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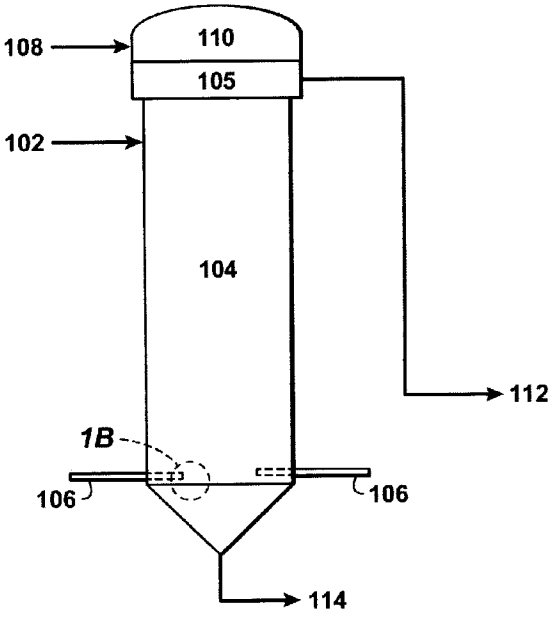


(57) Abrégé/Abstract:
A disclosed method comprises operating a flotation process for separating a bitumen-containing stream in a flotation column into an overflow and an underflow; and maintaining a steam cap above a froth layer in the flotation column for reducing a gas content in the froth layer.

ABSTRACT

A disclosed method comprises operating a flotation process for separating a bitumen-containing stream in a flotation column into an overflow and an underflow; and maintaining a steam cap above a froth layer in the flotation column for reducing a gas content in the froth layer.

FLOTATION COLUMN SEPARATION OF A BITUMEN-CONTAINING STREAM

BACKGROUND

Field of Disclosure

[0001] The disclosure relates generally to the field of oil sand processing, and more particularly to flotation column separation of a bitumen-containing stream.

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) or as a water-based oil sand extraction process. 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 WBE process, a water and oil sand slurry is separated into three major streams in the PSC: bitumen froth, middlings, and a PSC underflow (also referred to as coarse sand tailings (CST)).

[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, pentanes, hexanes, and heptanes) 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, which may comprise 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).

SUMMARY

[0012] A disclosed method comprises operating a flotation process for separating a bitumen-containing stream in a flotation column into an overflow and an underflow; and maintaining a steam cap above a froth layer in the flotation column for reducing a gas content in the froth layer.

[0013] 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 DRAWING

[0014] These and other features, aspects and advantages of the disclosure will become apparent from the following description, appending claims and the accompanying drawing, which is briefly described below.

[0015] Fig. 1A is a schematic of flotation column with a steam cap.

[0016] Fig. 1B is an exploded view of a sparger of Fig. 1A ejecting a water and gas mixture.

[0017] Fig. 2 is a schematic of system comprising a flotation column with a steam cap, and a cavitation pump.

[0018] It should be noted that the figure is merely an example and no limitations on the scope of the present disclosure is intended thereby. Further, the figure is generally not drawn to scale, but is drafted for purposes of convenience and clarity in illustrating various aspects of the disclosure.

DETAILED DESCRIPTION

[0019] 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.

[0020] 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.

[0021] Throughout this disclosure, where a range is used, any number between or inclusive of the range is implied.

[0022] 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.

[0023] "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.

[0024] "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.

[0025] "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.

[0026] "Coarse particles" are generally defined as those solids having a size of greater than 44 microns (μm).

[0027] The term "solvent" as used in the present disclosure should be understood to mean either a single solvent, or a combination of solvents.

[0028] 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.

[0029] 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.

[0030] 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 pentanes, hexanes, and heptanes.

