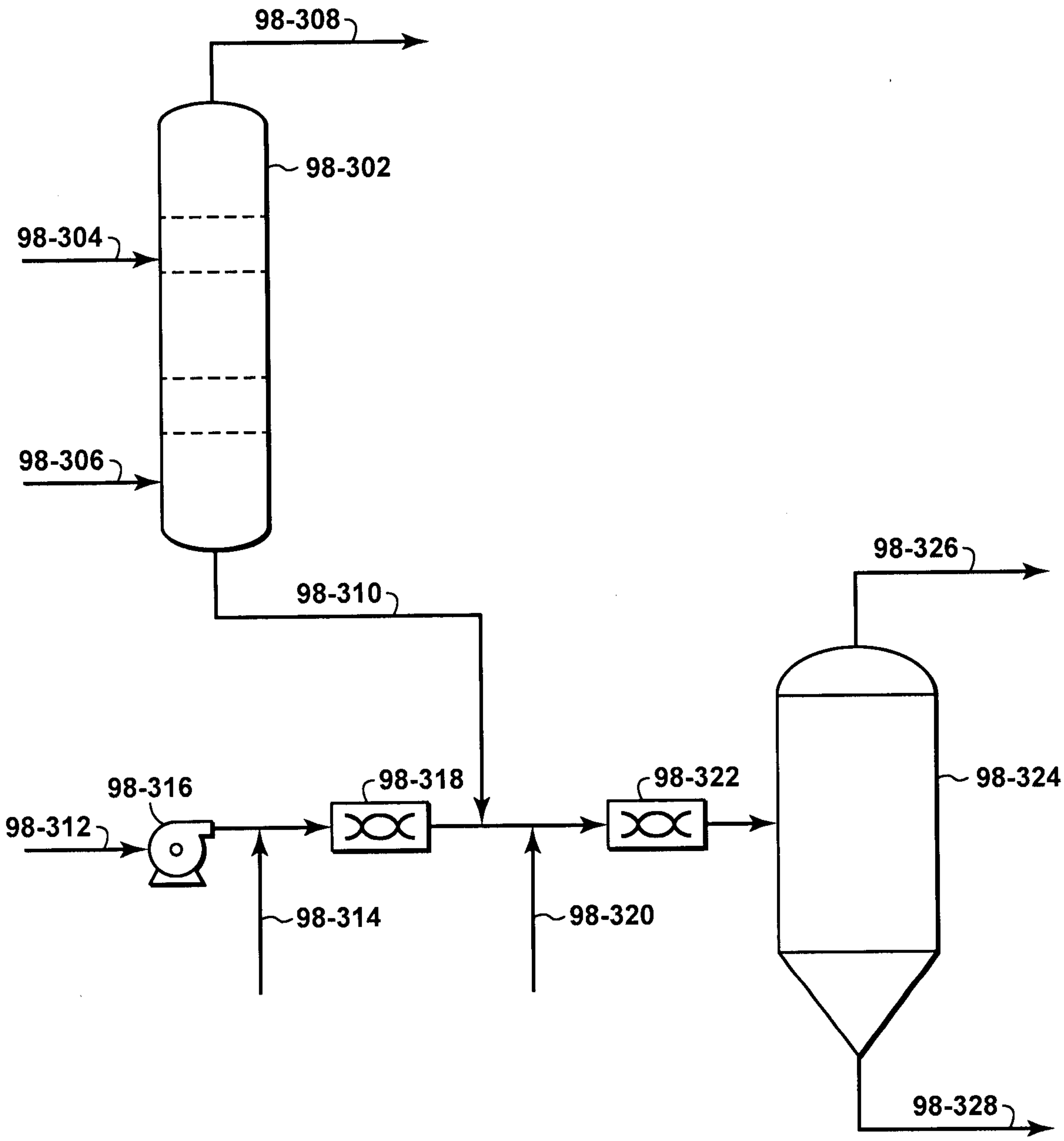

98-308
98-302
98-304
98-306
98-310
98-326
98-316
98-318
98-322
98-324
98-312
98-314
98-320
98-328

