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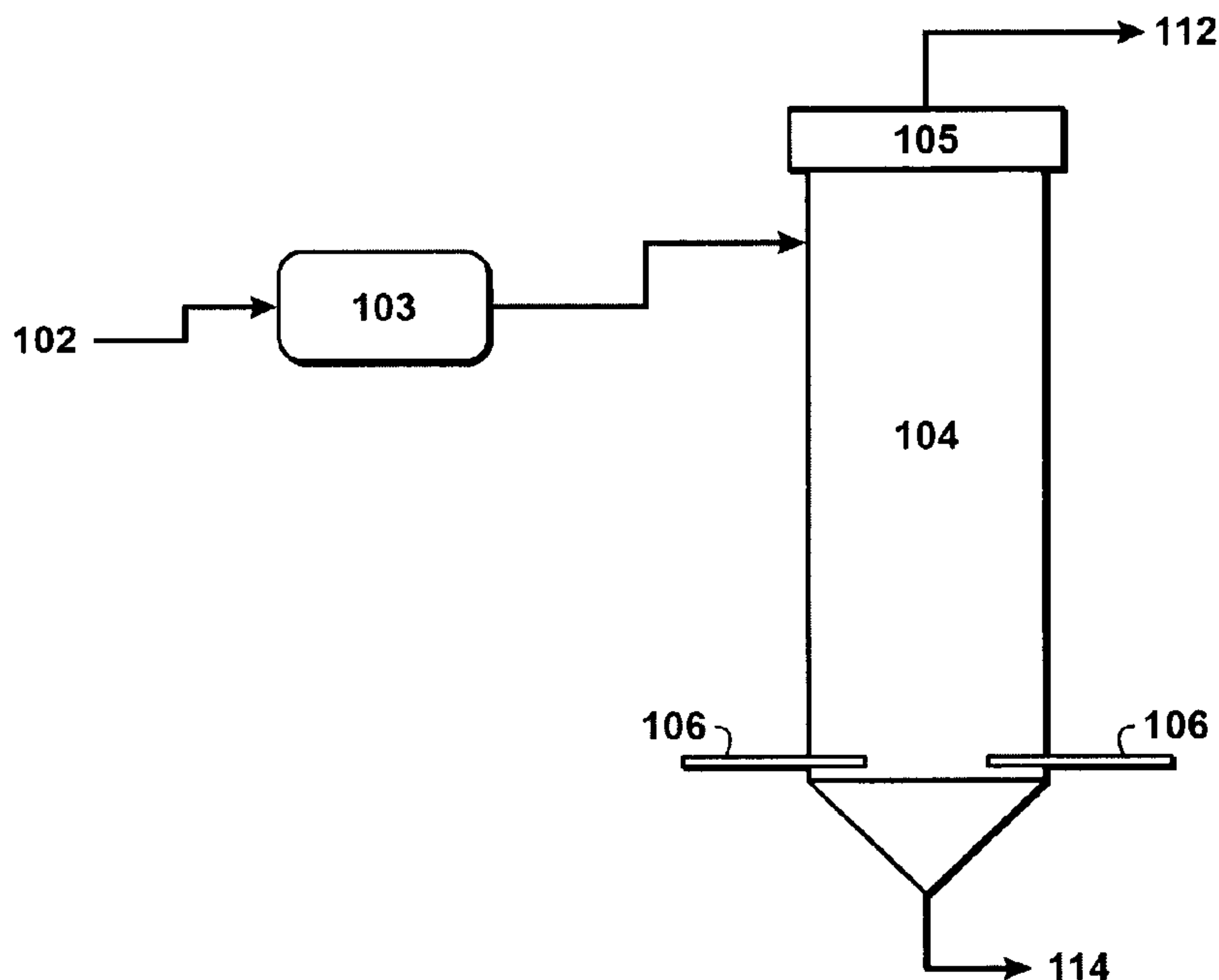
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(54) Titre : RECUPERATION D'HYDROCARBURES A PARTIR DE RESIDUS DE TRAITEMENT DE MOUSSE DE BITUME

(54) Title: BITUMEN FROTH TREATMENT TAILINGS HYDROCARBON RECOVERY



(57) Abrégé/Abstract:

A disclosed method comprises providing tailings from a bitumen froth treatment using solvent, introducing the tailings into a flotation column, using a shearing device to break asphaltenes flocs in the tailings, introducing water and gas into the flotation column through sparging; and removing an overflow and an underflow from the flotation column.