[0031] One method may comprise operating a flotation process for separating a bitumen-containing stream in a flotation column into an overflow and an underflow. The flotation column may be a generally vertical cylindrical vessel with a high length to diameter ratio. The flotation column may have a cone bottom to mitigate solids build up. An external sparging system may inject a gas/water mixture into a lower portion of the flotation column. The flotation column may operate with a deep froth layer to improve drainage of entrained mineral particles. Froth washing, a water spray over the collected froth layer at the top of the column, may be incorporated to mitigate clays and minerals from reporting to the froth product (overflow). The spargers may be designed or controlled to provide the appropriate amount and size of bubbles to provide the required surface area for bitumen recovery, for instance by controlling gas and water pressures or by selecting the size of the spargers. The spargers may be (evenly) distributed around the column to provide an even distribution of gas across the cross-section of the column. For TSRU tailings in which floc breakage is desired, after the

breakage of the flocs, the bubbles will attach to the hydrocarbon molecules due to the hydrophobicity of both surfaces (i.e. gas bubble and hydrocarbon) and float to the top of the flotation cell. For other tailings streams, bitumen is already dispersed and can be separated by gas flotation; after the tailings are fed to the column, small bubbles will attach to bitumen droplets and together they float to the top. Any suitable industrial, commercially available spargers may be used. Bubbles may be generated by any suitable means of bubble generation, for example, diffusion or sparging.

[0032] Due to a high gas injection rate through spargers, the resulting froth could have, for instance, as high as about 60% gas volume at the top of column. High gas content in the froth may negatively affect downstream operation, such as pumping (i.e. gas-locking). In general, pump capacity decreases with increased gas content. With the system described herein, lowering of gas content was visually observed.

[0033] In order to reduce the gas content of the froth from a flotation column, disclosed herein is the use of a steam cap in conjunction with the flotation column. In this concept, a cap may be placed on the top of flotation column. Any suitable source of steam may be injected into the cap so the top surface of the froth gets exposed to a higher temperature. Elevating the temperature to about 60 °C can help to significantly reduce the froth gas content, primarily due to a viscosity drop at the elevated temperature. Higher temperatures can reduce froth gas content and reduce bitumen viscosity.

[0034] One method may comprise operating a flotation process for separating a bitumen-containing stream in a flotation column into an overflow and an underflow; and maintaining a steam cap above a froth layer in the flotation column for reducing a gas content in the froth layer. The steam cap may reduce viscosity and improve flow, which may reduce the chance of plugging in downstream piping.

[0035] The steam cap may comprise a volume of steam covered by a cap disposed on the flotation column. The steam cap may be open cap where the cap is placed over the flotation column but not sealed to the flotation column, or may be a closed cap where the cap is sealed

to the flotation column. The area between the top of the cylindrical section of the flotation column and the cap may have open areas or vents and thus the cap may be unsealed. The steam cap may comprise a volume of steam disposed within a physical cap which is located on the top of the flotation column. The physical cap may be any suitable shape and may be dome-shaped.

[0036] The bitumen-containing stream may comprise a water-based extraction stream. The water-based extraction stream may comprises middlings, tailings solvent recovery unit (TSRU) tailings, coarse tailings, flotation tailings, or ore slurry. The water-based extraction stream may comprise bitumen and 5 – 65% wt. % solids.

[0037] The method may comprise injecting steam into the flotation column above the froth layer to provide the steam cap. Sufficient steam may be injected to maintain a temperature of the froth layer within a range of 40 – 80 °C. Sufficient steam may be injected to maintain the gas content of the froth in a range of 5-45%, 5-25 %, or 5-15 %, by volume.

[0038] The flotation column flotation process may comprise introducing water and gas into the flotation column using a shearing device (e.g. a cavitation pump, cavitation tube, or jet pump) to shear flocs in the bitumen-containing stream and generating bubbles for attaching to bitumen. The flotation process may comprise introducing water and gas into the flotation column through at least one sparger to provide bubbles for attaching to bitumen. The flotation column may comprise multiple spargers. The multiple spargers may be located at a bottom of a cylindrical section of the flotation column and above a bottom cone section of the flotation column. At least one of the spargers may be located in a bottom cone section of the flotation column. The multiple spargers may be disposed around a perimeter of the flotation column.

[0039] The gas may be any suitable gas and may comprise air, CH_4, O_2, CO_2, N_2, flue gas, any other inert gas or a combination thereof. In view of the presence of residual solvent, an air-free operation may be selected in which the spargers use gases such as N_2, CO_2 or CH_4.