FIG. 98

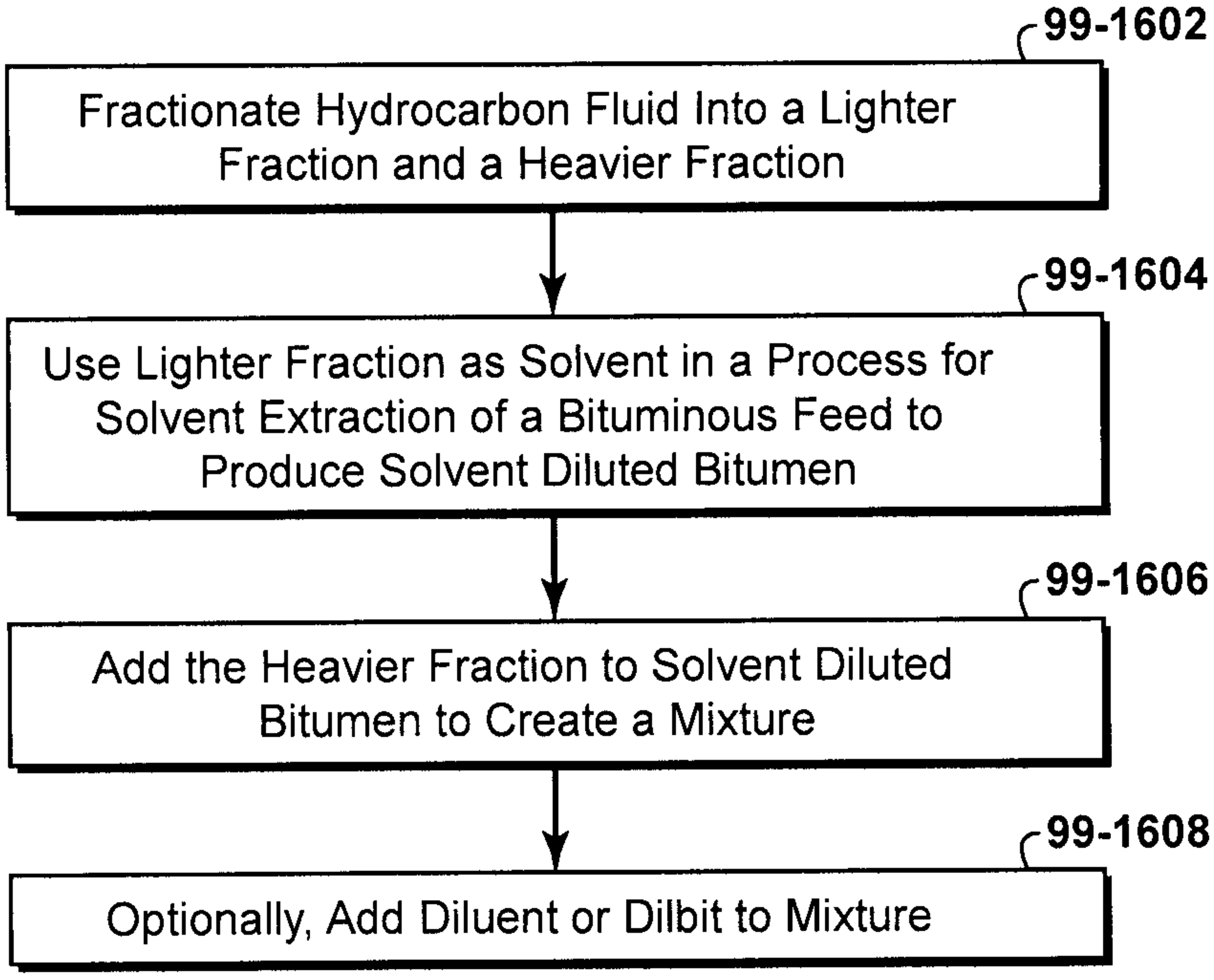


FIG. 99

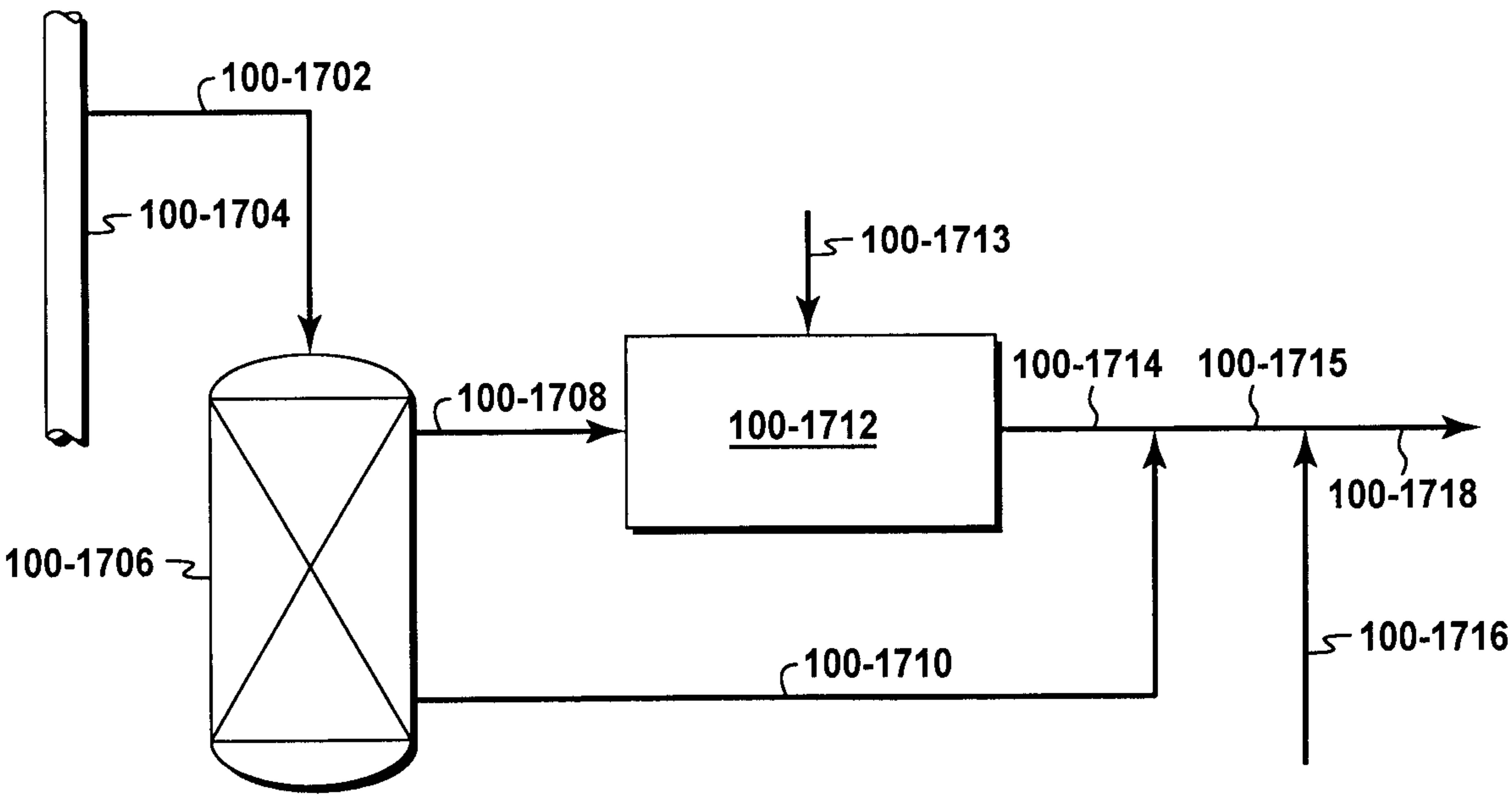


FIG. 100

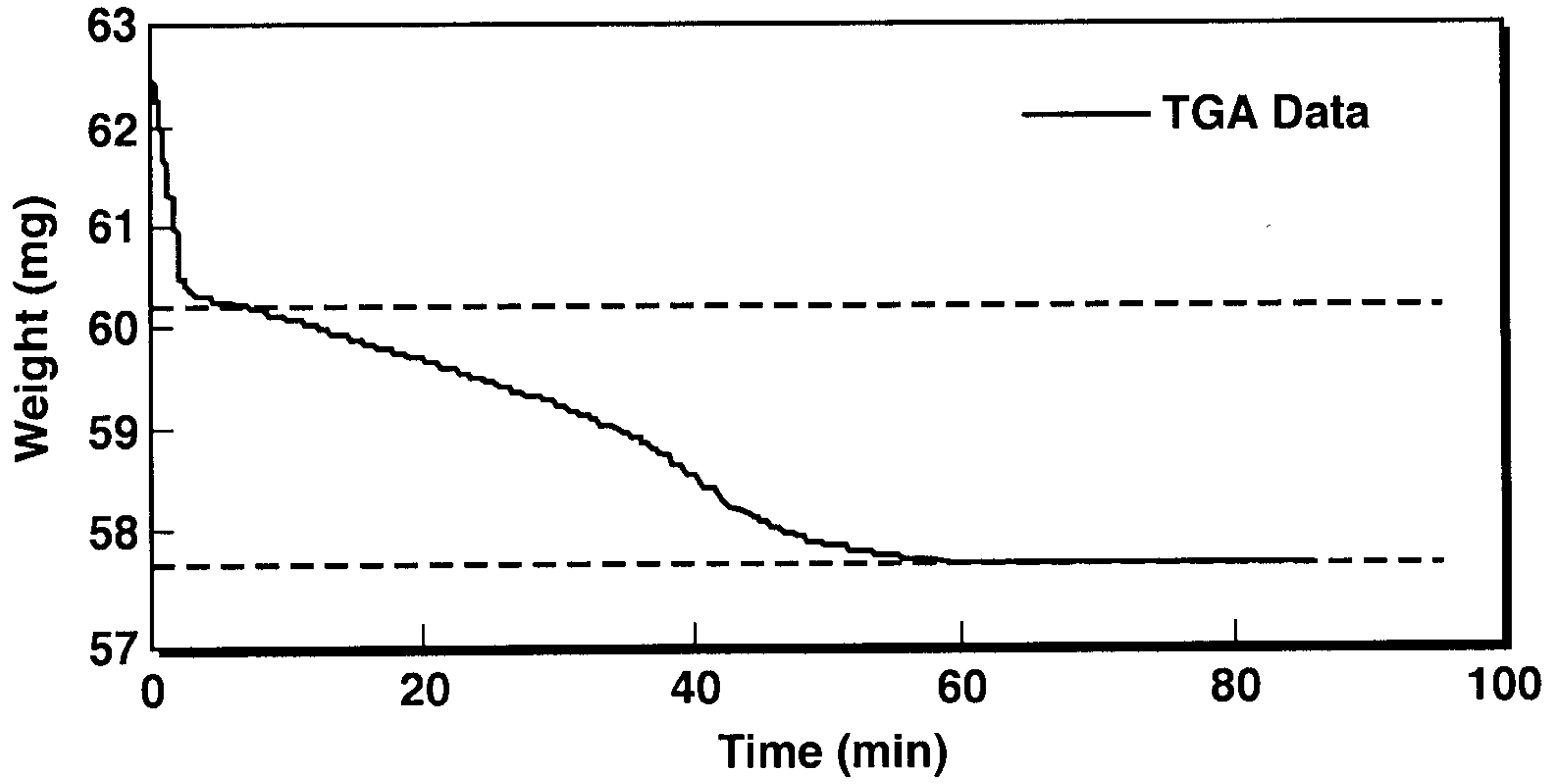


FIG. 101

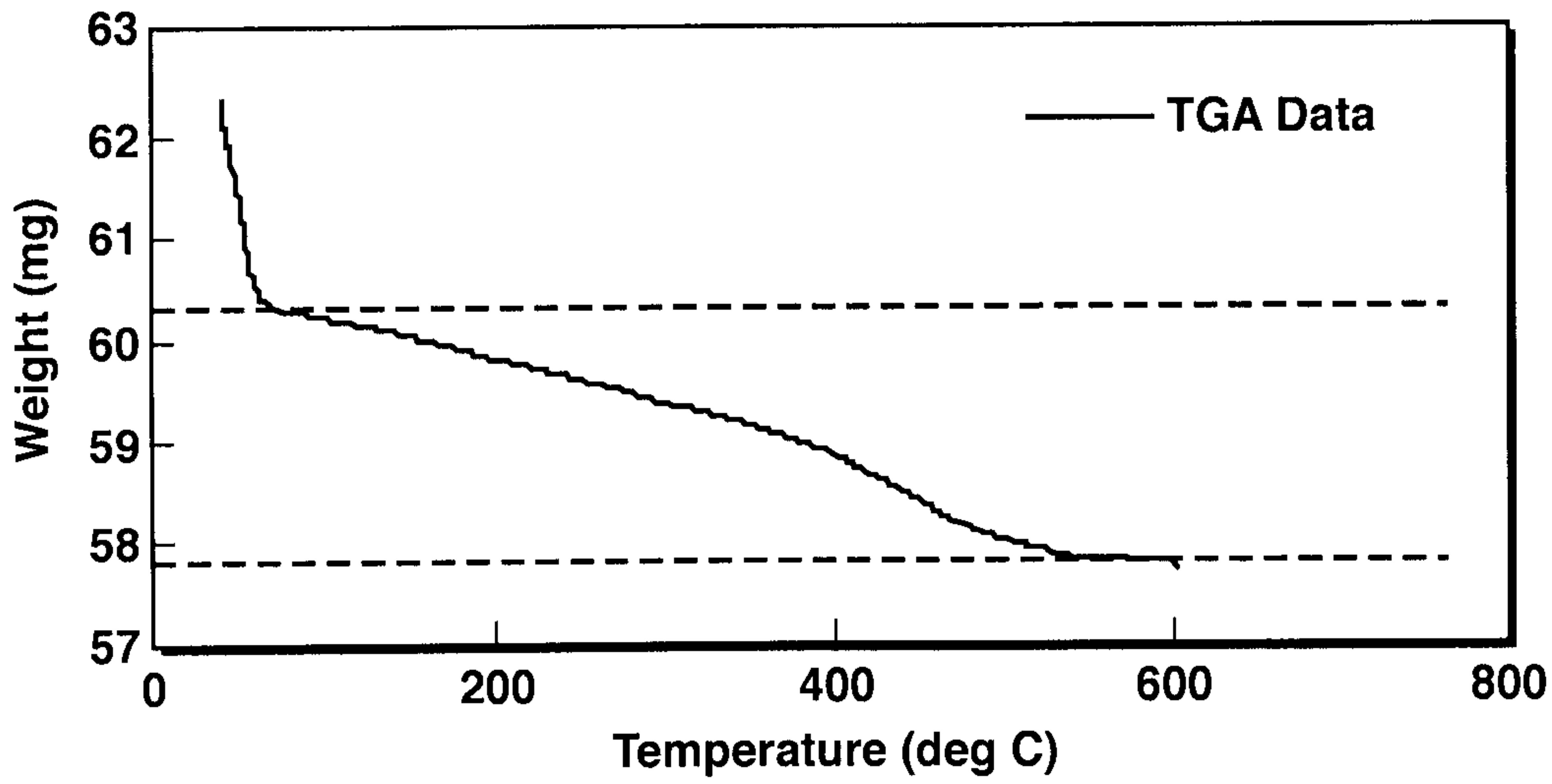


FIG. 102

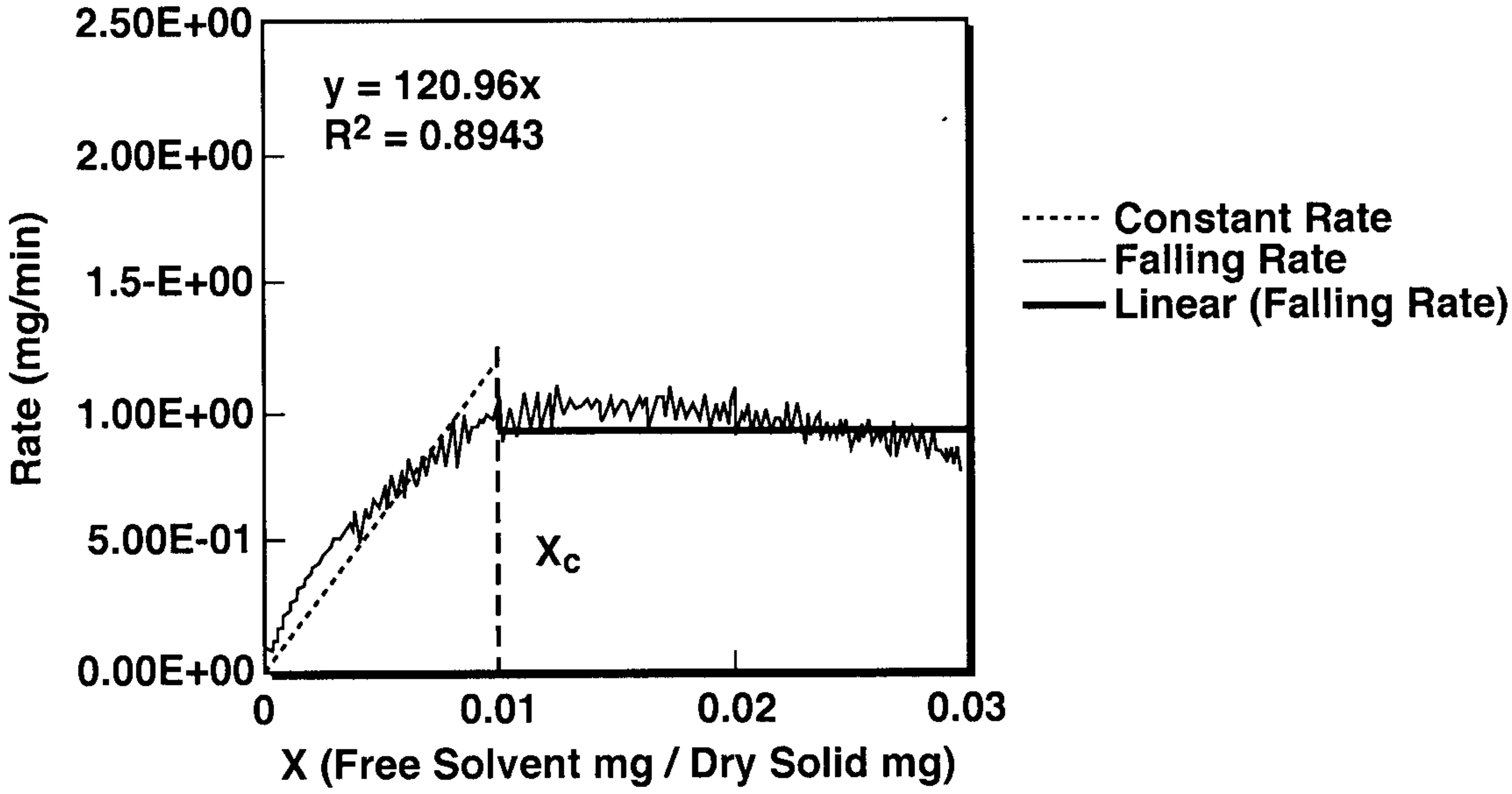


FIG. 103

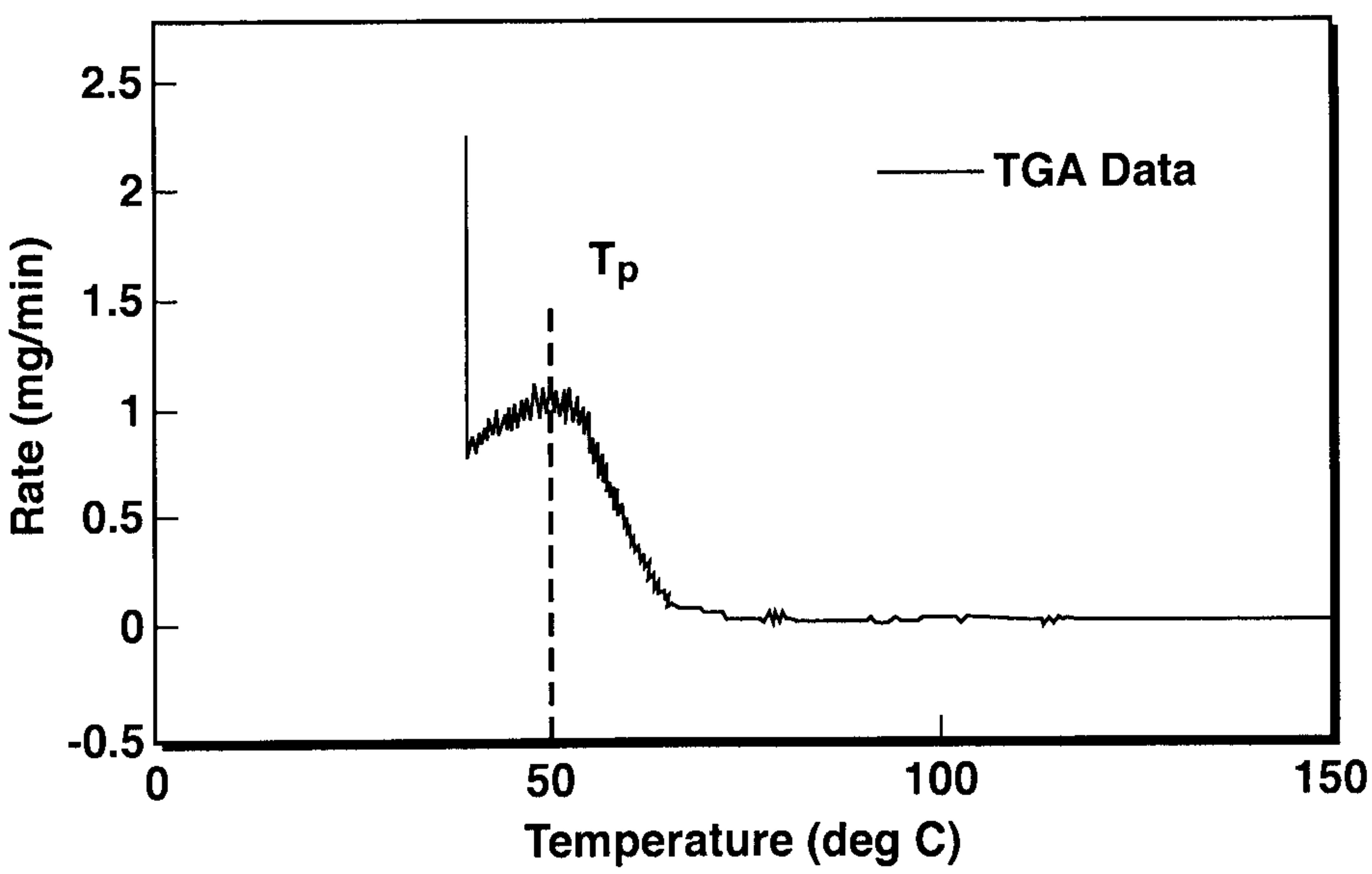
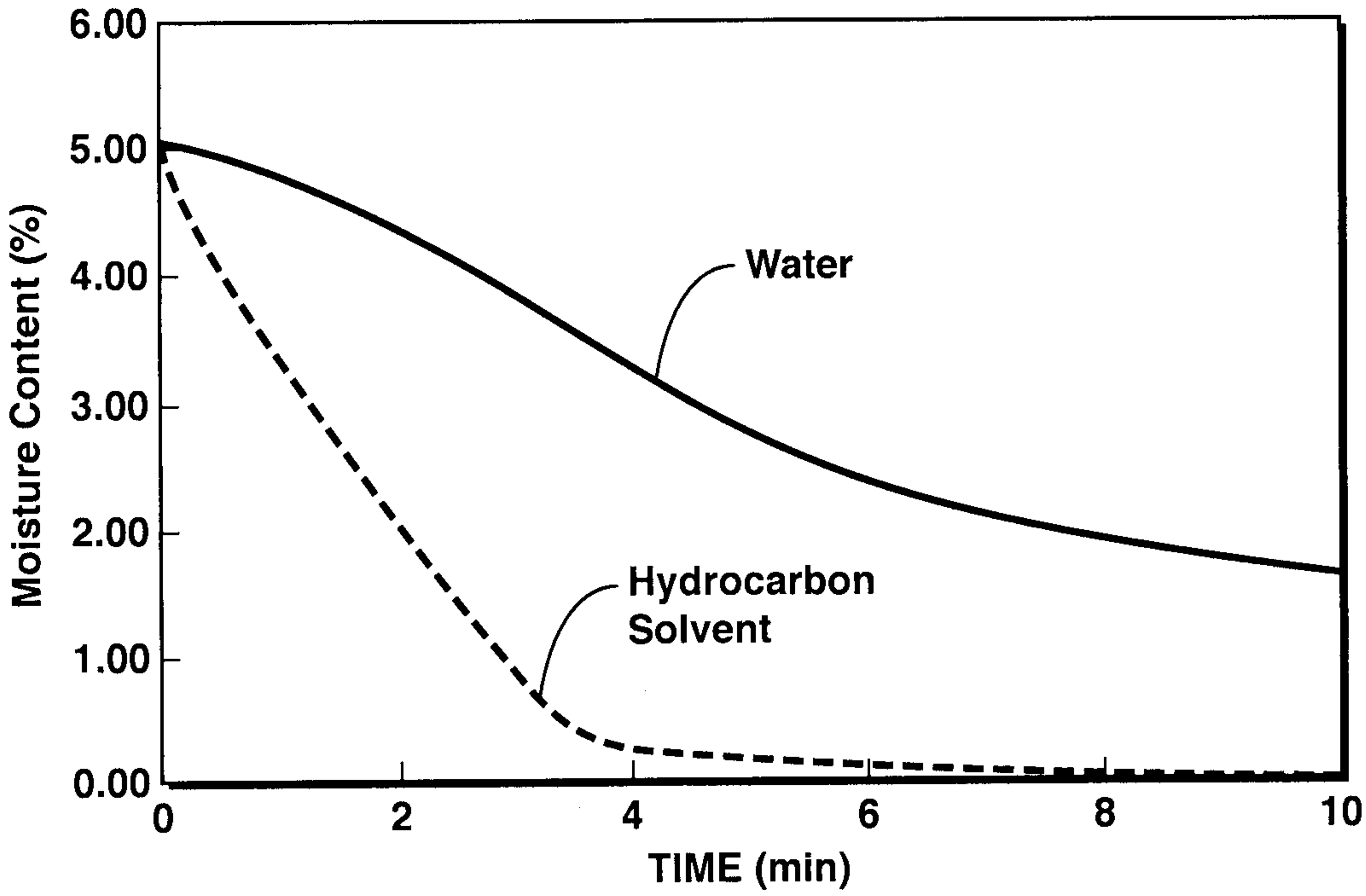


FIG. 104



6.00
5.00
4.00
3.00
2.00
1.00
0.00
Moisture Content (%)
Water
Hydrocarbon Solvent
0
2
4
6
8
10
TIME (min)