ABSTRACT

A disclosed method comprises providing tailings from a bitumen froth treatment using solvent, introducing the tailings into a flotation column, using a shearing device to break asphaltene flocs in the tailings, introducing water and gas into the flotation column through sparging; and removing an overflow and an underflow from the flotation column.

BITUMEN FROTH TREATMENT TAILINGS HYDROCARBON RECOVERY

BACKGROUND

Field of Disclosure

[0001] The disclosure relates generally to the field of oil sand processing, and more particularly to bitumen tailings separation.

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 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 providing tailings from a bitumen froth treatment using solvent, introducing the tailings into a flotation column, using a shearing

device to break asphaltenes flocs in the tailings, introducing water and gas into the flotation column through sparging; and removing an overflow and an underflow from the flotation column.

[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. 1 is a schematic of a process configuration utilizing a flotation column for separating bitumen tailings herein.

[0016] Fig. 2 is a schematic of a process configuration utilizing a flotation column for separating bitumen tailings herein.

[0017] Fig. 3 is a schematic of a process configuration for processing bitumen froth herein.

[0018] It should be noted that these figures are merely examples and no limitations on the scope of the present disclosure is 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

[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 C₄ to C₂₀ or C₄ to C₆ paraffinic hydrocarbon solvent or a combination of iso and normal components thereof. The paraffinic solvent may comprise pentane, iso-pentane, or a combination thereof..

[0031] TSRU tailings are generated from bitumen froth treatment using solvents (i.e. paraffinic or naphthenic). In the case of paraffinic processes, the tailings may be rich in asphaltenes (rejected by design) and may have some maltenes (considered a loss). TSRU tailings include valuable thermal energy as they may be at a temperature of about 80-90 degrees C.

[0032] Disclosed herein is a process to recover hydrocarbons (in the form of maltenes). In the processes herein, a flotation column equipped with a shearing device and/or gas spargers is used. The role of the shearing device (e.g., cavitation tubes, cavitation pumps, jet pumps, etc.) is to use an extensive shear in order to break the structure of asphaltene flocs in the tailings. After the breakage of asphaltene flocs, the dispersed particles get exposed to a microbubbles stream, generated through gas spargers. In this way, a greater amount of

hydrocarbons (in the form of maltenes) and heat can be retained rather than being lost to tailings.

[0033] A disclosed method comprises providing tailings from a bitumen froth treatment using solvent, introducing the tailings into a flotation column, using a shearing device to break asphaltene flocs in the tailings, introducing water and gas into the flotation column through sparging; and removing an overflow and an underflow from the flotation column. While shearing and sparging are generally described herein in this order, the method is not limited by any particular order as between the shearing and sparging. In fact, since the method is generally a continuous method, all steps are happening at once. The methods herein are directed at improved recovery of valuable hydrocarbons from the flotation column as a result of the process configurations disclosed herein. In particular, the processes herein are directed to improved maltenes recovery (valuable hydrocarbons that are normally rejected with the tailings in conventional froth treatment separation processes).

[0034] 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 gas or a gas/water mixture into a lower portion of the flotation column. In embodiments, the gas utilized may be air or a gas mixture comprised of air. 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. After, the breakage of the flocs, the small 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 flotation cell. Any suitable industrial, commercially available spargers may be used.

[0035] The bitumen froth treatment may comprise any suitable bitumen froth treatment and may be a paraffinic froth treatment. The tailings may comprise any suitable tailings from a bitumen froth treatment and may comprise tailings solvent recovery unit (TSRU) tailings. TSRU tailings are tailings exiting a TSRU following solvent recovery.

