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Office de la Propriété Intellectuelle du Canada

Innovation, Science and Economic Development Canada
Canadian Intellectual Property Office

CA 2909029 C 2018/02/27

(11)(21) **2 909 029**

(12) **BREVET CANADIEN
CANADIAN PATENT**

(13) **C**

(22) Date de dépôt/Filing Date: 2015/10/14
(41) Mise à la disp. pub./Open to Public Insp.: 2015/12/11
(45) Date de délivrance/Issue Date: 2018/02/27

(51) Cl.Int./Int.Cl. *G01N 33/24* (2006.01), *C10G 1/04* (2006.01)

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(54) Titre : UNE METHODE DE CONTROLE D'UN TRAITEMENT DE RESIDUS DE SABLES BITUMINEUX
(54) Title: A METHOD FOR CONTROLLING AN OIL SAND TAILINGS TREATMENT

(57) Abrégé/Abstract:
A method of controlling an oil sand tailings treatment process includes analyzing an oil sand tailings stream of the oil sand tailings treatment process to obtain a stream parameter comprising a particle size parameter, a clay parameter, or both in the oil sand tailings stream, and adjusting a parameter of the oil sand tailings treatment process based on the stream parameter.

ABSTRACT

A method of controlling an oil sand tailings treatment process includes analyzing an oil sand tailings stream of the oil sand tailings treatment process to obtain a stream parameter comprising a particle size parameter, a clay parameter, or both in the oil sand tailings stream, and adjusting a parameter of the oil sand tailings treatment process based on the stream parameter.

A METHOD FOR CONTROLLING AN OIL SAND TAILINGS TREATMENT

BACKGROUND

Field of Disclosure

[0001] The disclosure relates generally to the field of oil sand processing. More particularly, the disclosure relates to oil sand tailings 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. Other processes are non-aqueous solvent-based processes. An example of a solvent-based process 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 Sands”). Solvent may be used in both aqueous and non-aqueous processes.

[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 (also known as coarse tailings or primary separation tailings).

[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 naphthenic froth treatment (NFT) processes. Other processes use 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 Unit (SRU) and Tailings Solvent Recovery Unit (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] It would be desirable to have an alternative or improved method of processing oil sand tailings.

SUMMARY

[0014] It is an object of the present disclosure to provide a method of processing oil sand tailings.

[0015] A method of controlling an oil sand tailings treatment process includes analyzing an oil sand tailings stream of the oil sand tailings treatment process to obtain a stream parameter comprising a particle size parameter, a clay parameter, or both in the oil sand tailings stream; and adjusting a parameter of the oil sand tailings treatment process based on the stream parameter.

[0016] 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

[0017] 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.

[0018] Fig. 1 is a flow chart of a method of controlling an oil sand tailings treatment process.

[0019] Fig. 2 is a schematic of an oil sand tailings treatment process.

[0020] Fig. 3 is a schematic of an oil sand tailings treatment process.

[0021] Fig. 4 is a schematic of an oil sand tailings treatment process.

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

DETAILED DESCRIPTION

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

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

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

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

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

19 weight (wt.) % aliphatics (which can range from 5 wt. % - 30 wt. %, or higher);

19 wt. % asphaltenes (which can range from 5 wt. % - 30 wt. %, or higher);

30 wt. % aromatics (which can range from 15 wt. % - 50 wt. %, or higher);

32 wt. % resins (which can range from 15 wt. % - 50 wt. %, or higher); and

some amount of sulfur (which can range in excess of 7 wt. %), 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.

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

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

[0030] "Fine particles" or "fines" are generally defined as those solids having a size (i.e diameter) of less than 44 microns (μm), as determined by laser diffraction particle size measurement.

[0031] "Coarse particles" are generally defined as those solids having a size (i.e. diameter) of greater than 44 microns (μm).

[0032] The term "solvent" as used in the present disclosure should be understood to mean either a single solvent, or a combination of solvents.

[0033] 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.

[0034] 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.

[0035] 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.

[0036] The present disclosure provides a method of controlling an oil sand tailings treatment process. With reference to Figure 1, a method of controlling an oil sand tailings treatment process includes a) analyzing (102) an oil sand tailings stream of the oil sand tailings treatment process to obtain a stream parameter comprising a particle size parameter, a clay parameter, or both in the oil sand tailings stream; and b) adjusting (104) a parameter of the oil sand tailings treatment process based on the stream parameter.

[0037] A stream parameter means a parameter of the oil sand stream that is obtained by analyzing the oil sand tailings stream. The stream parameter may be a particle size parameter or a clay parameter in the oil sand tailings stream.