FIG. 105

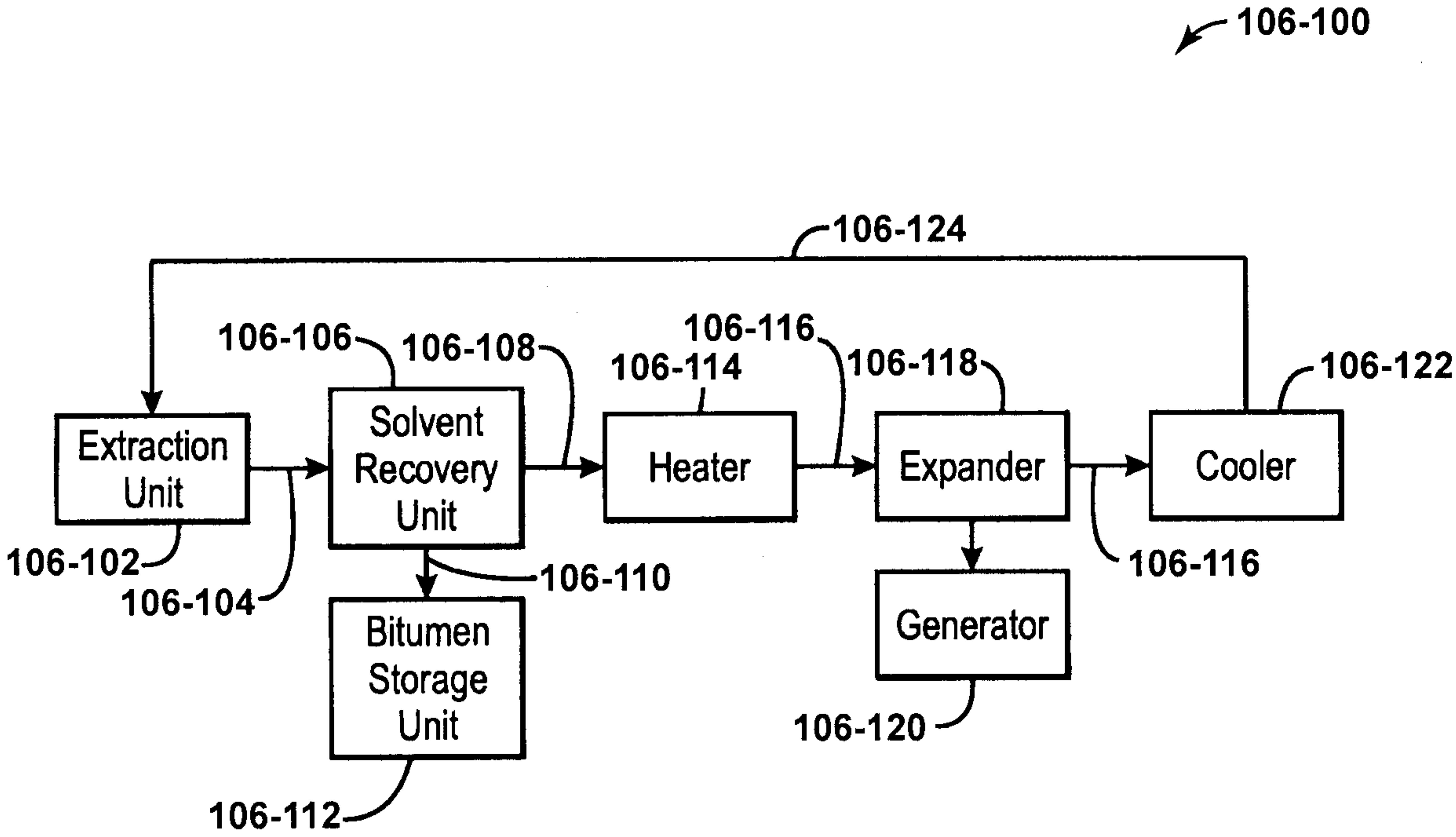

106-100
106-124
106-106
106-108
106-114
106-116
106-118
106-122
Extraction Unit
Solvent Recovery Unit
Heater
Expander
Cooler
106-102
106-104
106-110
106-116
Bitumen Storage Unit
Generator
106-120
106-112

FIG. 106

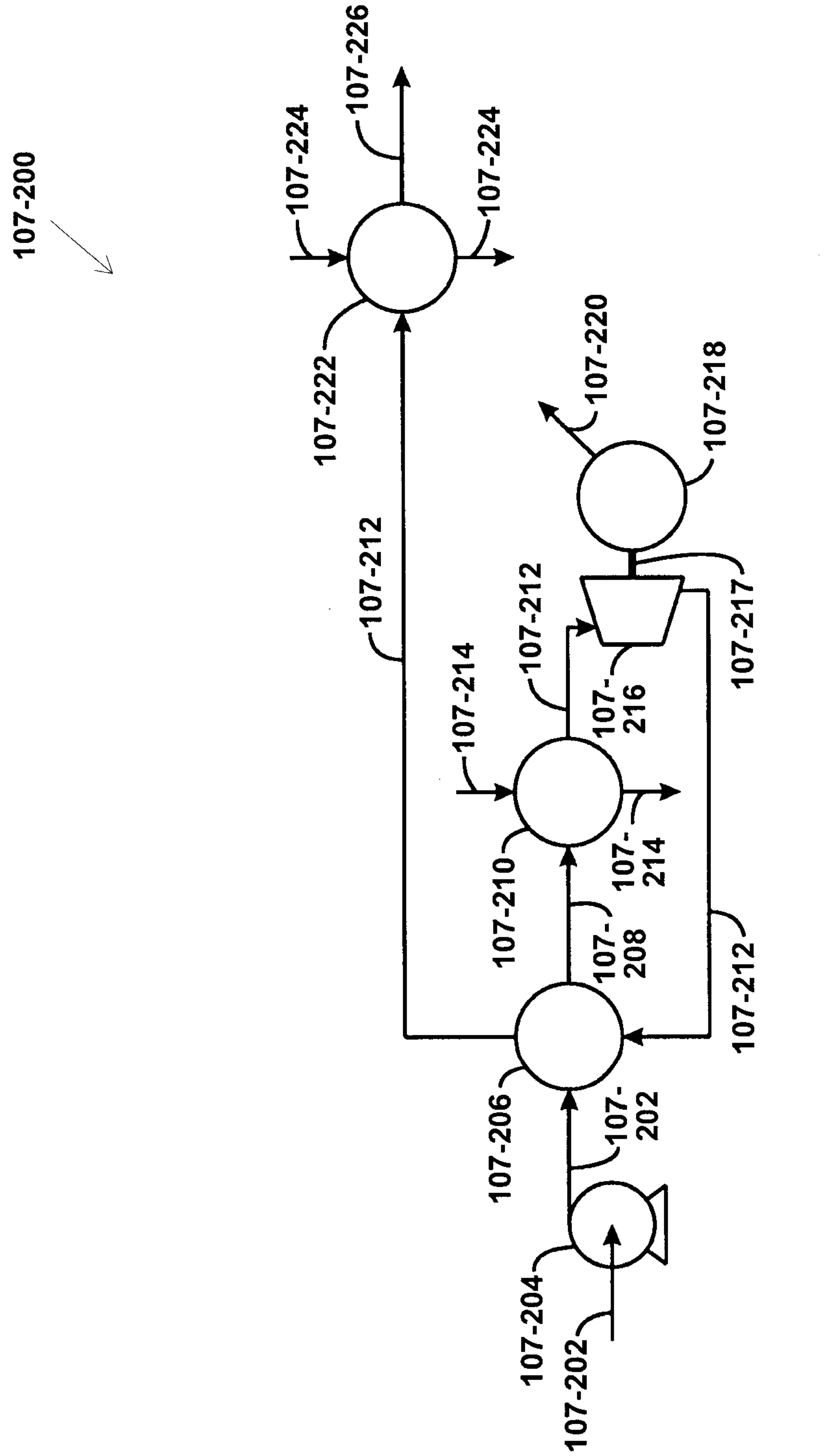

107-200
107-224
107-226
107-224
107-222
107-220
107-218
107-212
107-212
107-214
107-216
107-217
107-210
107-214
107-208
107-212
107-206
107-202
107-204
107-202

FIG. 107

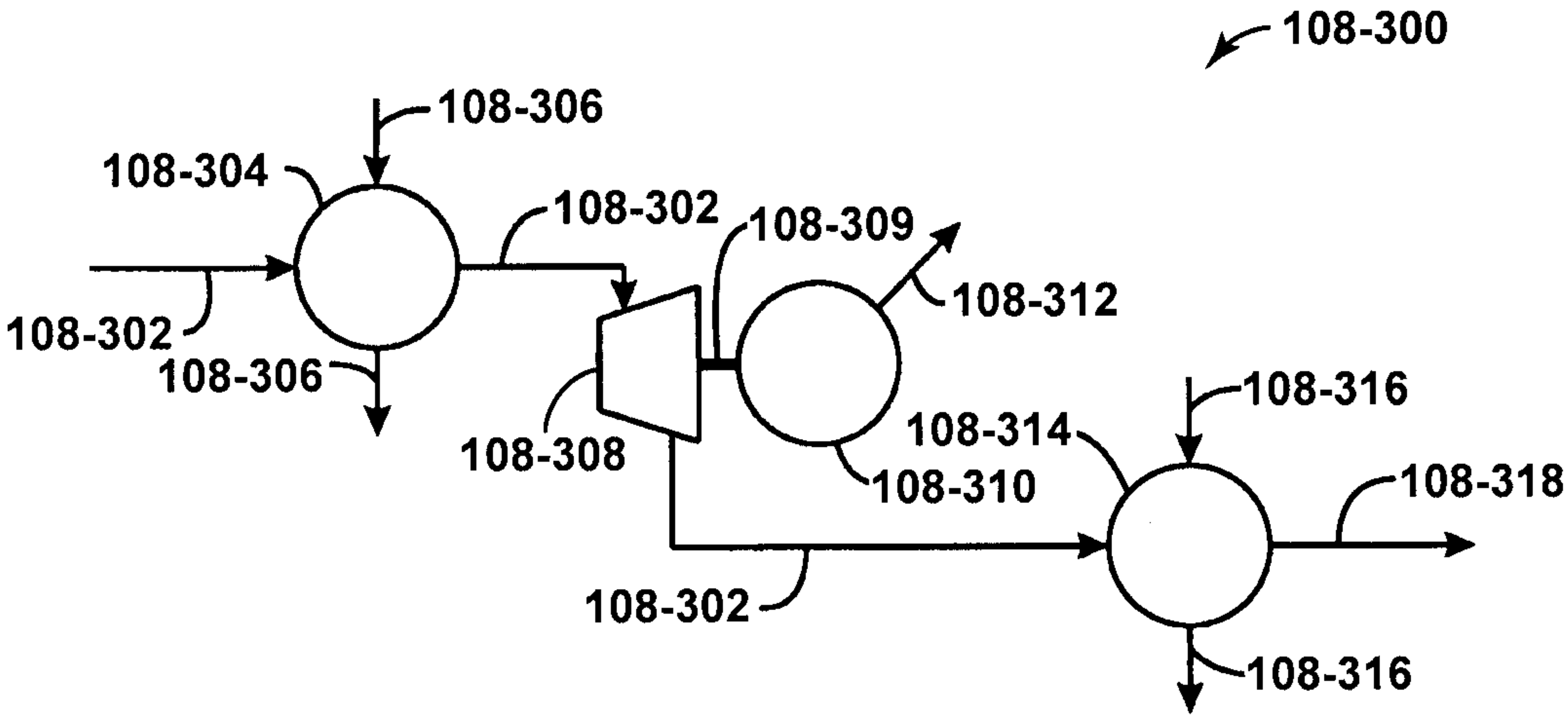

108-300
108-306
108-304
108-302
108-309
108-312
108-302
108-306
108-308
108-310
108-314
108-316
108-318
108-302
108-316

FIG. 108

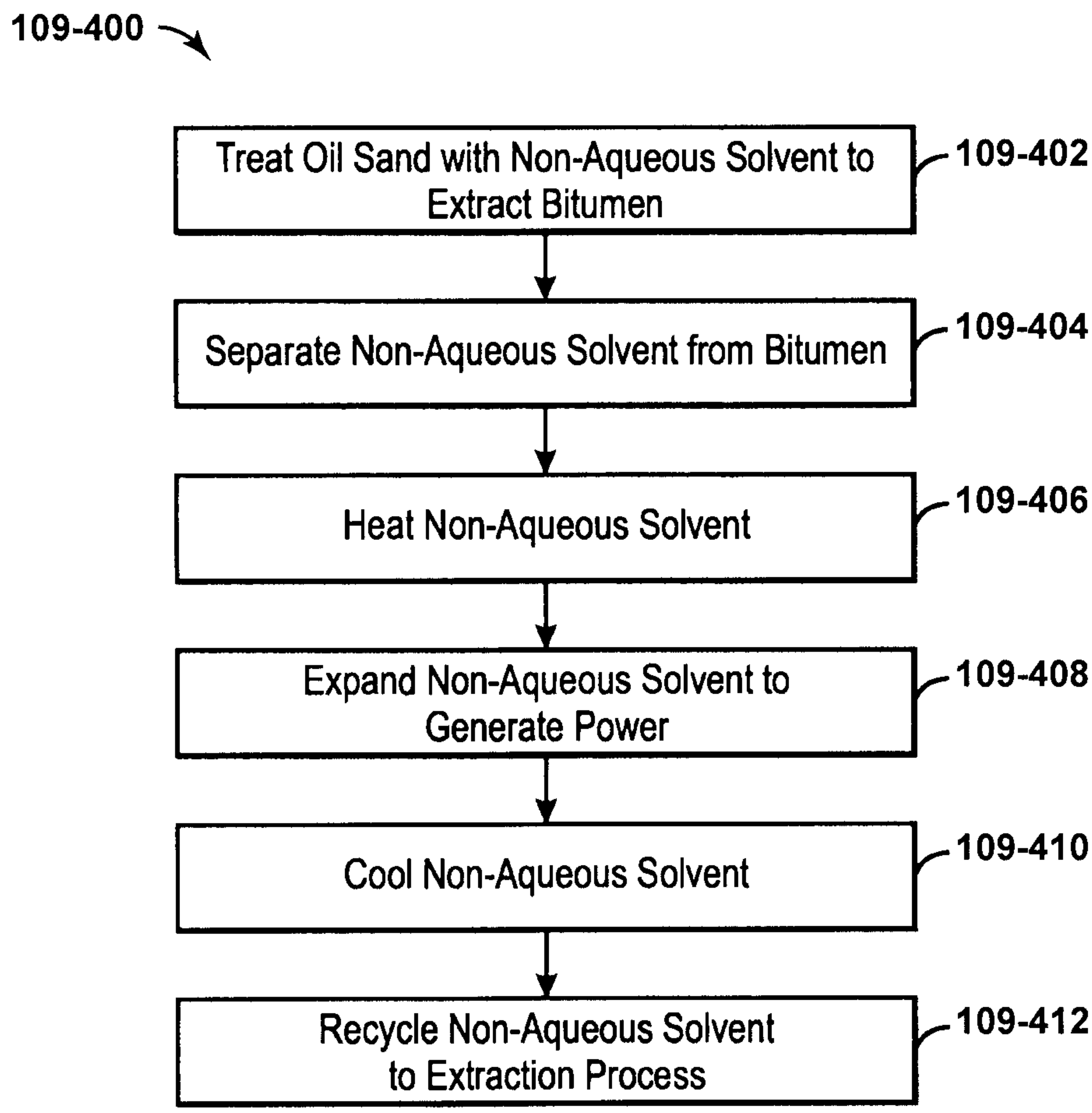

109-400
Treat Oil Sand with Non-Aqueous Solvent to Extract Bitumen
109-402
Separate Non-Aqueous Solvent from Bitumen
109-404
Heat Non-Aqueous Solvent
109-406
Expand Non-Aqueous Solvent to Generate Power
109-408
Cool Non-Aqueous Solvent
109-410
Recycle Non-Aqueous Solvent to Extraction Process
109-412