[0036] The gas may be any suitable gas and may comprise air, N₂, CO₂, CH₄, 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 CO₂, N₂ or CH₄.

[0037] The method may further comprise spraying water onto the top of a froth layer in the flotation column for mitigating minerals from reporting to the overflow.

[0038] Depending on the severity and conditions of flotation, the underflow may be a high water, low fines content stream. The underflow may be used as dilution water or process water in the bitumen froth treatment process. The underflow may be used as primary separation cell (PSC) dilution water, froth separation cell (FSU) cone dilution water, TSRU underflow dilution water, or a combination thereof. Where two FSUs are used in series (commonly referred to as FSU-1 and FSU-2), the underflow may be used in either or both FSUs. Using the underflow in these ways may significantly reduce PFT water usage and may significantly reduce heating requirements.

[0039] The method may further comprise removing solids from the overflow.

[0040] The method may comprise recycling the overflow to an FSU (e.g. FSU-1). Such recycling may lower the amount of required asphaltene rejection to meet pipeline specification by acting as a seed for asphaltene precipitation. Asphaltene seeding results in the formation of asphaltene flocs with a lower porosity and a higher density. These flocs will entrain less hydrocarbon (solvent and maltenes) as they settle through the FSU units, which ultimately reduces bitumen and solvent loss. By tuning the process variables (e.g., gas injection rate, shear, etc.) or using chemicals, it is possible to selectively recover the maltenes fraction. These additional hydrocarbons would go to FSU product upon recycling to FSU.

[0041] The method may further comprise recycling the overflow to the flotation column together with the tailings that are fed into the flotation column.

[0042] The method may further comprise using the overflow as a feedstock for producing advanced materials. The advanced materials may comprise carbon fiber, graphene oxide, or a combination thereof. The method may also further comprise sending the overflow as a feedstock to an upgrader unit, or to road paving or construction materials.

[0043] The method may further comprise adding a chemical additive or a gas additive to selectively separate maltenes during the flotation so that more maltenes report to the overflow and more asphaltenes report to the underflow as compared to without the chemical additive or the gas additive. The method may further comprise effecting a two-stage process to selectively recover maltenes, comprising: i) liberating maltenes from asphaltenes using a collector additive, gas injection, and an asphaltene flocculant; and ii) selective flotation of maltenes from asphaltenes using a chemical additive. The collector additive may comprise light hydrocarbons (e.g., pentane or kerosene). The asphaltene flocculant may comprise sulfonated polystyrene. The chemical additive may comprise a depressant, which may comprise a humic acid. The chemical additive may comprise a pH variation additive, which may comprise a multivalent metal ion.

[0044] The tailings may comprise, for example, water, 0.5 to 7 wt. % hydrocarbon, and 5 to 20 wt. % solids; or water, 10 to 20 wt. % hydrocarbon, and 10 to 20 wt. % solids; or water, 0 to 0.5 wt. % bitumen, and 1 to 5 wt. % solids.

[0045] The method may be operated at any suitable temperature and may be operated at a temperature of 20 to 90 degrees C.

[0046] The shearing device may comprise a cavitation pump, a cavitation tube, a jet pump, or a combination thereof. The shearing device may comprise a cavitation pump through which the tailings are passed prior to introduction into the flotation column (as described below with reference to Fig. 1). The shearing device may comprise a cavitation pump and subsequent cavitation tube and/or jet pump, arranged in series, through which a

portion of the underflow from the flotation column are passed prior to recycling into the flotation cell (as described below with reference to Fig. 2). The shearing device may comprise a cavitation pump through which the water and gas are passed prior to introduction into the flotation column (as described below).

[0047] The sparging may be provided by one or more spargers preferentially distributed around the flotation column.

[0048] Fig. 1 is a schematic of a process herein utilizing a flotation column. With reference to Fig. 1, a hydrocarbon-containing stream (102) is passed through a cavitation pump (103) and 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. 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).