[0040] The method may comprise spraying water onto the froth layer in the flotation column for mitigating minerals from reporting to the overflow.

[0041] The method may further comprise passing the water and gas through a shearing device such as a cavitation pump, prior to passing through the sparger, to shear flocs in the bitumen-containing stream.

[0042] Fig. 1A is a schematic of flotation column with a steam cap. With reference to Fig. 1A, a bitumen-containing stream (102) is introduced into a flotation column (104) comprising a froth launder (105). Water and gas are introduced into the flotation column (104) through spargers (106) to provide bubbles for attaching to bitumen. Figure 1B is an exploded view of a sparger ejecting a water and gas mixture (106a). Steam (108) is injected into the flotation column (104) to maintain a steam cap (110) above a froth layer in the flotation column (104) for reducing a gas content in the froth layer. Flotation separation in the flotation column (104) produces an overflow (112) and an underflow (114). Water (not shown) may be sprayed onto the froth layer in the flotation column (104) for mitigating minerals from reporting to the overflow (112). The steam may be any suitable pressure, temperature, and level of saturation.

[0043] Steam may be added to a pipe carrying the overflow from the flotation column, as such pipes are not full; and the steam then travels to the top of the cap. Potential benefits of adding steam in this pipe may include: a single point of injection as opposed to multiple points of injection where more than one column is used since the steam will travel to the top of each column from one injection point; a higher efficiency due to a higher surface exposure of the steam, and avoiding a requirement to change to the mechanical specifications (pressure and temperature) due to steam conditions.

[0044] Fig. 2 is a schematic of a system comprising a flotation column with a steam cap, a cavitation pump and downstream arrangements to transport froth. With reference to Fig. 2, a bitumen-containing stream (202) is introduced into a flotation column (204) comprising a froth launder (205). Water and gas (together 209) are introduced into the flotation column (204) through a cavitation pump (optional) (207) and/or through spargers (206) to shear flocs in the bitumen-containing stream and to provide bubbles for attaching to bitumen. A recycled stream (not shown) from (214) may also be added to the water and gas (209), particularly where TSRU tailings are being processed. The cavitation pump causes air addition and also shearing of the

asphaltene/maltenes flocs. Similar to Fig. 1A, steam (208) is injected into the flotation column (204) to maintain a steam cap (210) above a froth layer in the flotation column (204) for reducing a gas content in the froth layer. Flotation separation in the flotation column (204) produces an overflow (212) and an underflow (114). Water (not shown) may be sprayed onto the froth layer in the flotation column (204) for mitigating minerals from reporting to the overflow (212). As additionally shown in Fig. 2, the overflow (212) (a deaerated froth, which may be partially deaerated) is passed through a froth pump feedbox (216) and froth handling pumps (218a and 218b) and to an inlet of a primary separation cell (PSC) inlet (not shown) or may be combined with the primary froth. Deaerated froth may be added in other locations in bitumen extraction or may be sent for further processing and be used as a value-added hydrocarbon stream.

[0045] Multiple spargers may be used, may be located at a bottom of the flotation column above a bottom cone section, and may be disposed around a perimeter of the flotation column. At least one of the spargers may be located in a bottom cone section of the flotation column.

[0046] In order to test the concept in the laboratory, a small scale flotation column was used. An oil sands tailings stream containing about 1 to 2 weight % bitumen was fed to the column while air was injected from the bottom of a column. The air bubbles collided with bitumen droplets while they were rising in the column, forming an aerated froth on the top of column. In order to break this foamy froth, two experiments were conducted.

[0047] In one experiment, low pressure steam was added to the top of the flotation column, where the froth is generated, using a lab steamer. The steam addition collapsed the bubbles thereby reducing froth air content.

[0048] In another experiment, the foamy froth was exposed to hot air. In order to understand if the stream shear flow caused the collapse of the froth, a hot air stream was added to the foamy froth on the top of the column. While steam was very effective in collapsing the foam in froth (i.e. reducing froth air content), the hot air did not have an appreciable effect.