FIG. 109

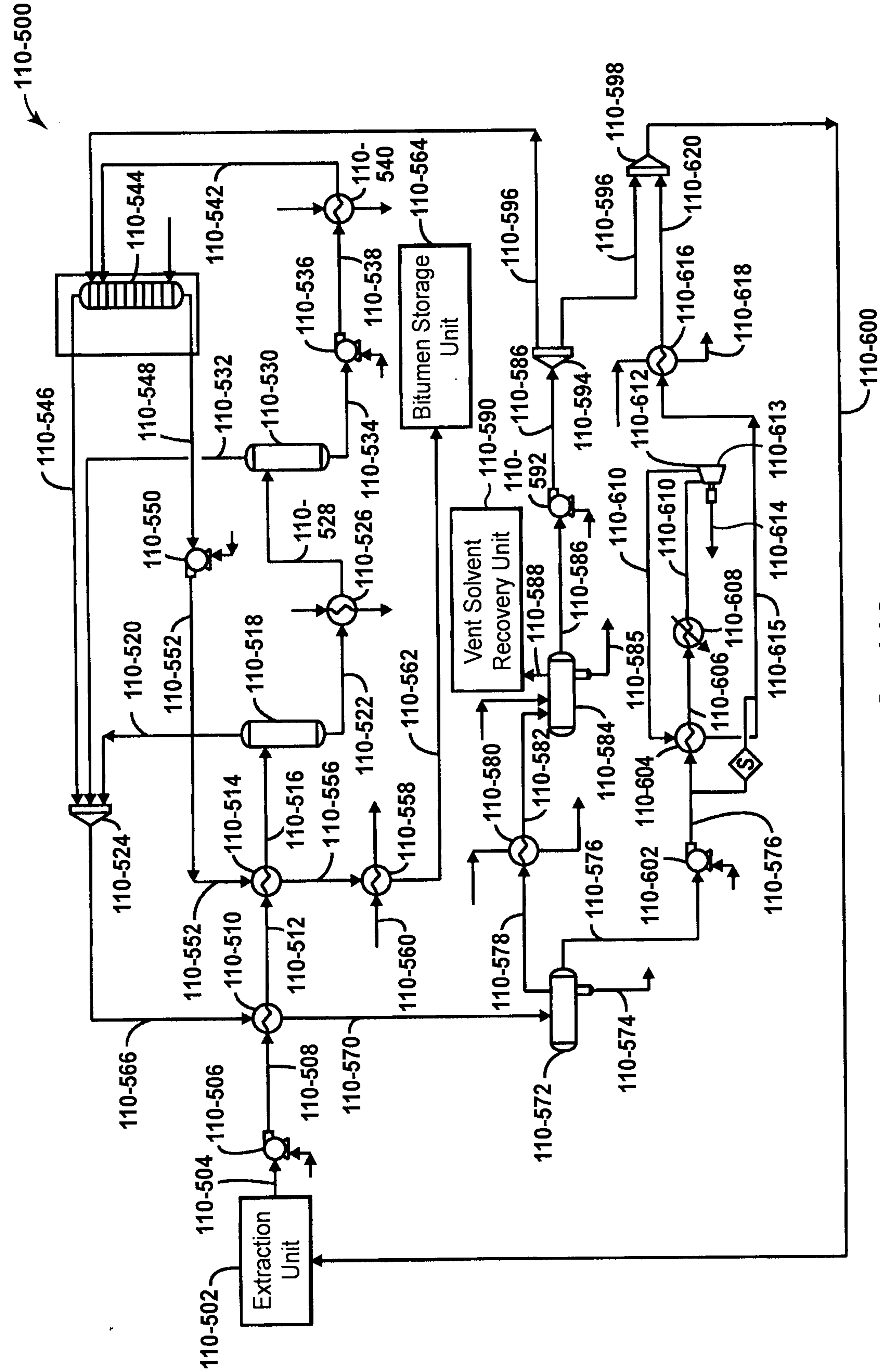

110-500
Extraction Unit
110-502
110-504
110-506
110-508
110-510
110-512
110-514
110-516
110-518
110-520
110-522
110-524
110-526
110-528
110-530
110-532
110-534
110-536
110-538
110-540
110-542
110-544
110-546
110-548
110-550
110-552
110-556
110-558
110-560
110-562
Bitumen Storage Unit
110-564
110-566
110-570
110-572
110-574
110-576
110-578
110-580
110-582
110-584
110-585
110-586
110-588
Vent Solvent Recovery Unit
110-590
110-592
110-594
110-596
110-598
110-600
110-602
110-604
110-606
110-608
110-610
110-612
110-613
110-614
110-615
110-616
110-618
110-620
S

FIG. 110

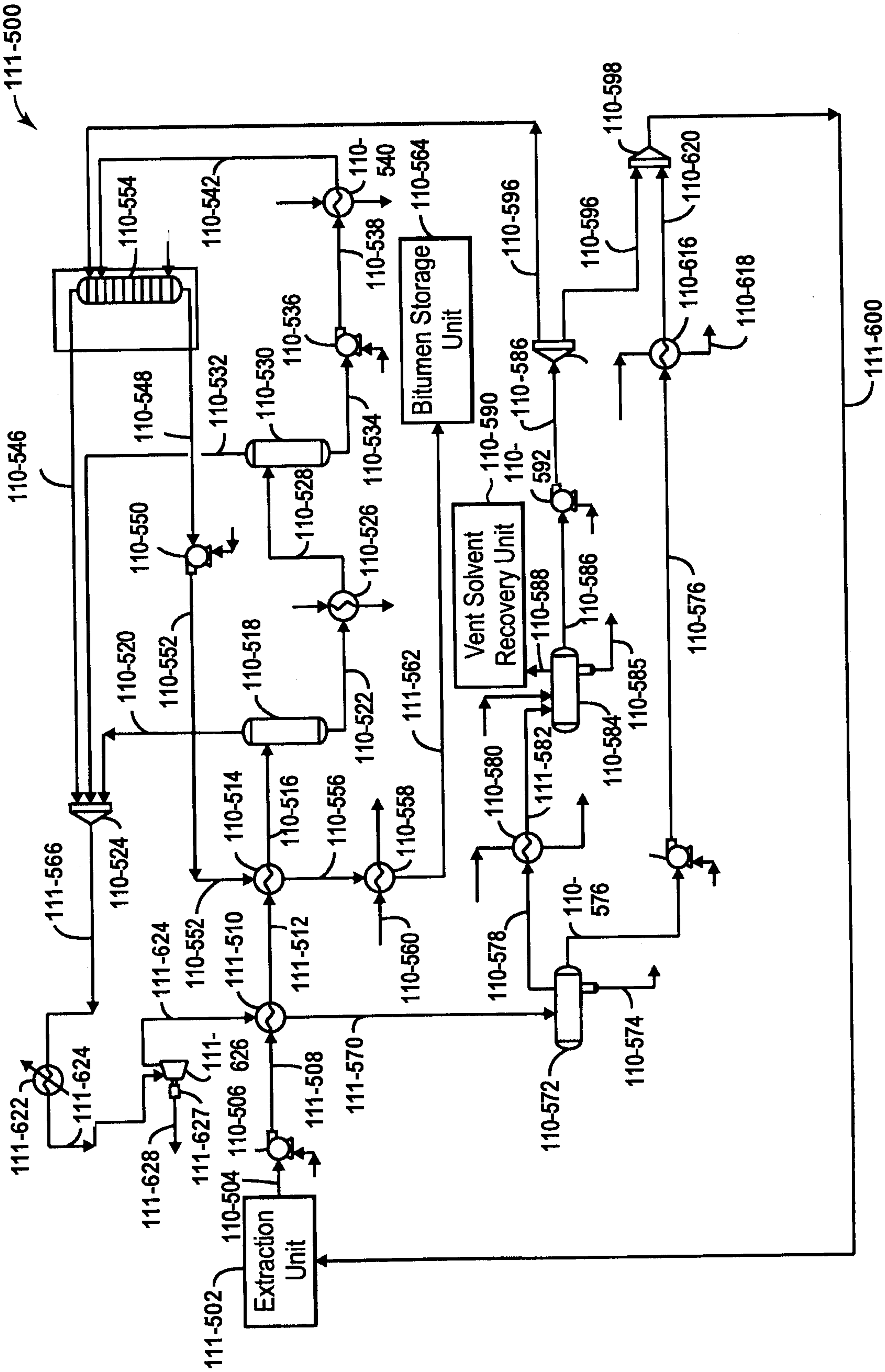

111-500
Extraction Unit
111-502
Bitumen Storage Unit
110-564
Vent Solvent Recovery Unit
110-590
110-504
110-506
111-508
111-510
111-512
110-514
110-516
110-518
110-520
110-522
110-524
110-526
110-528
110-530
110-532
110-534
110-536
110-538
110-540
110-542
110-546
110-548
110-550
110-552
110-554
110-556
110-558
110-560
111-562
111-566
111-570
110-572
110-574
110-576
110-578
110-580
111-582
110-584
110-585
110-586
110-588
110-592
110-596
110-598
111-600
110-616
110-618
110-620
111-622
111-624
111-626
111-627
111-628

FIG. 111

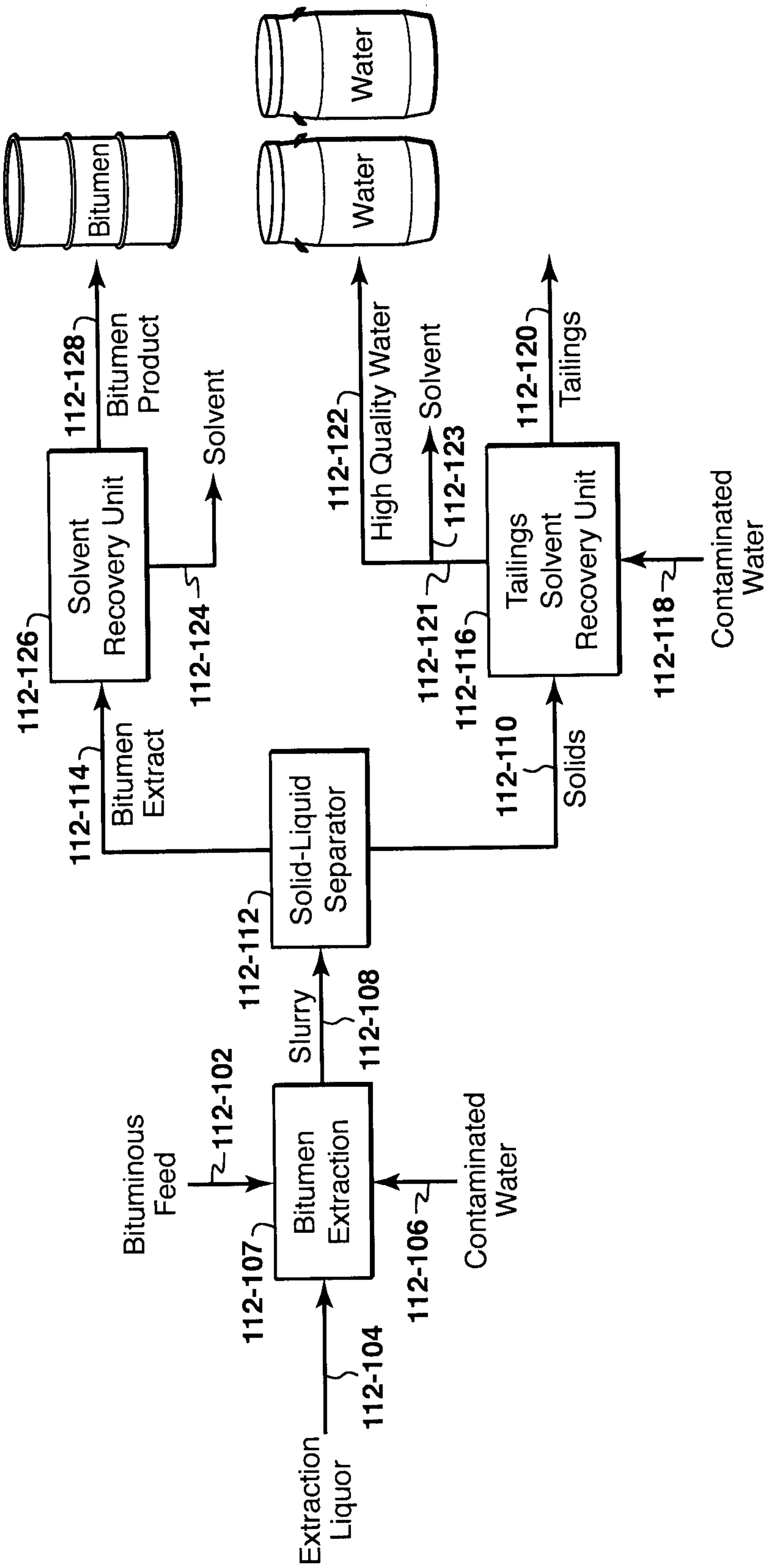

Extraction Liquor
112-104
Bituminous Feed
112-102
Bitumen Extraction
112-107
Contaminated Water
112-106
Slurry
112-108
Solid-Liquid Separator
112-112
Bitumen Extract
112-114
Solids
112-110
Solvent Recovery Unit
112-126
112-124
Solvent
Bitumen Product
112-128
Bitumen
Tailings Solvent Recovery Unit
112-116
112-121
Contaminated Water
112-118
High Quality Water
112-122
Solvent
112-123
Tailings
112-120
Water
Water

FIG. 112

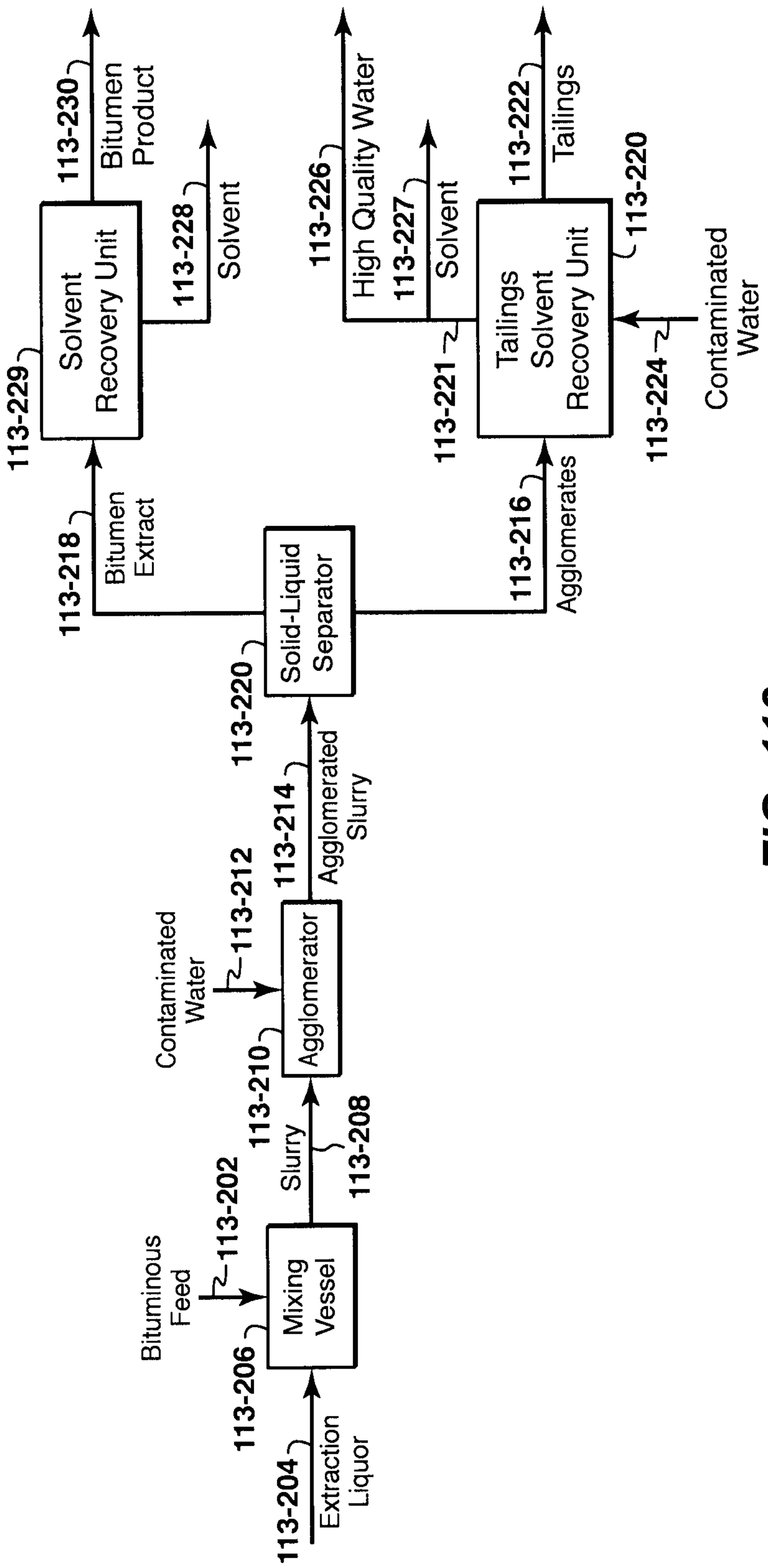

Extraction Liquor
113-204
113-206
Bituminous Feed
113-202
Mixing Vessel
Slurry
113-208
113-210
Agglomerator
Contaminated Water
113-212
113-214
Agglomerated Slurry
113-220
Solid-Liquid Separator
113-218
Bitumen Extract
113-216
Agglomerates
113-229
Solvent Recovery Unit
113-228
Solvent
113-230
Bitumen Product
113-221
Tailings Solvent Recovery Unit
113-220
113-224
Contaminated Water
113-226
High Quality Water
113-227
Solvent
113-222
Tailings