[0038] The particle size parameter may comprise a weight or volume percentage of particles in a predetermined size range, such as 0-44 microns in diameter which corresponds to a "fines" category of solids. The particle size parameter may be a D-value, such as a D-50 value. D-values are commonly used to represent the point in a range of particle sizes in a given sample. A D-50 value is the diameter at which 50% of a sample's mass or volume is comprised of smaller particles and 50% of a sample's mass or volume is comprised of larger particles. A D-10 value is the diameter at which 10% of a sample's mass or volume is comprised of smaller particles and 90% of a sample's mass or volume is comprised of larger particles. The particle size parameter may be obtained using any suitable means, such as laser diffraction, image analysis, ultrasonic attenuation, or chord length measurement.

[0039] The clay parameter may comprise a weight percentage of particles that are clay. The clay parameter may comprise a methylene blue index (MBI), which may be used as an indication of clay content.

[0040] The clay parameter may be obtained using any suitable means, such as gamma ray spectroscopy, LIBS (Laser-Induced Breakdown Spectroscopy), XRF (X-Ray Fluorescence), rheology clay content correlation, Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES), or Atomic Absorption (AA). The gamma ray spectroscopy may comprise PGNAA (Prompt Gamma Neutron Activation Analysis) or K40 analysis.

[0041] The "oil sand tailings stream" may be any suitable stream stemming from oil sand. Examples include, but are not limited to, coarse tailings (also known as primary separation tailings), middlings, flotation tailings, froth separation tailings, tailings solvent recovery unit (TSRU) tailings, fluid fine tailings (FFT), mature fine tailings (MFT), thickened tailings, centrifuged tailings, hydrocycloned tailings, or a combination thereof. The oil sand tailings stream may stem from aqueous based extraction. The oil sand tailings stream may stem from solvent based extraction.

[0042] The "oil sand tailings treatment process" means a process used to treat an oil sand tailings stream. Examples of treatment are vast and may include removing bitumen, solvent, or water.

[0043] Step a) may further comprise combining the particle size parameter, the clay parameter, or both with a slurry flow rate and slurry density, or a solids content of the oil sand stream, to obtain a mass flow rate parameter comprising a particle size mass flow rate parameter or a clay mass flow rate parameter. For instance, a tailings stream comprising primarily water and mineral solids may be analyzed for particle size to determine that 50 wt. % of the solids are fines. If the density of the tailings stream is measured as 1140 kg/m^3, the solids content of the slurry can be estimated as 20 wt. % using typical density values for water, quartz and clay. The corresponding fines content of the slurry would be 10 wt. %. If the total mass flow rate of the slurry is measured to be 5000 tons/hr, the fines mass flow rate in that stream would be 500 tons/hr.

[0044] The particle size mass flow rate parameter may comprise a mass flow rate of particles in a mass flow rate predetermined size range, such as 0-44 microns in diameter.

[0045] The clay parameter may be obtained from the particle size parameter and reference data.

[0046] Step b) may comprise adjustment of flocculent dosage, coagulant dosage, flocculent mixing equipment operation, downstream thickener operation, or blending ratio with another oil sand tailings stream or a dilution water stream. Adjustment of flocculent dosage may be particularly useful or convenient.

[0047] Step b) may comprise adjustment of flocculent dosage to a thickened tailings stream during a re-flocculation step.

[0048] Step b) may comprise adjustment to achieve a sands to fines ratio (SFR) of a resultant tailings stream to within a predetermined range.

[0049] Step b) may comprise adjustment of a flow rate of the oil sand tailings stream.

[0050] Step a) may comprise analyzing at least two oil sand tailings streams.

[0051] Step b) may comprise adjustment of a flow rate of at least one of the two or more oil sand tailings streams.

[0052] Step b) may comprise passing at least one of the at least two oil sand tailings to a disposal site thereby bypassing the oil sand tailings treatment process.

[0053] The oil sand tailings stream may comprise coarse tailings stream, middlings, flotation tailings, froth separation tailings, tailings solvent recovery unit (TSRU) tailings, fluid fine tailings (FFT), mature fine tailings (MFT), thickened tailings, thickener overflow, centrifuged tailings, hydrocycloned tailings, or a combination thereof.

[0054] The analyzed oil sand tailings stream may be at least one of three streams, a flotation or TSRU (tailings solvent recovery unit) tailings stream, a coarse tailings stream, and a fluid fine tailings stream, for feeding into a mixbox upstream of a thickener. The three streams in admixture may be estimated to have a particle size parameter or clay parameter outside of a predetermined range, a flow rate of at least one of the three streams or of dilution water to the mixbox may be adjusted.

[0055] The analyzed oil sand tailings stream may be a flotation or TSRU tailings stream and where the flotation or TSRU tailings stream has a particle size parameter or clay parameter outside of a predetermined range, the flotation or TSRU tailings stream may be sent for disposal, bypassing the mixbox and thickener.

[0056] The analyzed oil sand tailings stream may be at least one of a feed stream to a thickener, a thickener overflow, and a thickener underflow.

[0057] The analysis may be effected online, inline, offline, or atline. Operation in real-time may be advantageous.