[0049] 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. The scope of the claims should not be limited by particular embodiments set forth herein, but should be construed in a manner consistent with the specification as a whole.

CLAIMS:

1. A method comprising:

a) operating a flotation process for separating a bitumen-containing stream in a flotation column into an overflow and an underflow; and

b) maintaining a steam cap above a froth layer in the flotation column for reducing a gas content in the froth layer.

2. The method of claim 1, wherein the steam cap comprises a volume of steam disposed within a physical cap which is located on a top of the flotation column.

3. The method of claim 1, wherein the physical cap is dome-shaped.

4. The method of claim 2 or 3, wherein the physical cap is sealed to a top of the flotation column.

5. The method of claim 2 or 3, wherein the physical cap is unsealed to the flotation column.

6. The method of any one of claims 1 to 5, comprising injecting steam into the flotation column above the froth layer to provide the steam cap.

7. The method of any one of claims 1 to 6, wherein sufficient steam is injected to maintain a temperature of the froth layer within a range of 40 – 80 °C.

8. The method of any one of claims 1 to 7, wherein sufficient steam is injected to maintain the gas content of the froth layer in a range of 5 – 25 % by volume.

9. The method of any one of claims 1 to 8, wherein the bitumen-containing stream comprises a water-based extraction stream.

10. The method of claim 9, wherein the water-based extraction stream comprises middlings, TSRU tailings, coarse tailings, flotation tailings, or ore slurry.

11. The method of claim 10, wherein the water-based extraction stream comprises bitumen and 5-65 wt. % solids.

12. The method of any one of claims 1 to 11, wherein the flotation process comprises introducing water and gas into the flotation column through at least one sparger to provide bubbles for attaching to bitumen.

13. The method of claim 12, wherein the flotation column comprises multiple spargers.

14. The method of claim 13, wherein the multiple spargers are located at a bottom of a cylindrical section of the flotation column and above a bottom cone section of the flotation column.

15. The method any one of claims 12 to 14, wherein at least one of the spargers is located in a bottom cone section of the flotation column.

16. The method of claim 13 or 14, wherein the multiple spargers are disposed around a perimeter of the flotation column.

17. The method of any one of claims 13 to 16, further comprising passing the water and gas through a cavitation pump, prior to passing through the sparger, to shear flocs in the bitumen-containing stream.

18. The method of any one of claims 1 to 17, further comprising spraying water onto the froth layer in the flotation column for mitigating minerals from reporting to the overflow.

19. The method of any one of claims 1 to 18, further comprising passing the overflow through a froth pump feedbox and at least one froth handling pump and to a primary separation cell.

20. The method of any one of claims 1 to 18, further comprising passing the overflow through a froth pump feedbox and at least one froth handling pump and then combining the overflow with a primary froth.

21. The method of any one of claims 12 to 17, wherein the gas introduced in the flotation column comprises air, CH_4, O_2, CO_2, N_2, or a combination thereof.