FIG. 113

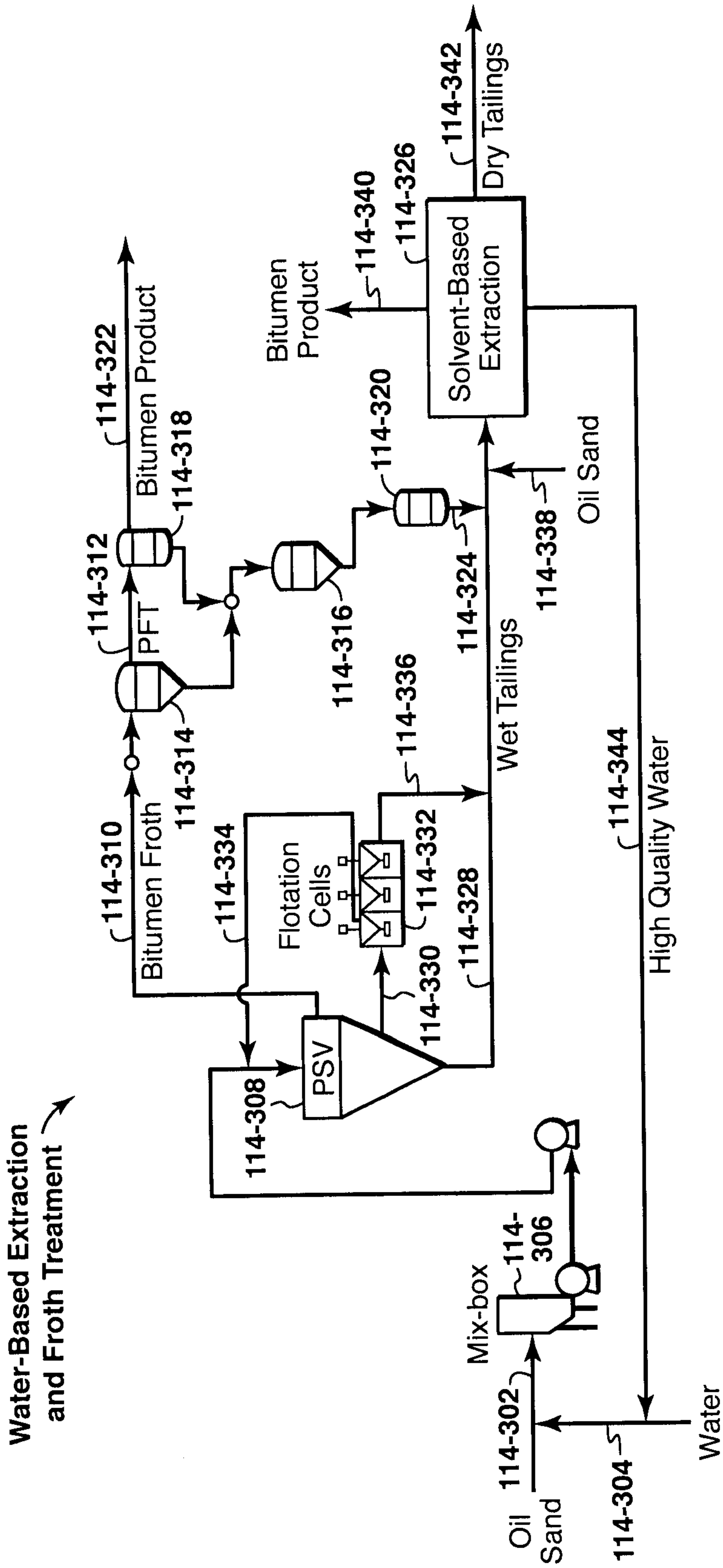
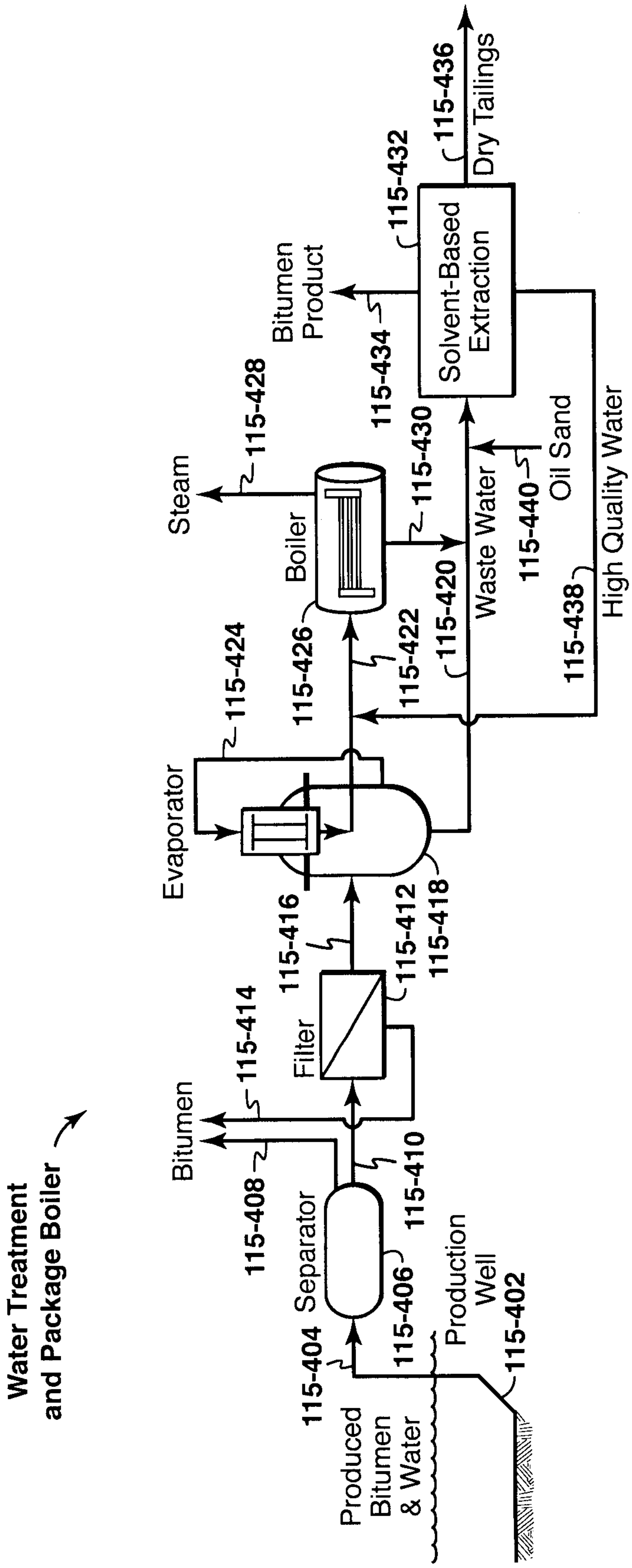

Water-Based Extraction and Froth Treatment
Oil Sand
114-302
Water
114-304
Mix-box
114-306
114-308
PSV
Bitumen Froth
114-310
114-334
114-314
PFT
114-312
114-318
Bitumen Product
114-322
114-316
114-320
114-324
Flotation Cells
114-330
114-332
114-328
114-336
Wet Tailings
Oil Sand
114-338
Solvent-Based Extraction
114-326
Bitumen Product
114-340
Dry Tailings
114-342
High Quality Water
114-344

FIG. 114



Water Treatment
and Package Boiler
Produced
Bitumen
& Water
115-404
Production
Well
115-402
Separator
115-406
115-408
Bitumen
115-410
115-414
Filter
115-412
115-416
115-418
Evaporator
115-424
115-426
115-422
Boiler
Steam
115-428
115-420
Waste Water
115-430
115-440
Oil Sand
115-438
High Quality Water
115-434
Bitumen
Product
Solvent-Based
Extraction
115-432
115-436
Dry Tailings

FIG. 115

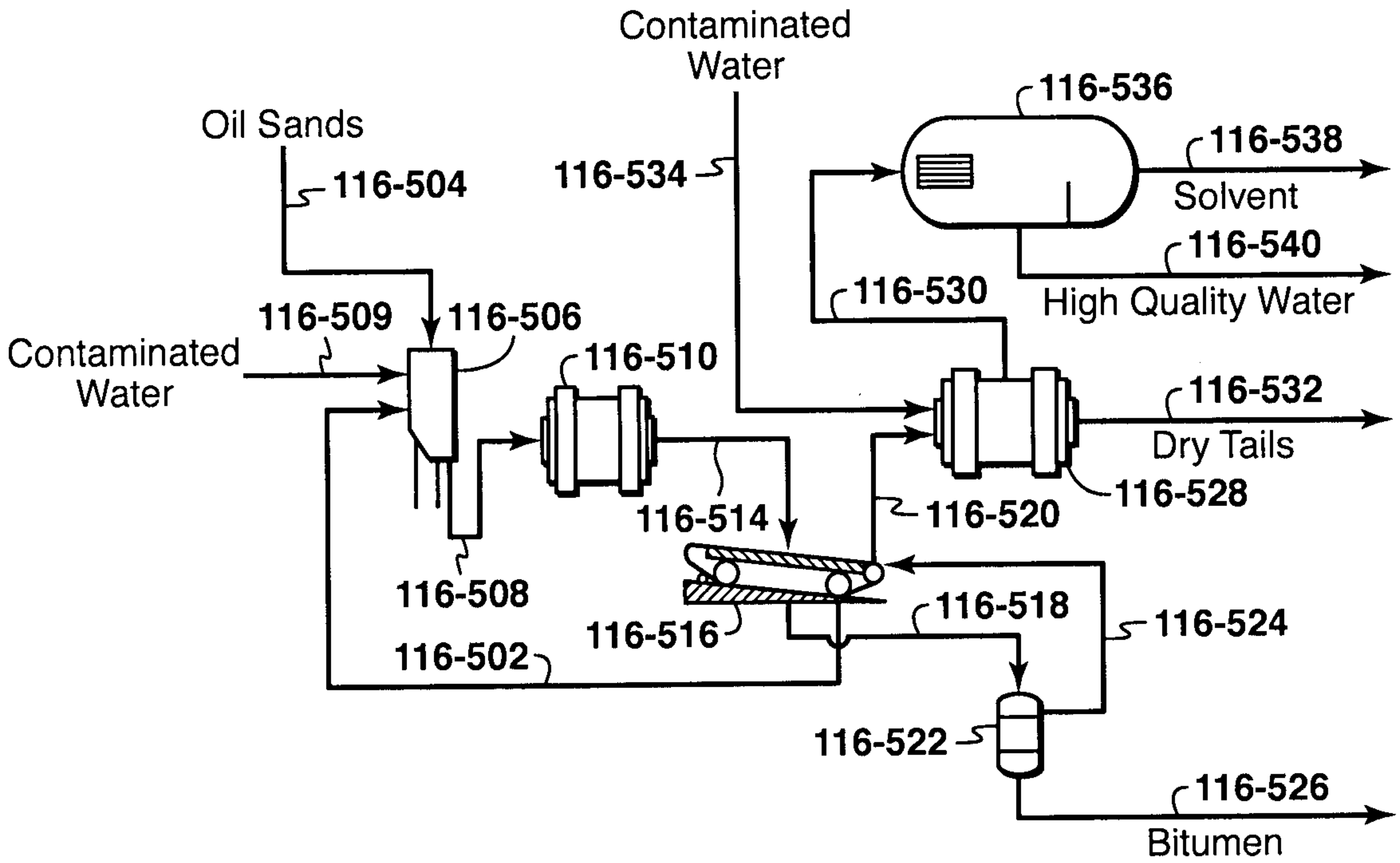

Contaminated Water
Oil Sands
116-504
116-534
116-536
116-538
Solvent
116-540
High Quality Water
116-530
116-509
116-506
Contaminated Water
116-510
116-532
Dry Tails
116-528
116-514
116-520
116-508
116-518
116-524
116-516
116-502
116-522
116-526
Bitumen