[0058] Step a) may be effected on a slipstream of the oil sand tailings stream. The slipstream may be a representative sample of the stream and may be on a vertical section of a pipe or after a pump.

[0059] Step b) may be effected automatically or manually.

[0060] While the stream parameter may be used to adjust the process, the parameter may also be converted to another measurement, which can provide useful information and which can in turn be used to adjust a process parameter.

[0061] One existing method for online clay measurement is the K40 Analyzer, available from Industrial Sensors Technologies (Edmonton, Canada). The K40 Analyzer measures gamma ray emissions from radioactive decay of potassium (K).

[0062] The process adjustment may be any suitable process adjustment. The process adjustment may be adjustment of polymer dosage, caustic dosage, or blending ratio with another oil sand stream. The process adjustment may be adjustment to achieve a sands to fines ratio (SFR) of a resultant tailings stream within a predetermined range. The process adjustment may be adjustment of a flocculant addition rate. The process adjustment may be adjustment to achieve 0-44 μm particle content of a hydrotransport slurry within a predetermined range. The process adjustment may be adjustment of a caustic dosage to a hydrotransport slurry based on reference data. The reference data may be experimental data or otherwise.

[0063] Figs. 2 to 4 are used to illustrate example configurations of the use of the process. Fig. 2 illustrates an oil sands tailing treatment process. A first flotation tailings stream (202) and a second flotation tailings stream (204) are fed into a mix box (206). Depending on the composition of these streams (202 and 204), they may bypass tailings treatment and be passed to a tailings pond (208). Coarse tailings (210) and fluid fine tailings (212) may also be added to the mixbox (206). Out of the mixbox (206), a mixbox stream (214) may be passed to a thickener (216) along with a flocculant (218). Out of the thickener (216), a thickener overflow (220) and a thickener underflow (222) may flow. The thickener underflow (222) may be passed to secondary treatment or to a tailings pond. At least one additional mixbox stream (224) may be passed to additional thickeners (not shown).

[0064] Fig. 3 shows a portion of Fig. 2 with instruments for analyzing certain streams. As in Fig. 2, Fig. 3 includes a mixbox (306), a thickener (316), and flocculant (318). In Fig. 3, the following streams are shown with an instrument (325) for analyzing the stream: a mixbox stream (314), a thickener overflow (320), a thickener underflow (322), and at least one additional mixbox stream (324). As few as one stream may be analyzed.

[0065] Fig. 4 shows a portion of Fig. 2 with instruments for analyzing certain streams. As in Fig. 2, Fig. 4 includes a mixbox (406), a mixbox stream (414), at least one additional mixbox stream (424), and tailing pond (408). In Fig. 4, the following streams are shown with an instrument (425) for analyzing the stream: a first flotation tailings stream (402), a second flotation tailings stream (404), coarse tailings (410), and fluid fine tailings (412). The mixbox stream (414) and/or the at least one additional mixbox stream (424) may also be analyzed (not shown). As few as one stream may be analyzed.

[0066] The following are examples of the parameter of the oil sand treatment process that may be adjusted based on the analysis, with reference to Figs. 2 to 4 where appropriate:

- The rate at which the fluid fine tailings (FFT) (212, 412) are fed to the mixbox (206, 306, 406).
- The rate at which an additional tailings stream, such as coarse tailings (210, 410) is fed to the mixbox (206, 306, 406).
- The rate at which one or more flocculants (218, 318) are added to the thickener (216, 316).
- The rate at which one or more flocculants (not shown) are added to the thickener underflow (222, 322) during re-flocculation.
- The rate at which additives (not shown), for instance coagulants, are added to the oil sand tailings treatment process.
- Operating parameters of flocculant mixing equipment during re-flocculation, for instance a dynamic mixer rotating speed.
- Which thickener(s) are operated if they are not all being operated, as the individual thickeners may have different characteristics, such as different underflow piping systems.
- Operating parameters of the thickener, for instance underflow and overflow rates, rake speed, and shear thinning loop speed, to control residence time and bed height in the thickener.
- The rate at which a dilution stream (e.g. water, FFT, MFT, flotation tailings, etc.) is added to the thickener underflow (222, 322) or a thickened tailings stream to optimize transport and re-flocculation.

[0067] Particular control options may include the following:

- Measuring particle size distribution (PSD) or clay content or other clay indicator (e.g. MBI) of one or more of feeds to the thickener and combining with flow rate and solids content measurements to determine the mass flow rate of particles within certain size ranges (e.g. particles having diameters < 44 μm) or having particular size indicators (e.g. D50) or the mass flow rate of clay particles and using this information to inform a realtime change in process conditions.
- Measuring the PSD or clay content or other clay indicator of one or more feeds to the mixbox and combining with flow rate, density and/or solids content measurements to infer the PSD and mass flow rate of particles within certain size fractions to the mixbox.
- A single stream parameter (PSD, clay content or clay indicator) may be measured and used to infer values for one or more other stream parameters (PSD, clay content, or clay indicator) based on correlations developed in separate lab tests.
- The PSDs/clay contents of the feeds to the thickeners may be compared to an acceptable operating window of the tailings treatment process to determine whether the stream should be fed to the thickeners or diverted to a tailings pond.
- Measuring the PSD/clay content in conjunction with the flow rate, density and/or solids content of the FT (or TSRU) feeds to the mixbox, and then adjusting the feed rate of FFT or another stream (e.g. coarse tailings or dilution water) to the mixbox to achieve a desired combined feed composition to the thickener based on a feed-forward control strategy.
- The PSD/clay content and particle mass flow rates of the feed to the thickener may be adjusted by varying the feed rates of FFT or another stream (e.g. coarse tailings) by using a feed-back control strategy.
- The FFT addition rate may be between 0 and 50% of the total FT addition rate on a weight percent solids basis. It also may be higher than this range.
- A rate of flocculant addition to the thickeners may be adjusted to an optimal value or within an optimal range for the PSD/clay content and solids feed rate of the

thickener feed using a feed-forward control strategy. The optimal flocculant dosage or dosage range may be determined from lab test data.

- A decision about which thickener is used if only one thickener is operational may be informed by the PSD/clay content and particle mass flow rates of the feeds to the thickeners.
- The PSD/clay content of the feed to the thickener may be combined with a thickener residence time estimate and solids content and flow rate measurements on the thickener underflow to inform the flocculant dose added during secondary re-flocculation. The PSD or clay content of the thickener underflow may be directly measured by installing an analyzer on that stream. The characteristics of the feed to a secondary re-flocculation step may be used to inform the operating parameters of dynamic flocculant-slurry mixing systems, if used. The thickener underflow characterstics may be used to determine how much of a dilution stream should be added to the underflow, in a case where underflow dilution is employed.
- Using measurement of the PSD/clay content of the thickener overflow water to make a process control decision such as whether to inject more flocculant, or whether to switch to by-pass mode if the thickener is off specification.

[0068] It should be understood that numerous changes, modifications, and alternatives to the preceding disclosure can be made without departing from the scope of the disclosure. The preceding description, therefore, is not meant to limit the scope of the disclosure. Rather, the scope of the disclosure is to be determined only by the appended claims and their equivalents. It is also contemplated that structures and features in the present examples can be altered, rearranged, substituted, deleted, duplicated, combined, or added to each other.

[0069] The scope of the claims should not be limited by particular embodiments set forth herein, but should be construed in a manner consistent with the specification as a whole.

CLAIMS:

1. A method of controlling an oil sand tailings treatment process, the method comprising:

   (a) analyzing an oil sand tailings stream of the oil sand tailings treatment process to obtain a stream parameter comprising a clay parameter in the oil sand tailings stream and combining the clay parameter with a slurry flow rate and slurry density, or a solids content of the oil sand stream, to obtain a mass flow rate parameter comprising a clay mass flow rate parameter; and

   (b) adjusting a parameter of the oil sand tailings treatment process based on the mass flow rate parameter comprising the clay mass flow rate parameter;

   wherein the clay parameter is obtained using gamma ray spectroscopy, LIBS (Laser-Induced Breakdown Spectroscopy), XRF (X-Ray Fluorescence), rheology clay content correlation, Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES), or Atomic Absorption (AA); and

   wherein the oil sand tailings stream comprises coarse tailings stream, middlings, flotation tailings, froth separation tailings, tailings solvent recovery unit (TSRU) tailings, fluid fine tailings (FFT), thickened tailings, thickener overflow, centrifuged tailings, hydrocycloned tailings, or a combination thereof.

2. The method of claim 1, wherein the stream parameter further comprises a particle size parameter.

3. The method of claim 2, wherein the particle size parameter is obtained using laser diffraction, image analysis, ultrasonic attenuation, or chord length measurement.

4. The method of claim 2 or 3, wherein the particle size parameter comprises a weight or volume percentage of particles in a predetermined size range.

5. The method of claim 4, wherein the predetermined size range is 0-44 microns in diameter.

6. The method of claim 2 or 3, wherein the particle size parameter comprises a D-value.

7. The method of claim 6, wherein the D-value is a D-50 value.

8. The method of any one of claims 1 to 7, wherein the clay parameter comprises a weight percentage of particles that are clay.

9. The method of any one of claims 1 to 7, wherein the clay parameter comprises a methylene blue index (MBI).

10. The method of claim 1, wherein the gamma ray spectroscopy comprises PGNAA (Prompt Gamma Neutron Activation Analysis) or K40 analysis.

11. The method of claim 2, wherein step a) further comprises combining the particle size parameter with a slurry flow rate and slurry density, or a solids content of the oil sand stream, to obtain a mass flow rate parameter comprising a particle size mass flow rate parameter.

12. The method of claim 11, wherein the particle size mass flow rate parameter comprises a mass flow rate of particles in a mass flow rate predetermined size range.