[0049] Fig. 2 is a schematic of a process herein utilizing a flotation column. With reference to Fig. 2, a hydrocarbon-containing stream (202) is introduced into a flotation column (204) comprising a froth launder (205). Water and gas are introduced into the flotation column (204) through spargers (206) to provide bubbles for attaching to hydrocarbon. Hydrocarbon separation in the flotation column (204) produces an overflow (212) and an underflow (214), a portion (214a) which is sent for additional tailings processing. Water (not shown) may be sprayed onto the froth layer in the flotation column (204) for mitigating minerals from reporting to the overflow (212). A portion (214b) of the underflow (214) may be passed through a cavitation pump (216) and a cavitation tube and/or jet pump (218) and recycled to the flotation column (204) to shear flocs in the bitumen-containing stream (202). The water and gas may be added before the cavitation pump (216) or after the jet pump (218).

[0050] Fig. 3 is a schematic of a process herein utilizing a flotation column as used in the context of a larger system of froth treatment. With reference to Fig. 3, bitumen froth (302)

is added to a first froth separation unit (“FSU-1”) (304) which separates the bitumen froth into an FSU-1 overflow product (306) and FSU-1 underflow (308). The FSU-1 underflow (308) is passed to a second froth separation unit (“FSU-2”) (310) which produces an FSU-2 overflow (312), which is passed to FSU-1 (304), and FSU-2 underflow (314) which is passed to a first tailings solvent recovery unit (“TSRU-1”) (316). The TSRU-1 tailings (318) are passed to a second TSRU (“TSRU-2”) (320). Solvent (322 and 324) from the TSRUs is recovered and combined with a makeup solvent (326) which is recycled as recycle solvent (328) to the FSU-2 (310). TSRU-2 tailings (330), comprising solids, maltenes, asphaltenes, solvent and water, are passed to a primary flotation column (332) as described herein. The primary flotation column (332) comprises spargers, cavitation pumps, and/or jet pumps (334) (shown collectively here, but as described in more detail in Fig. 2). TSRU-2 tailings (330) are passed through and cavitation means (336) prior to entering the primary flotation column (332). A primary flotation column overflow (338) containing valuable recovered hydrocarbons is combined with the bitumen froth (302). The primary flotation column underflow (340) is passed to an asphaltene flotation column (342) which produces an asphaltene flotation column overflow (344) comprising asphaltenes, and an asphaltene flotation column underflow (346). In preferred embodiments, heat and water from the asphaltene flotation column underflow (346) is recovered by utilizing the stream in the froth treatment process.

[0051] A small scale pilot test was conducted. Oil sands tailings were fully homogenized and their temperature was adjusted to process temperature (about 60 °C). The oil sands tailings were then pumped in a small flow rate to the feed section of a flotation column with a 4 inch diameter and a height of about 2 meters. Air was injected from the bottom of column through an air sparger which created micron size bubbles. While air bubbles were rising through the column in a plug flow regime, they collided with bitumen droplets in the tailings and generated aerated droplets. Due to their small density, the aerated droplets rose in the column and collected in the column launder. The experimental conditions and measurements for the test were as follows: feed hydrocarbon content: 3 to 4 weight %, experimental temperature: 55 to 60 °C, feed solid content: 6 to 8 weight %, asphaltenes % (out

of total hydrocarbon) in feed: about 72 weight %, asphaltenes % (out of total hydrocarbons) in froth: about 73%, froth hydrocarbon content: 13 to 17 weight %, froth solid content: 16 to 17.5 weight %, hydrocarbon recovery: 84 to 99 weight %. In Table 1, 'Feed 1' represents one feed introduced into the flotation column as described above, and producing 'Froth 1' and 'Underflow 1'. The 'Recovery' represents the amount of hydrocarbons which reports to the froth, as opposed to being lost to the underflow. Similarly, 'Feed 2' produces 'Froth 2' and 'Underflow 2', 'Feed 3' produces 'Froth 3' and 'Underflow 3', and 'Feed 4' produces 'Froth 4' and 'Underflow 4'. As can be seen from the experimental data in Table 1, the tailings (underflow) appeared to contain almost no hydrocarbons after leaving the column which is aligned with the high recovery observed during the test.