FIG. 116

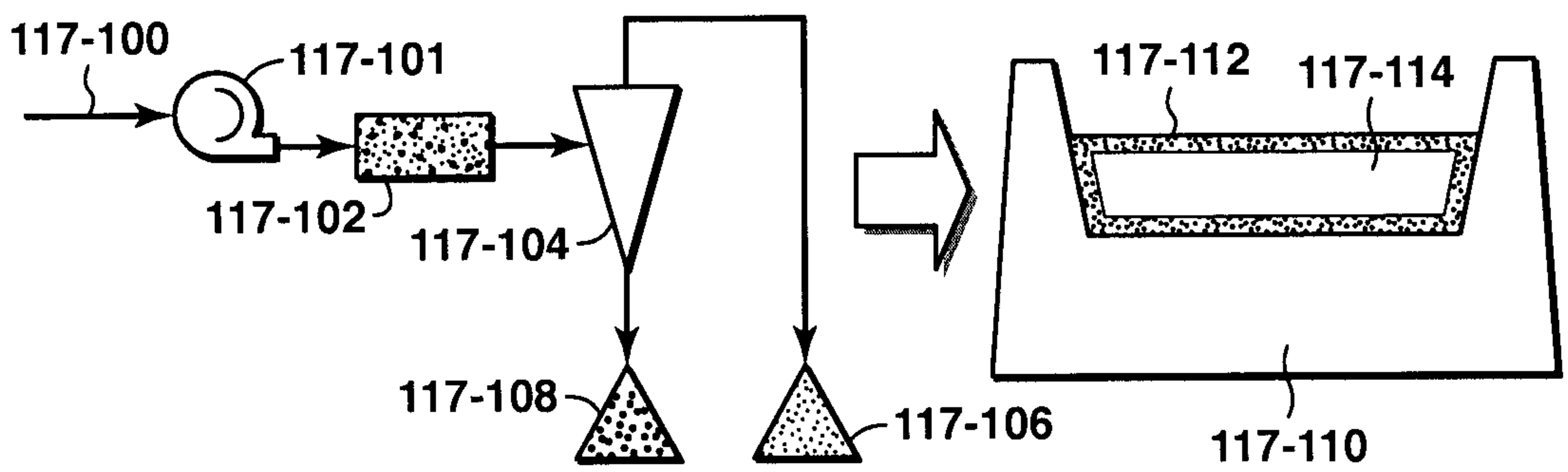


FIG. 117

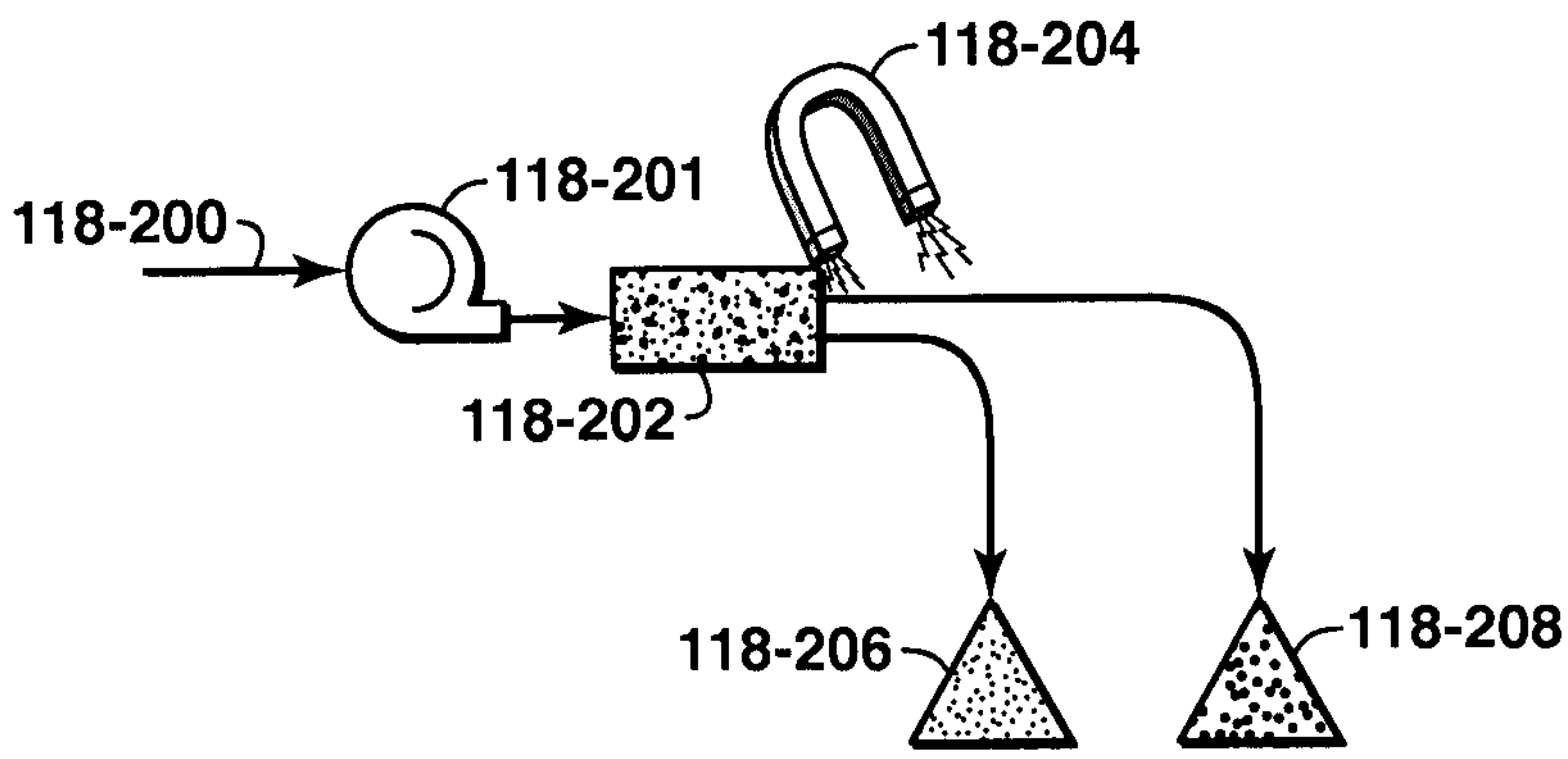


FIG. 118

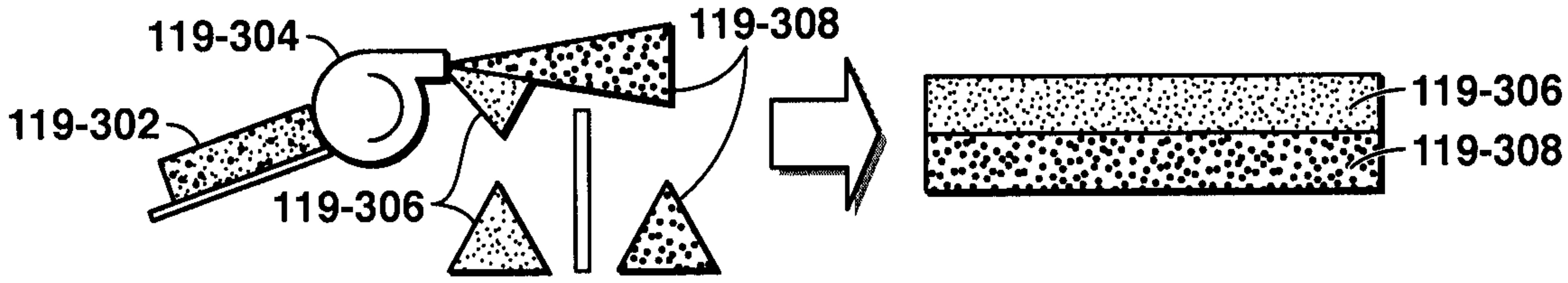


FIG. 119

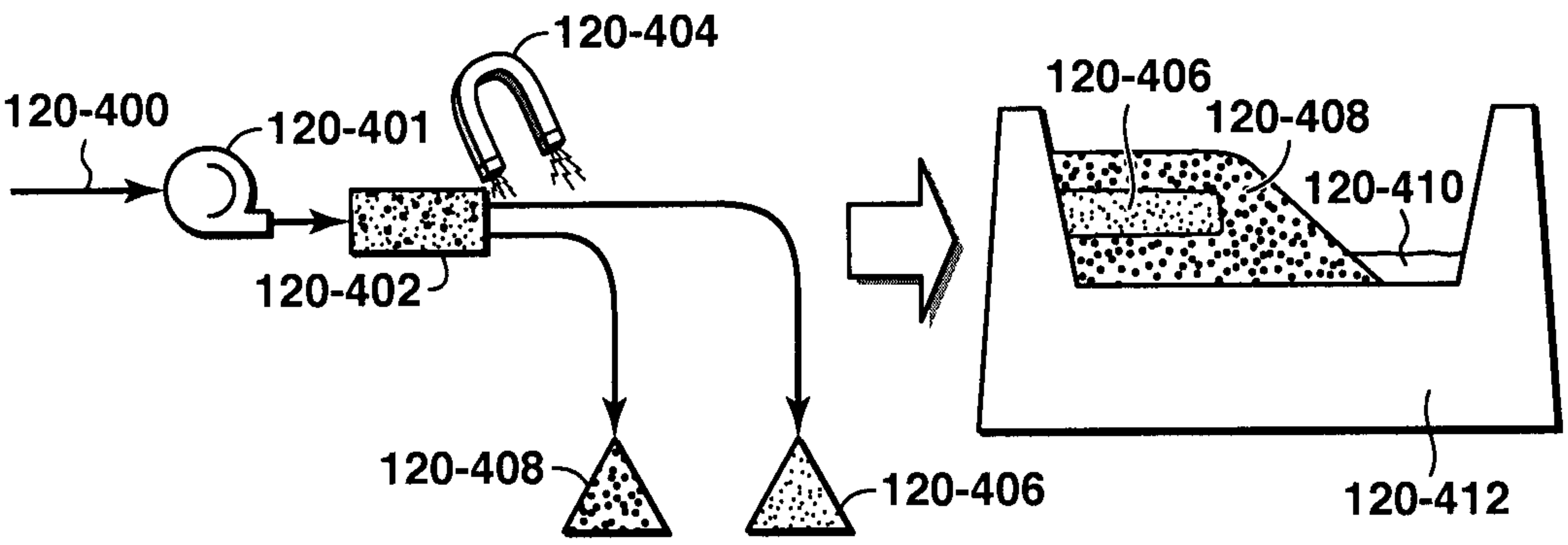


FIG. 120

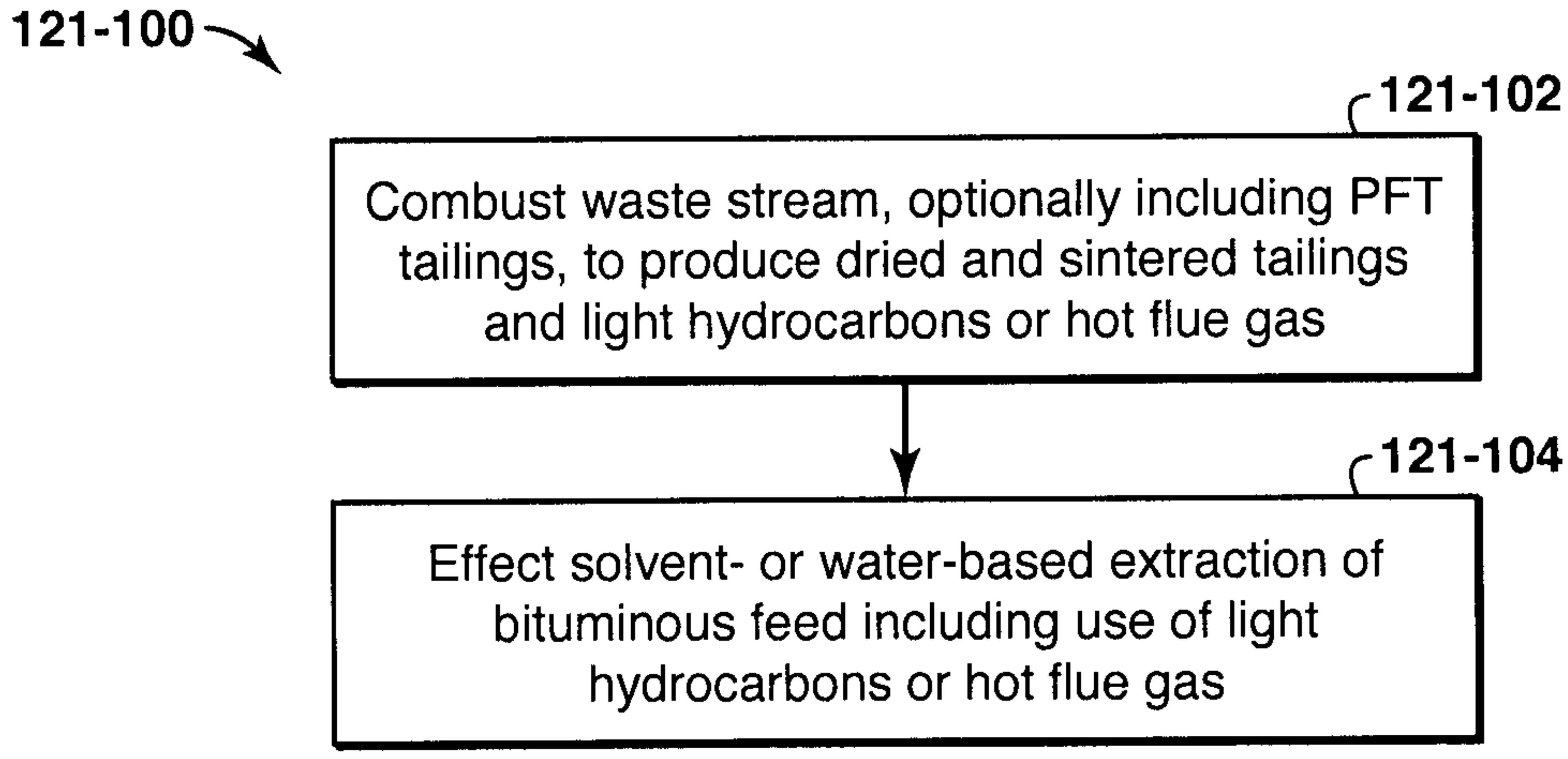


FIG. 121

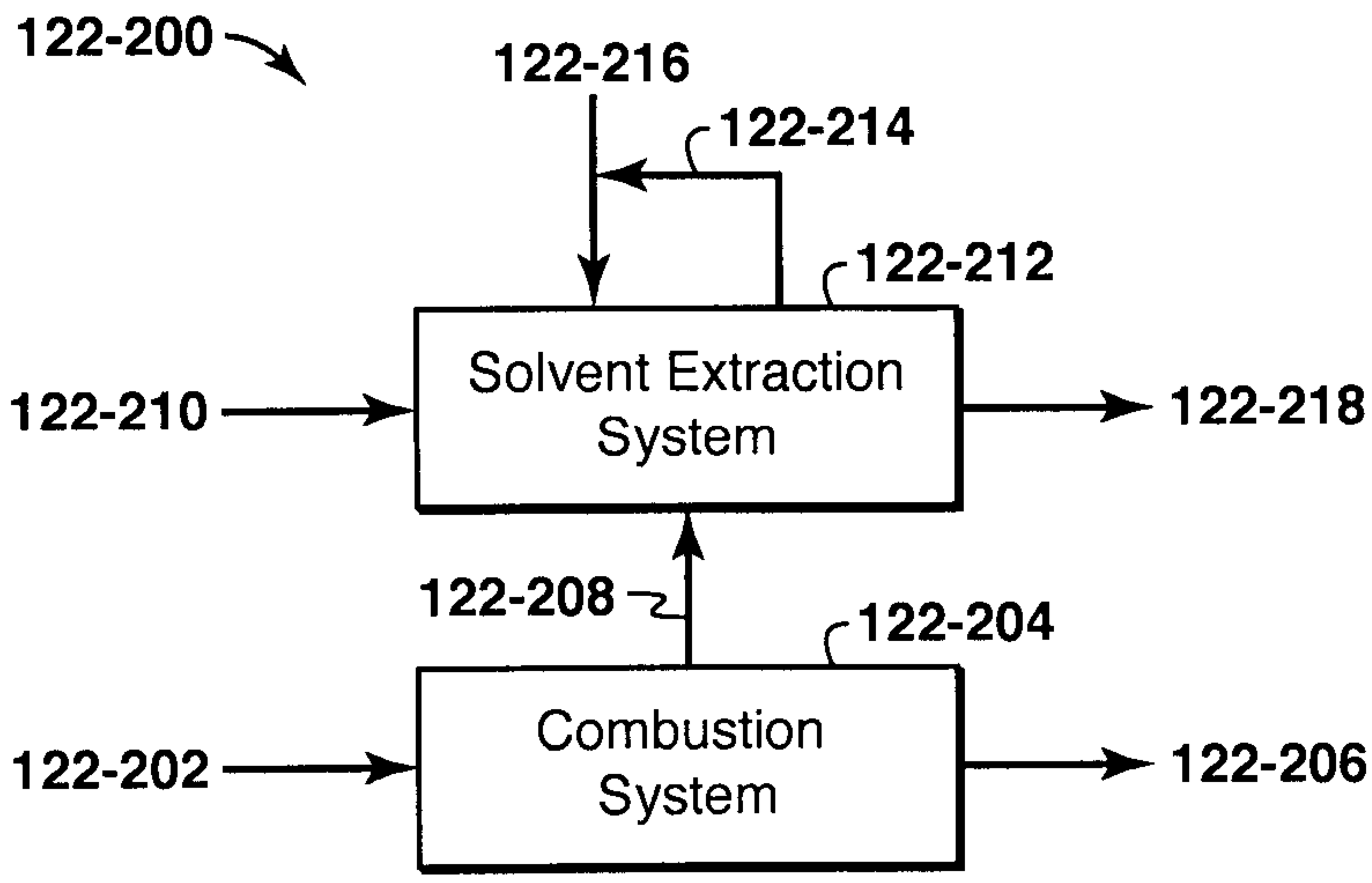


FIG. 122

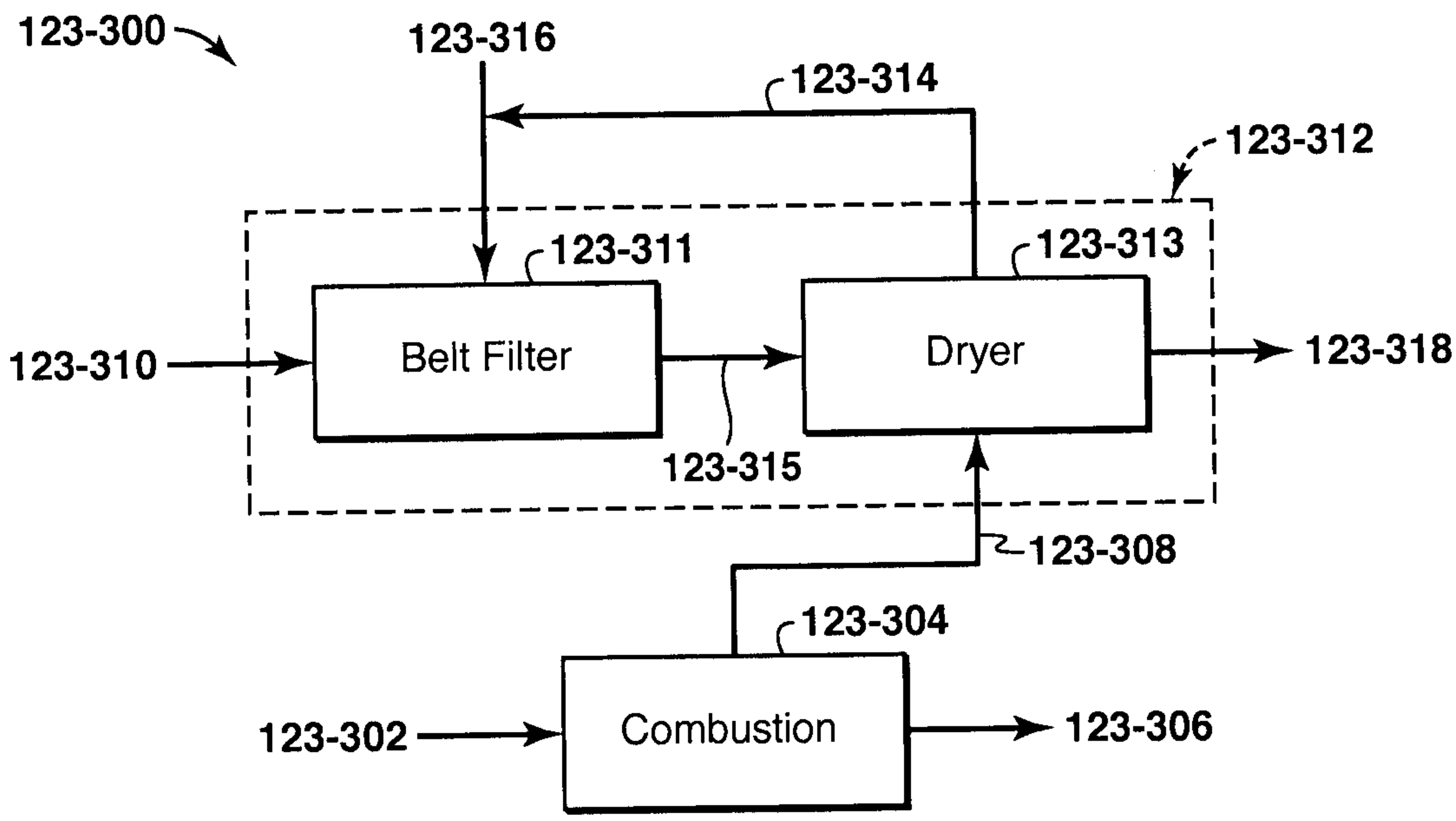

123-300
123-316
123-314
123-312
123-311
123-313
123-310
Belt Filter
Dryer
123-318
123-315
123-308
123-304
123-302
Combustion
123-306