13. The method of claim 12, wherein the mass flow rate predetermined size range is 0-44 microns in diameter.

14. The method of claim 1, wherein the clay parameter is obtained from a particle size parameter and reference data.

15. The method of any one of claims 1 to 14, wherein step b) comprises adjustment of flocculent dosage, coagulant dosage, flocculent mixing equipment operation, downstream

thickener operation, or blending ratio with another oil sand tailings stream or a dilution water stream.

16. The method of any one of claims 1 to 14, wherein step b) comprises adjustment of flocculent dosage.

17. The method of any one of claims 1 to 14, wherein step b) comprises adjustment of flocculent dosage to a thickened tailings stream during a re-flocculation step.

18. The method of any one of claims 1 to 14, wherein step b) comprises adjustment to achieve a sands to fines ratio (SFR) of a resultant tailings stream to within a predetermined range.

19. The method of any one of claims 1 to 14, wherein step b) comprises adjustment of a flow rate of the oil sand tailings stream.

20. The method of any one of claims 1 to 14, wherein step a) comprises analyzing at least two oil sand tailings streams.

21. The method of claim 20, wherein step b) comprises adjustment of a flow rate of at least one of the two or more oil sand tailings streams.

22. The method of claim 20, wherein step b) comprises passing at least one of the at least two oil sand tailings to a disposal site thereby bypassing the oil sand tailings treatment process.

23. The method of any one of claims 1 to 22, wherein the oil sand tailings stream stems from aqueous based extraction.

24. The method of any one of claims 1 to 22, wherein the oil sand tailings stream stems from solvent based extraction.

25. An oil sand tailings treatment process comprising the method of any one of claims 1 to 22, wherein the oil sand tailings stream is at least one of three streams, a flotation or TSRU (tailings solvent recovery unit) tailings stream, a coarse tailings stream, and a fluid fine tailings stream, for feeding into a mixbox upstream of a thickener.

26. The process of claim 25, wherein the three streams in admixture are estimated to have a clay parameter outside of a predetermined range, a flow rate of at least one of the three streams or of dilution water to the mixbox is adjusted.

27. The process of claim 25, wherein the analyzed oil sand tailings stream is a flotation or TSRU tailings stream and where the flotation or TSRU tailings stream has a clay parameter outside a predetermined range, the flotation or TSRU tailings stream is sent for disposal, bypassing the mixbox and thickener.

28. The process of claim 1, wherein the stream parameter further comprises a particle size parameter, wherein the oil sand tailings stream is at least one of three streams, a flotation or TSRU (tailings solvent recovery unit) tailings stream, a coarse tailings stream, and a fluid fine tailings stream, for feeding into a mixbox upstream of a thickener, and wherein the three streams in admixture are estimated to have a particle size parameter outside of a predetermined range, a flow rate of at least one of the three streams or of dilution water to the mixbox is adjusted.

29. The process of claim 1, wherein the stream parameter further comprises a particle size parameter, wherein the oil sand tailings stream is at least one of three streams, a flotation or TSRU (tailings solvent recovery unit) tailings stream, a coarse tailings stream, and a fluid fine tailings stream, for feeding into a mixbox upstream of a thickener, and wherein the analyzed oil sand tailings stream is a flotation or TSRU tailings stream and where the flotation or TSRU

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tailings stream has a particle size parameter outside a predetermined range, the flotation or TSRU tailings stream is sent for disposal, bypassing the mixbox and thickener.

30. An oil sand tailings treatment process comprising the method of any one of claims 1 to 22, wherein the oil sand tailings stream is at least one of a feed stream to a thickener, a thickener overflow, and a thickener underflow.

31. The method of any one of claims 1 to 30, wherein step a) is effected online, inline, offline, or atline.

32. The method of any one of claims 1 to 30, wherein step a) is effected on a slipstream of the oil sand tailings stream.