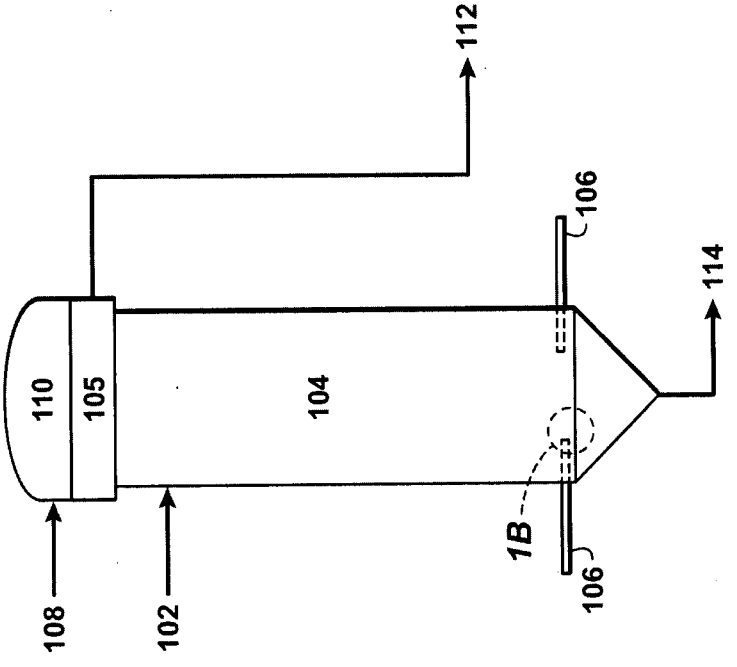


FIG. 1A

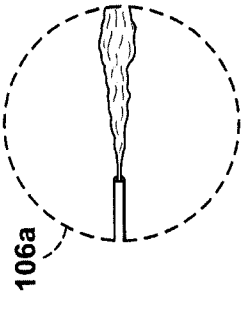


FIG. 1B

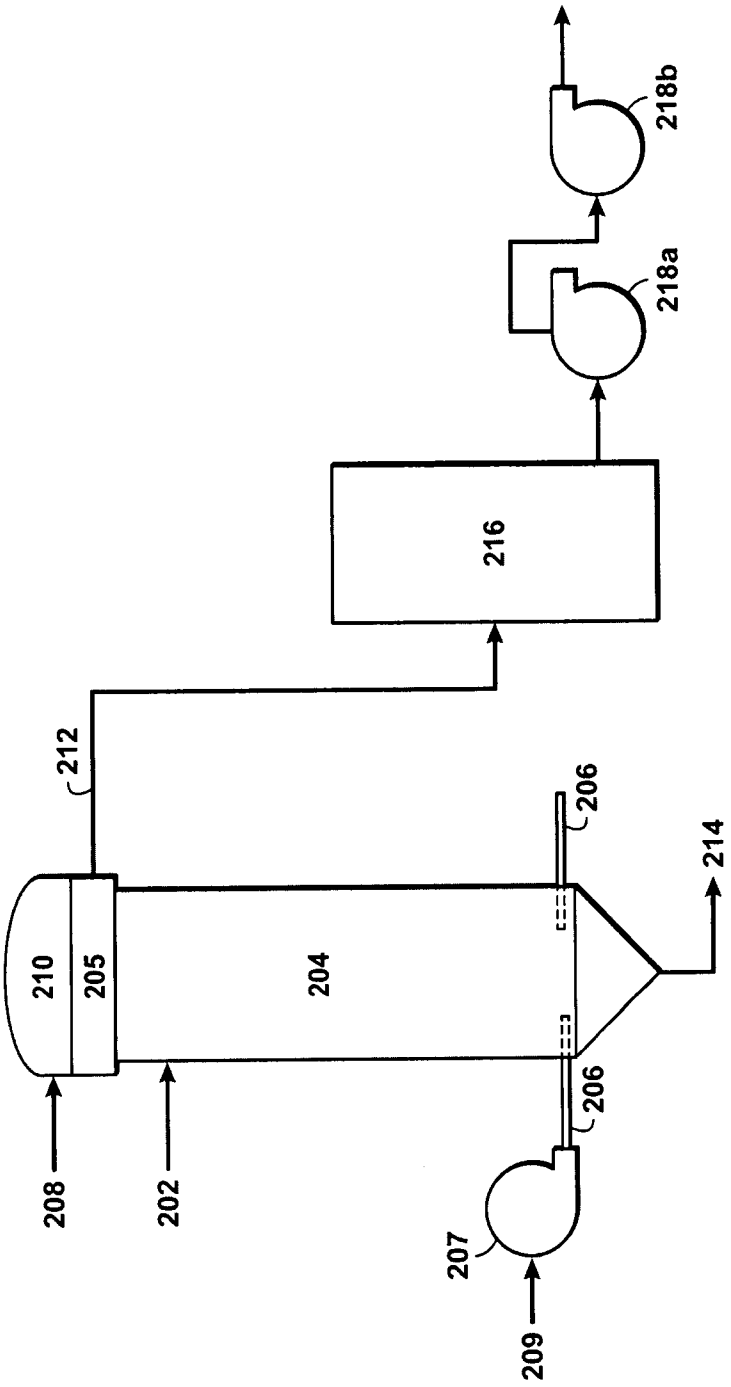