FIG. 123

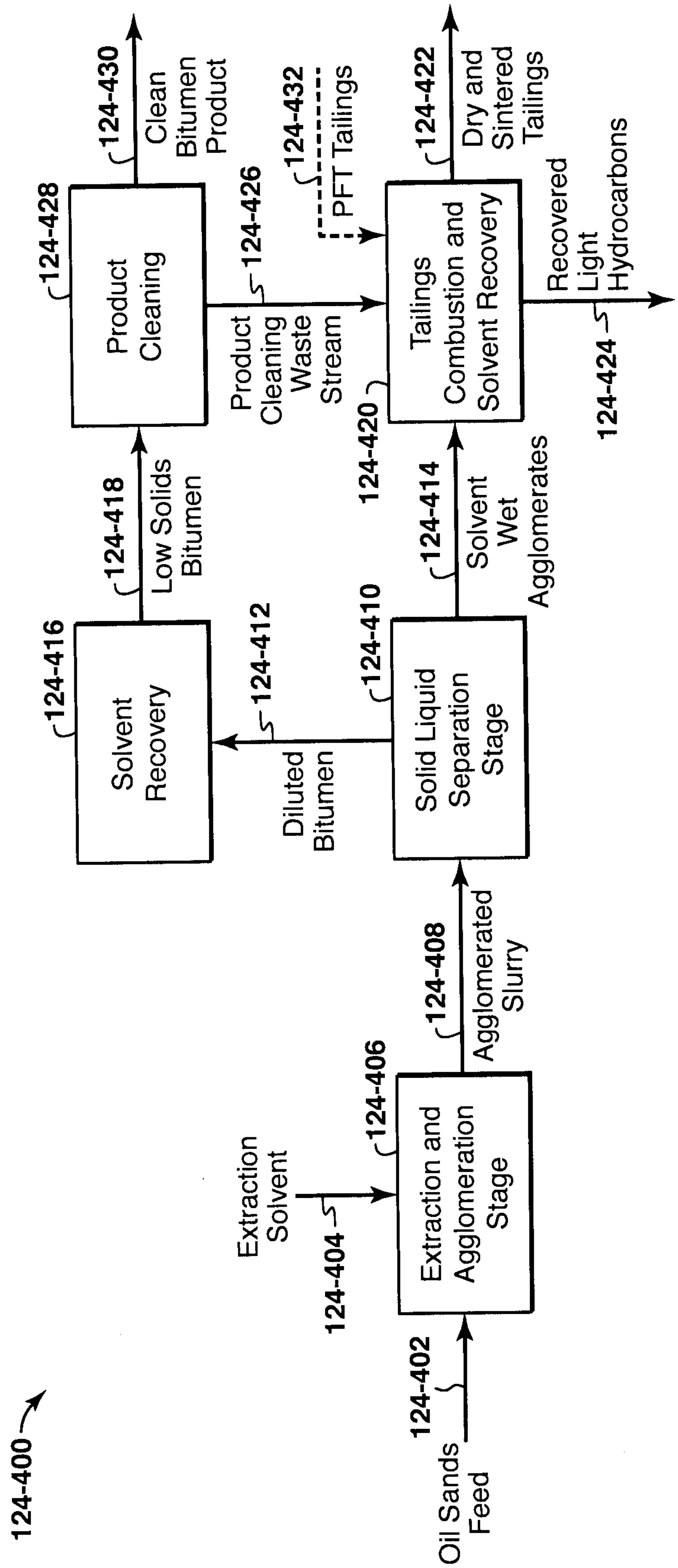
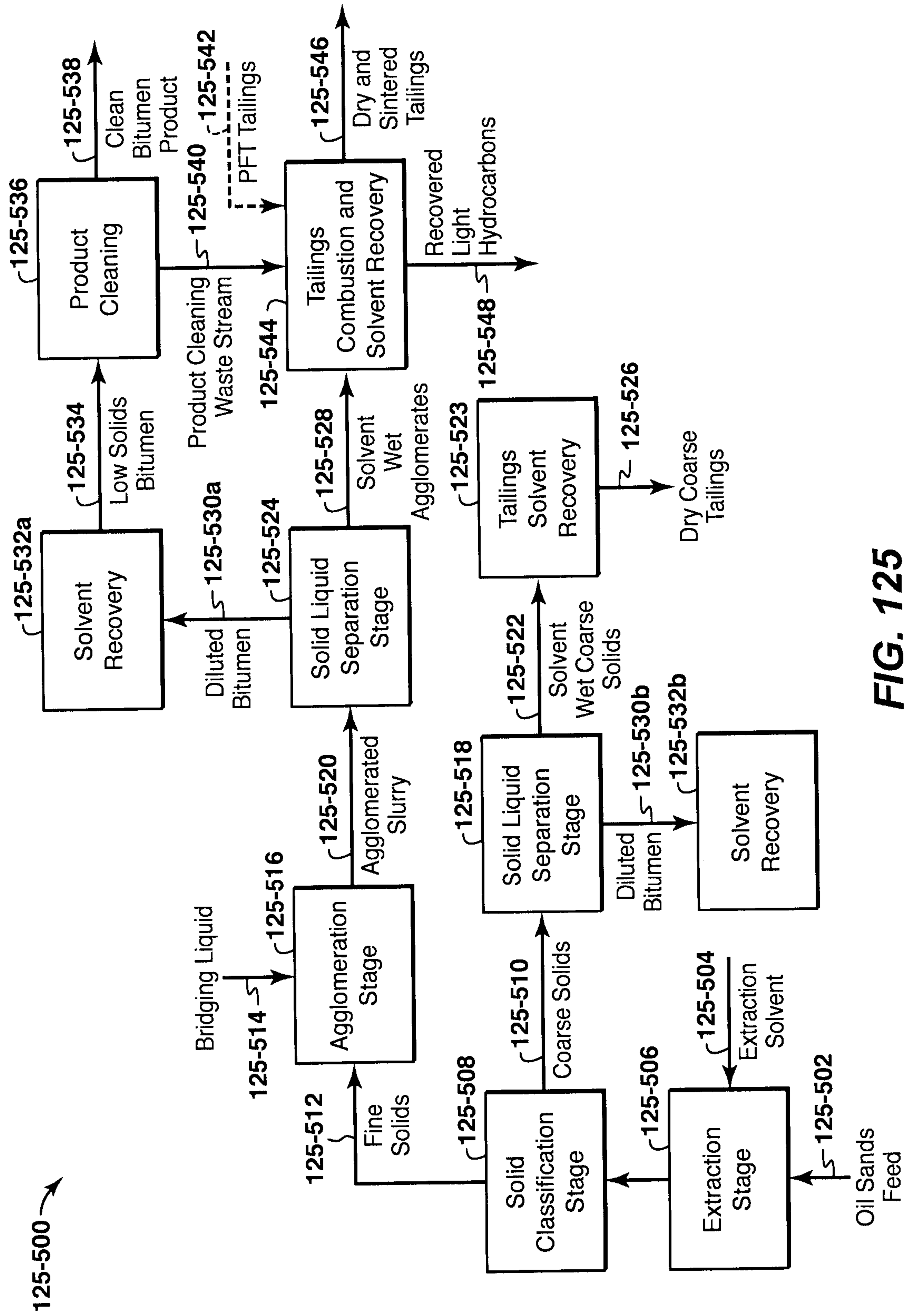

124-400
Oil Sands Feed
124-402
Extraction Solvent
124-404
Extraction and Agglomeration Stage
124-406
124-408
Agglomerated Slurry
Solid Liquid Separation Stage
124-410
Diluted Bitumen
124-412
Solvent Recovery
124-416
124-418
Low Solids Bitumen
124-414
Solvent Wet Agglomerates
Product Cleaning
124-428
124-430
Clean Bitumen Product
124-426
Product Cleaning Waste Stream
124-432
PFT Tailings
Tailings Combustion and Solvent Recovery
124-420
124-422
Dry and Sintered Tailings
124-424
Recovered Light Hydrocarbons

FIG. 124



125-500
Oil Sands Feed
125-502
Extraction Stage
125-504
Extraction Solvent
125-506
Solid Classification Stage
125-508
125-510
Coarse Solids
Fine Solids
125-512
Bridging Liquid
125-514
125-516
Agglomeration Stage
125-520
Agglomerated Slurry
Solid Liquid Separation Stage
125-524
Diluted Bitumen
125-530a
Solvent Recovery
125-532a
125-534
Low Solids Bitumen
Product Cleaning
125-536
125-538
Clean Bitumen Product
Product Cleaning Waste Stream
125-540
125-542
PFT Tailings
125-528
Solvent Wet Agglomerates
Tailings Combustion and Solvent Recovery
125-544
125-546
Dry and Sintered Tailings
125-548
Recovered Light Hydrocarbons
Solid Liquid Separation Stage
125-518
125-522
Solvent Wet Coarse Solids
Tailings Solvent Recovery
125-523
125-526
Dry Coarse Tailings
Diluted Bitumen
125-530b
Solvent Recovery
125-532b

FIG. 125

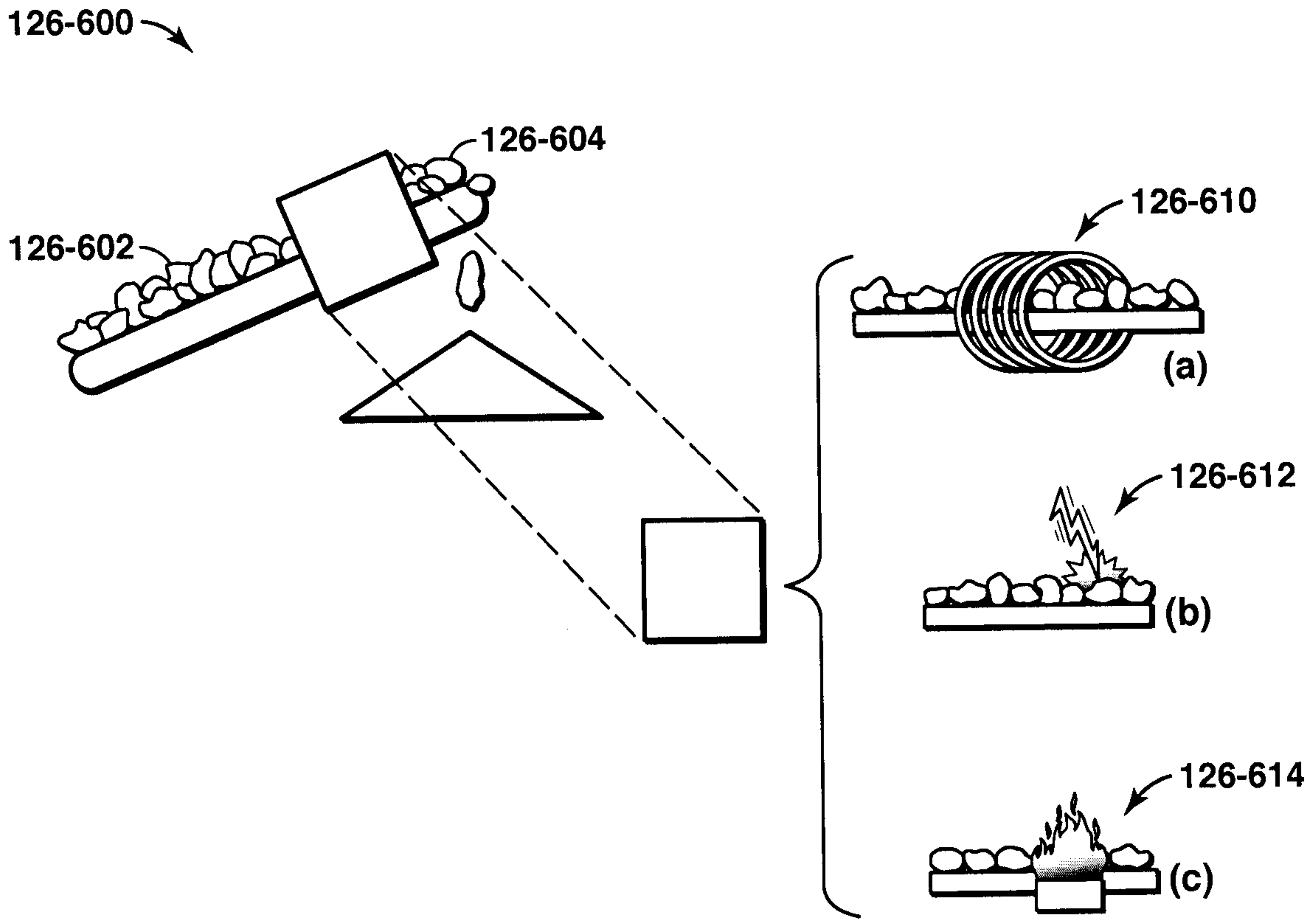


FIG. 126

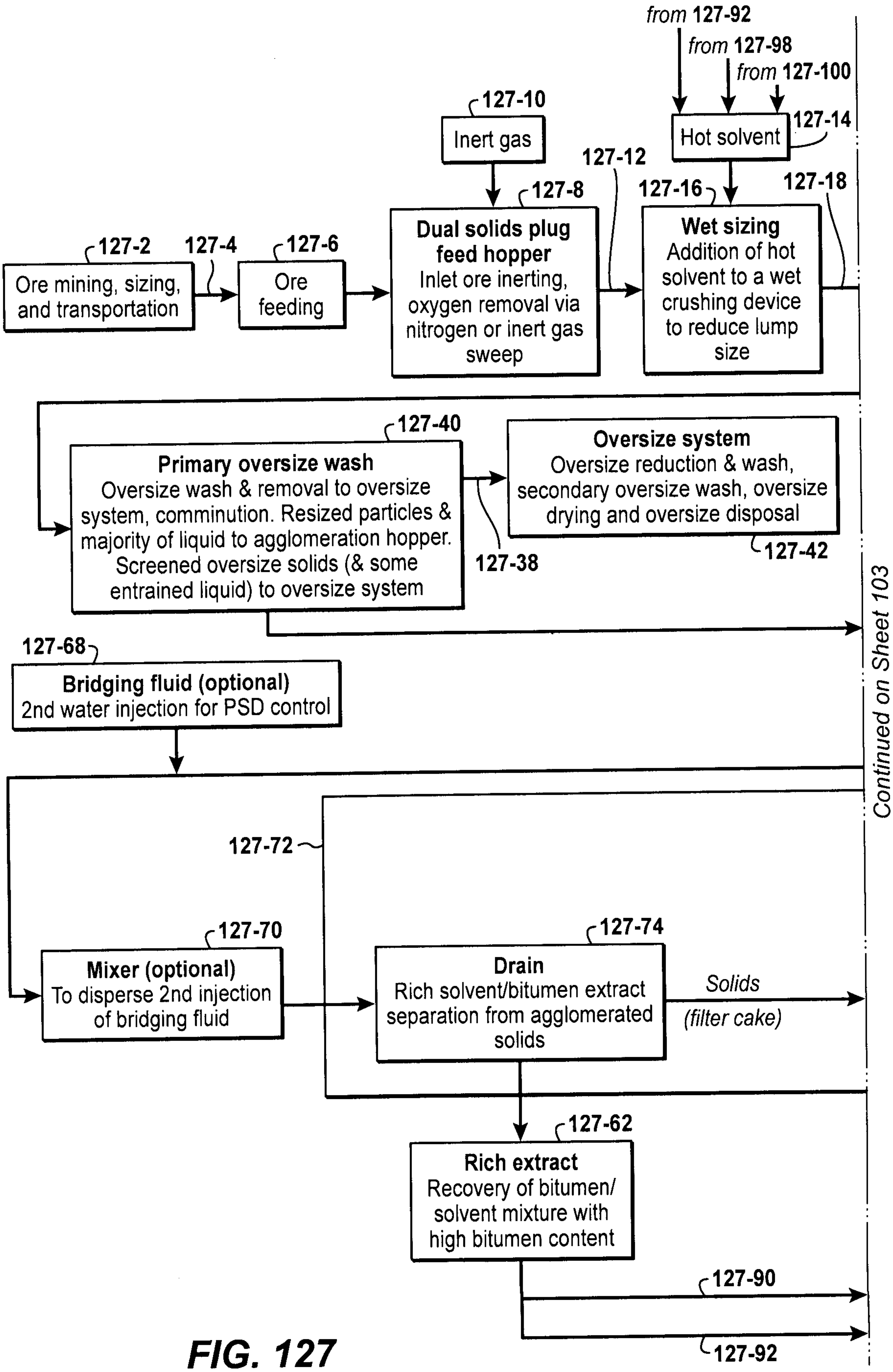

from 127-92
from 127-98
from 127-100
127-10
Inert gas
127-14
Hot solvent
127-12
127-8
127-16
127-18
127-2
127-4
127-6
Ore mining, sizing, and transportation
Ore feeding
Dual solids plug feed hopper
Inlet ore inerting, oxygen removal via nitrogen or inert gas sweep
Wet sizing
Addition of hot solvent to a wet crushing device to reduce lump size
127-40
Primary oversize wash
Oversize wash & removal to oversize system, comminution. Resized particles & majority of liquid to agglomeration hopper. Screened oversize solids (& some entrained liquid) to oversize system
Oversize system
Oversize reduction & wash, secondary oversize wash, oversize drying and oversize disposal
127-38
127-42
127-68
Bridging fluid (optional)
2nd water injection for PSD control
Continued on Sheet 103
127-72
127-70
Mixer (optional)
To disperse 2nd injection of bridging fluid
127-74
Drain
Rich solvent/bitumen extract separation from agglomerated solids
Solids
(filter cake)
127-62
Rich extract
Recovery of bitumen/ solvent mixture with high bitumen content
127-90
127-92