33. The method of any one of claims 1 to 32, wherein step b) is effected automatically or manually.

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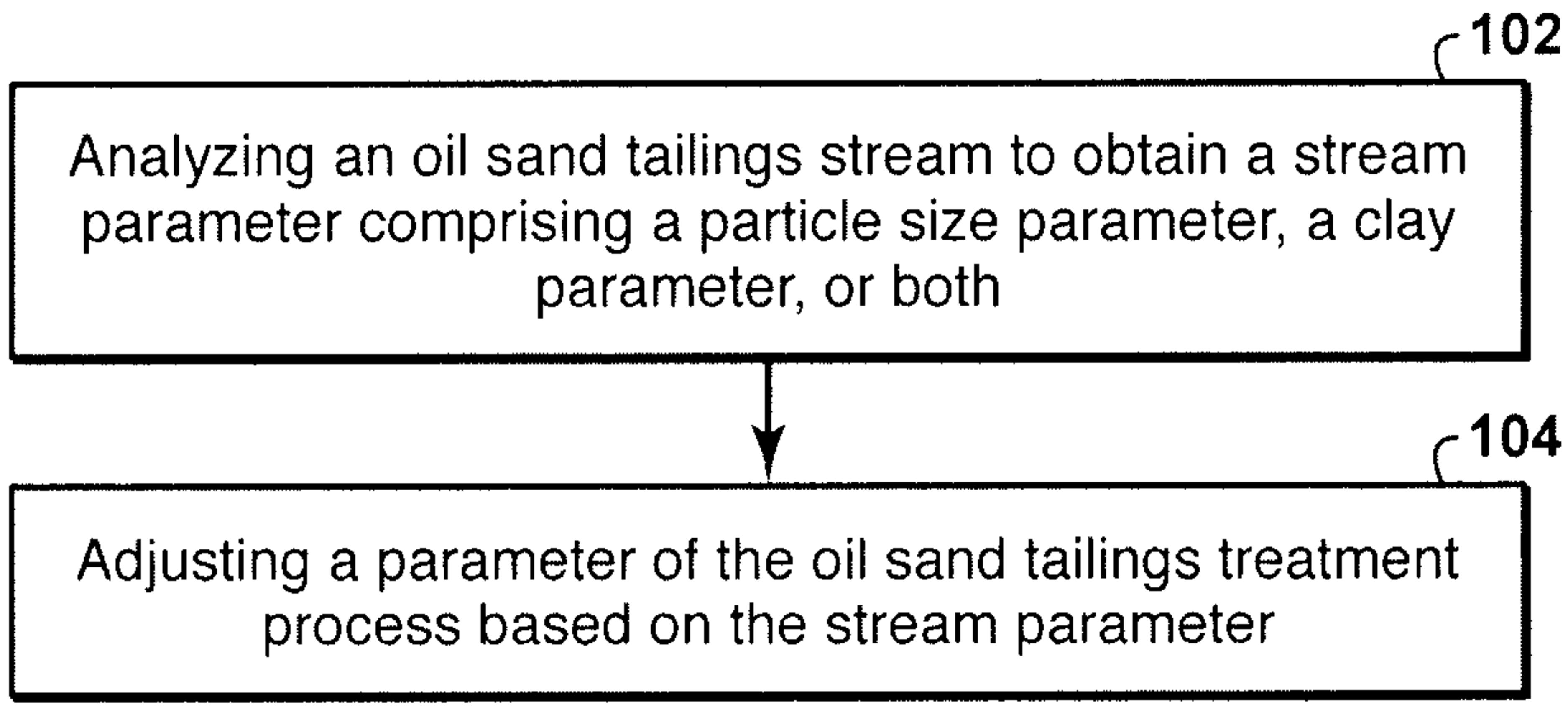
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Analyzing an oil sand tailings stream to obtain a stream parameter comprising a particle size parameter, a clay parameter, or both
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Adjusting a parameter of the oil sand tailings treatment process based on the stream parameter