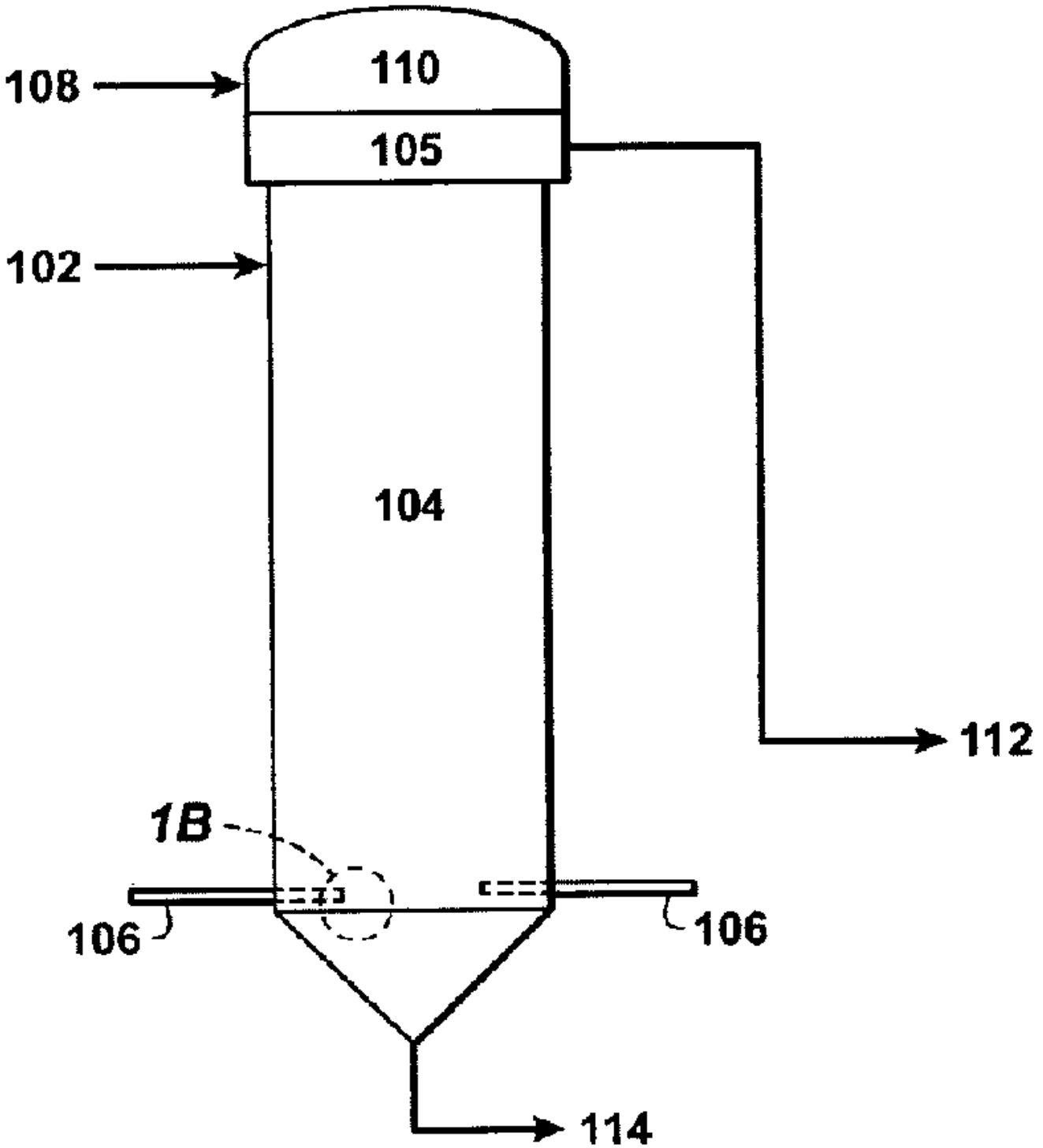


FIG. 2



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