FIG. 127

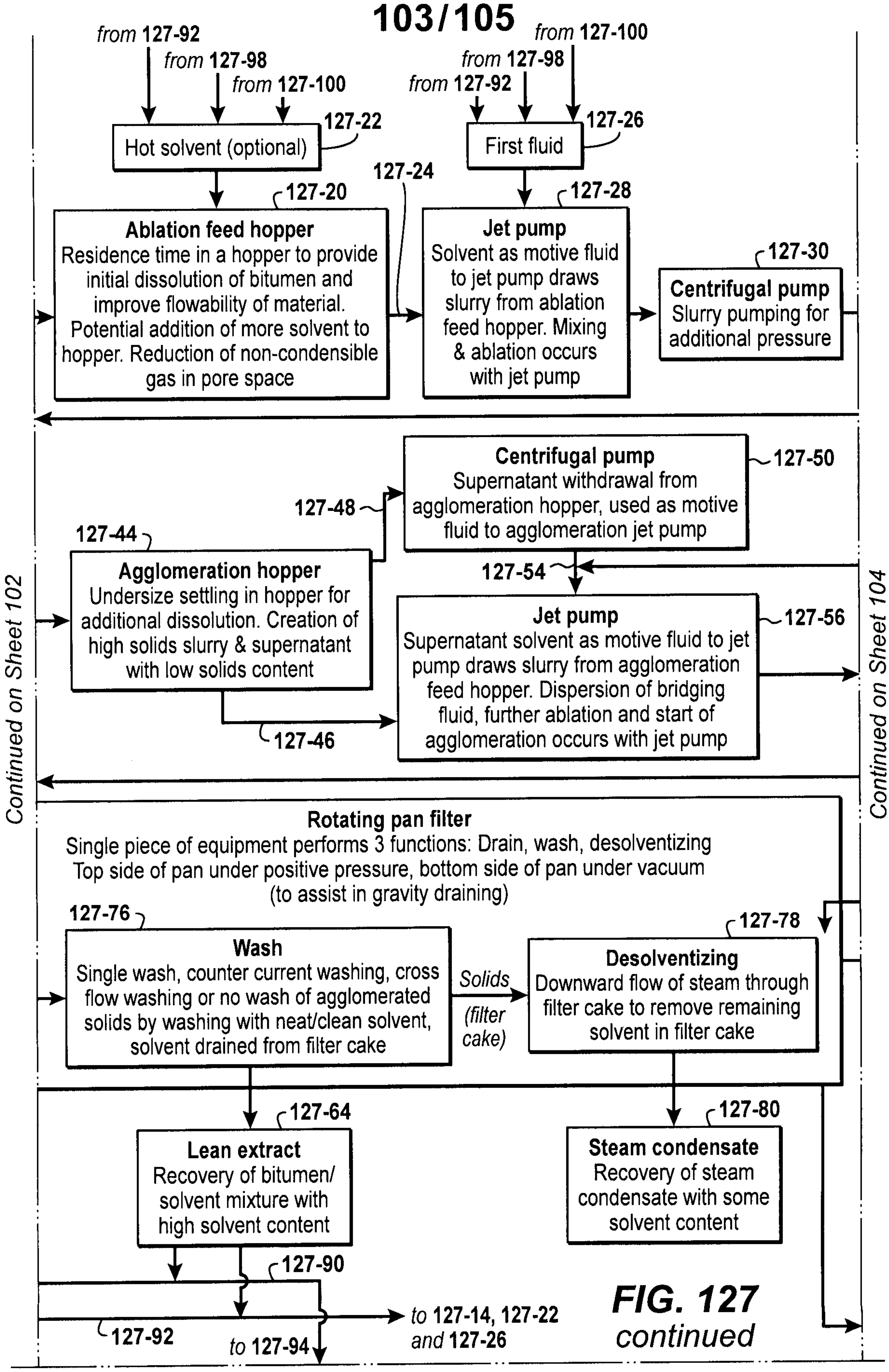


FIG. 127 *continued*

Continued on Sheet 105

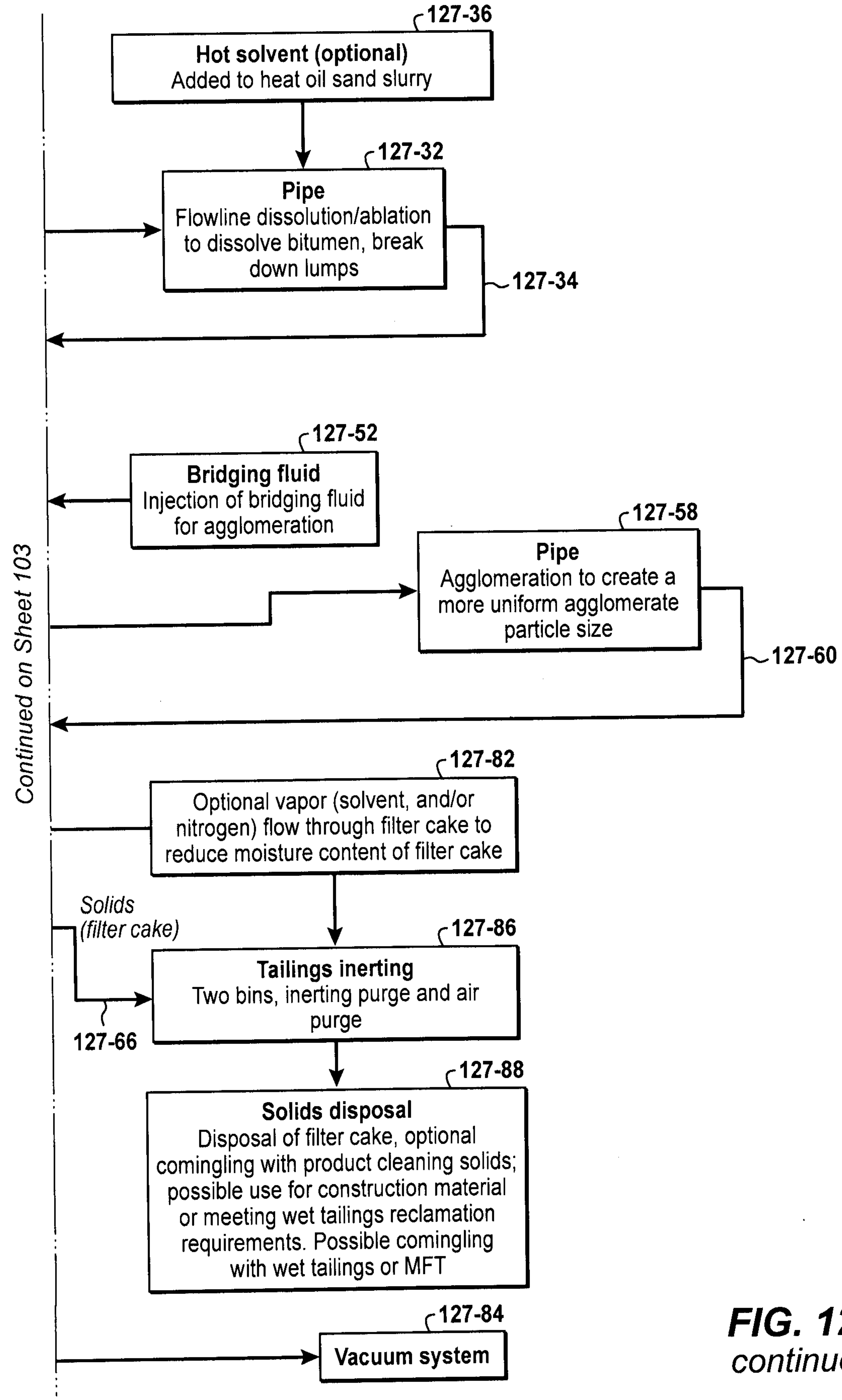


FIG. 127
continued

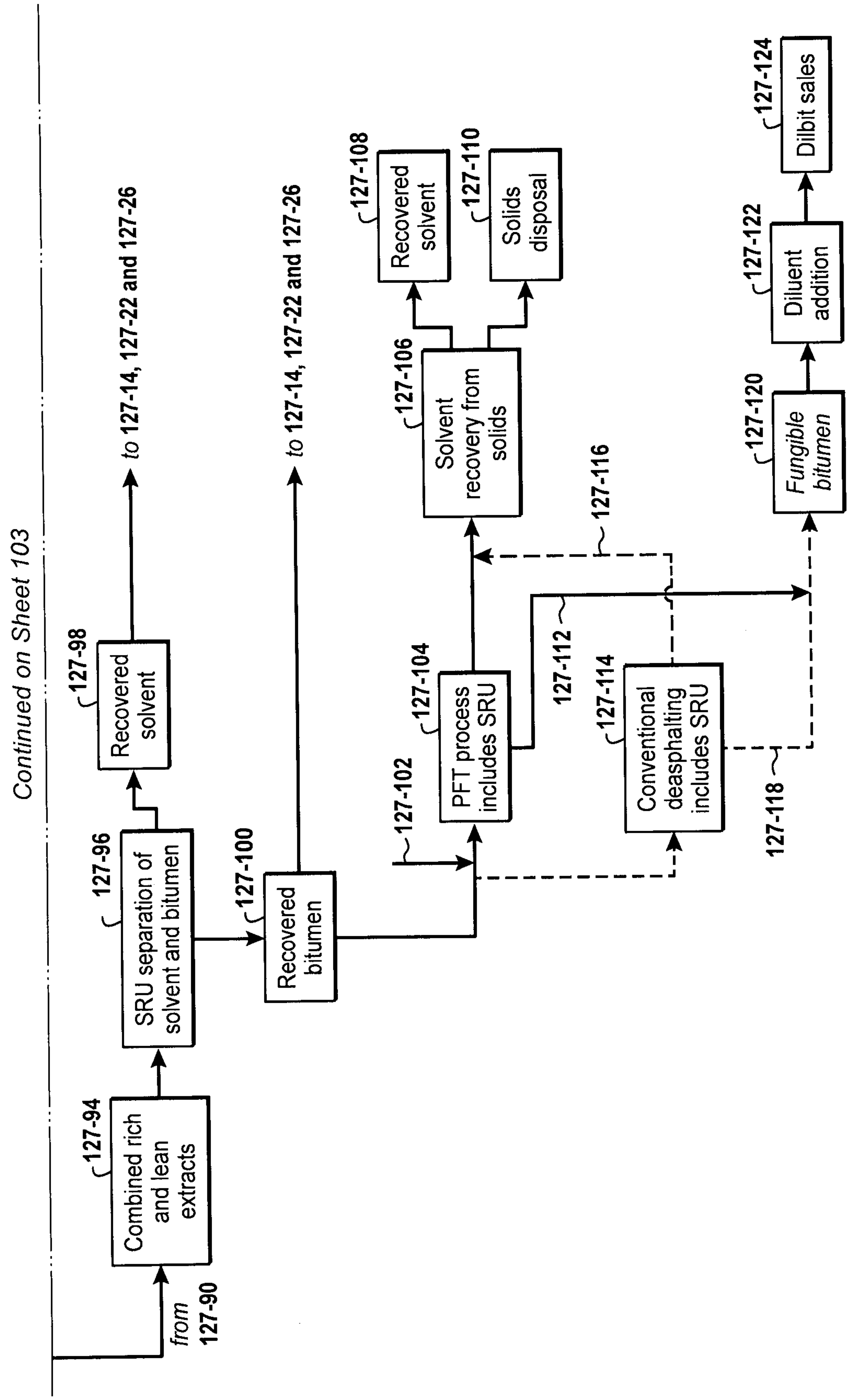
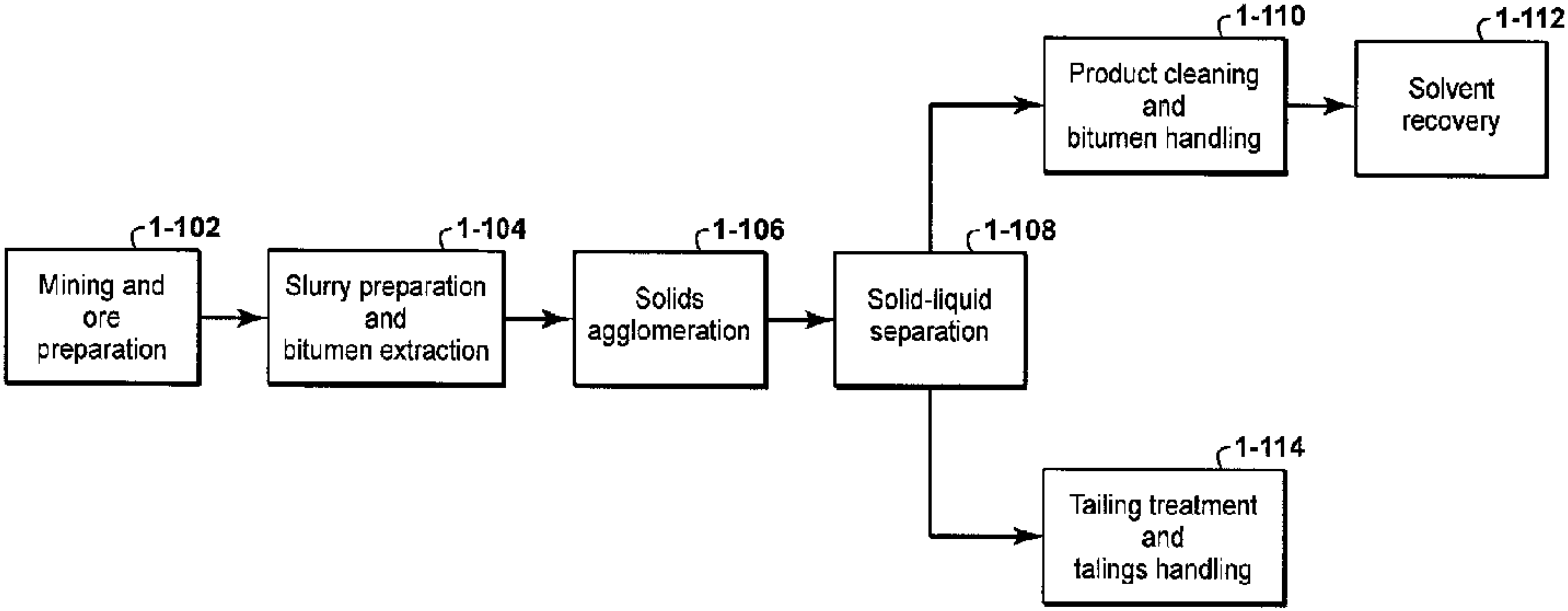


FIG. 127 continued



1-102
Mining and ore preparation
1-104
Slurry preparation and bitumen extraction
1-106
Solids agglomeration
1-108
Solid-liquid separation
1-110
Product cleaning and bitumen handling
1-112
Solvent recovery
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Tailing treatment and talings handling