FIG. 1

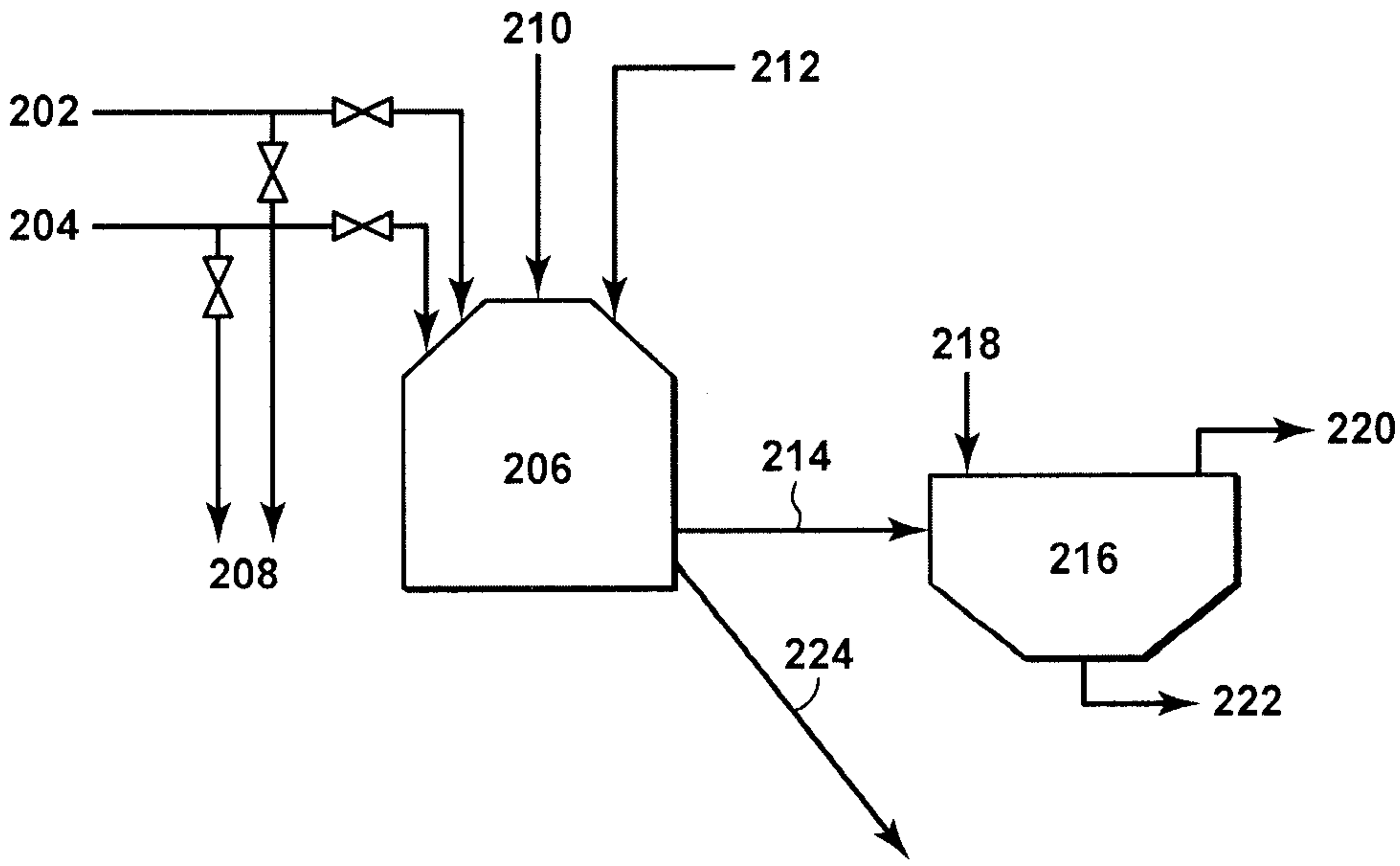
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FIG. 2

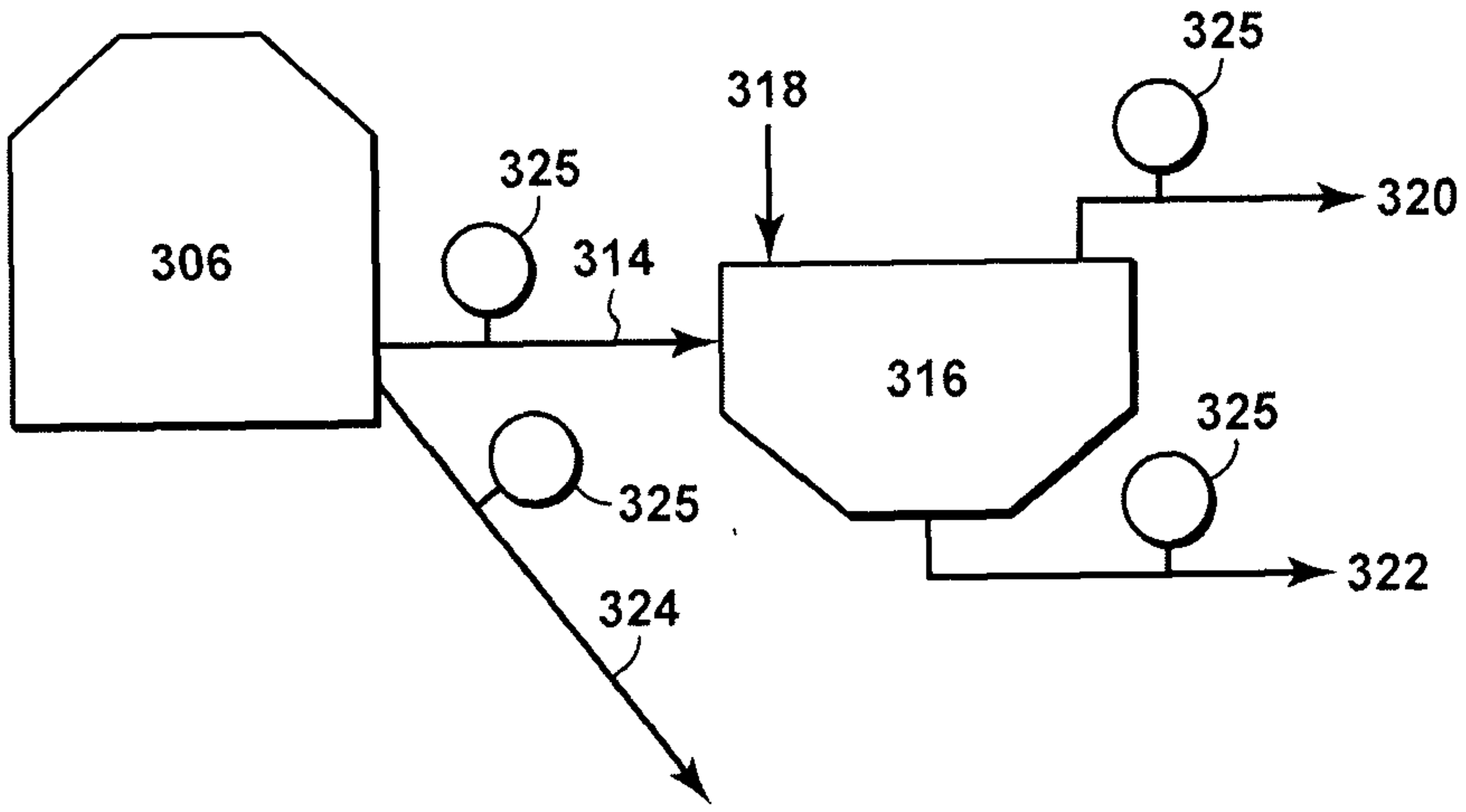
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FIG. 3

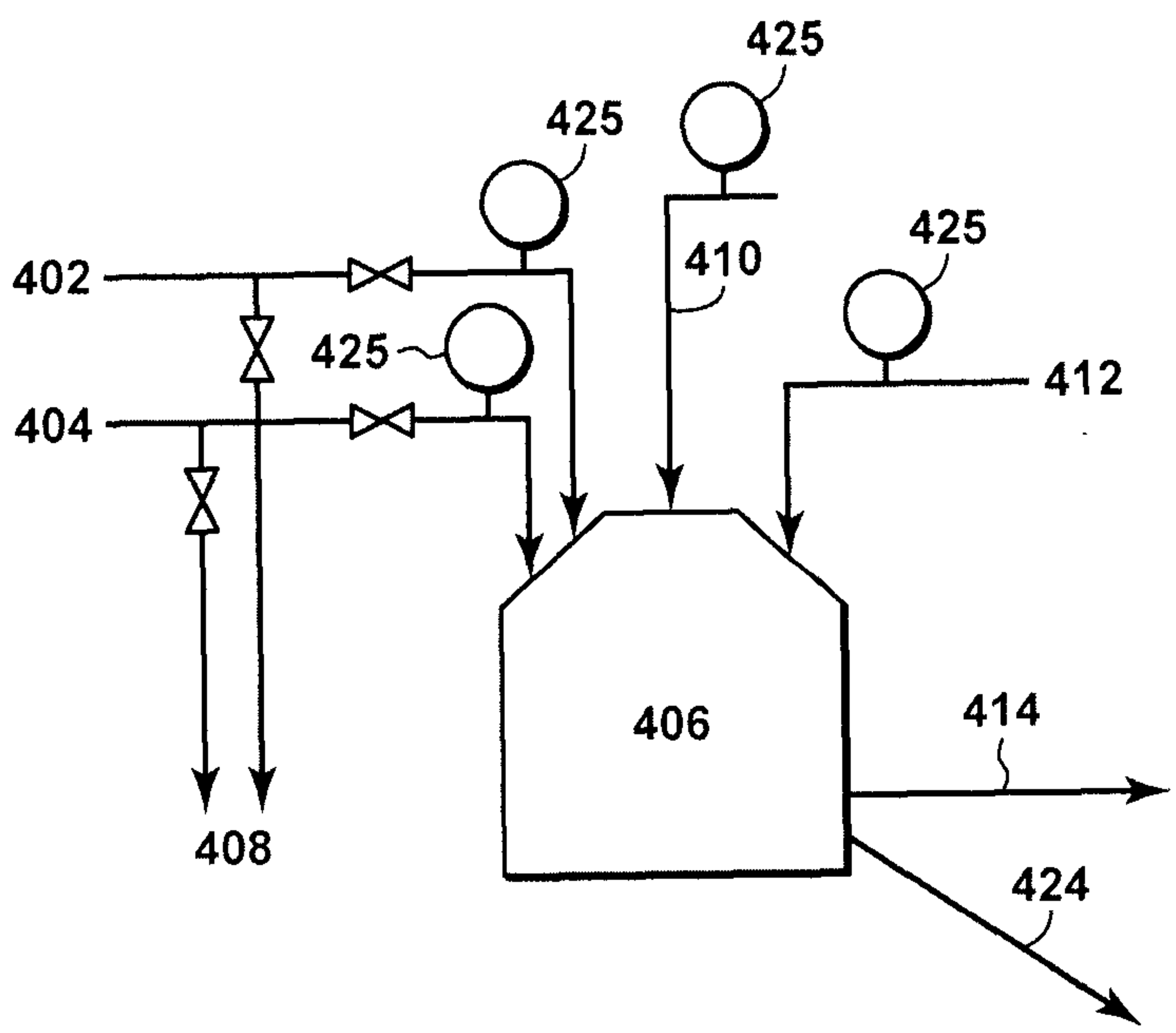
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FIG. 4