Table 1

	Feed 1	Froth 1	Underflow 1	Feed 2	Froth 2	Underflow 2	Feed 3	Froth 3	Underflow 3	Feed 4	Froth 4	Underflow 4
Mass % HC	2.96	16.45	0.02	2.84	12.97	0.15	3.75	12.58	0.11	4.42	12.66	0.97
Mass % Solids	5.58	17.22	1.43	6.00	15.61	1.77	8.24	15.86	2.11	9.41	15.18	2.23
Mass % Water	89.55	64.37	97.46	89.94	69.91	97.73	87.28	70.84	97.96	84.76	71.55	97.11
Recovery	99.50			96.14			97.88			84.28		

[0052] 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) providing tailings from a bitumen froth treatment using solvent;
 - b) introducing the tailings into a flotation column;
 - c) using a shearing device to break asphaltenes flocs in the tailings;
 - d) introducing water and gas into the flotation column through sparging; and
 - e) removing an overflow and an underflow from the flotation column.
2. The method of claim 1, wherein the bitumen froth treatment is a paraffinic froth treatment.
3. The method of claim 1 or 2, wherein tailings comprise TSRU tailings.
4. The method of any one of claims 1 to 3, wherein the gas comprises air, N₂, CO₂, CH₄, or a combination thereof.
5. The method of any one of claims 1 to 4, further comprising spraying water onto a froth layer in the flotation column for mitigating minerals from reporting to the overflow.
6. The method of any one of claims 1 to 5, further comprising using the underflow as dilution water or process water in the bitumen froth treatment.
7. The method of claim 6, wherein the underflow is used as PSC dilution water, FSU cone dilution water, TSRU underflow dilution water, or a combination thereof.
8. The method of any one of claims 1 to 7, further comprising removing solids from the overflow.

9. The method of any one of claims 1 to 8, further comprising recycling the overflow to an FSU.

10. The method of any one of claims 1 to 8, further comprising recycling the overflow to an FSU for lowering an amount of required asphaltene rejection to meet pipeline specifications by acting as a seed for asphaltene precipitation.

11. The method of any one of claims 1 to 10, further comprising recycling the overflow to the flotation column.

12. The method of any one of claims 1 to 11, further comprising using the overflow as a feedstock for producing advanced materials.

13. The method of claim 12, wherein the advanced materials comprise carbon fiber, graphene oxide, or a combination thereof.

14. The method of any one of claims 1 to 11, further comprising sending the overflow to an upgrader unit.

15. The method of any one of claims 1 to 14, further comprising adding a chemical additive or a gas additive to selectively separate maltenes during the flotation so that more maltenes report to the overflow and more asphaltenes report to the underflow as compared to without the chemical additive or the gas additive.

16. The method of claim 15, further comprising effecting a two-stage process to selectively recover maltenes, comprising:

i) liberating maltenes from asphaltenes using a collector additive, gas injection, and an asphaltene flocculant; and

ii) selective flotation of maltenes from asphaltenes using a chemical additive.

17. The method of claim 16, wherein the collector additive comprises light hydrocarbons.
18. The method of any one of claims 1 to 17, wherein the tailings comprise water, 0.5 to 7 wt. % hydrocarbon, and 5 to 20 wt. % solids.
19. The method of any one of claims 1 to 18, wherein the tailings comprise water, 10 to 20 wt. % hydrocarbon, and 10 to 20 wt. % solids.
20. The method of any one of claims 1 to 19, wherein the tailings comprise water, 0 to 0.5 wt. % hydrocarbon, and 1 to 5 wt. % solids.
21. The method of any one of claims 1 to 20, wherein the method is operated at a temperature of 20 to 90 °C.
22. The method of any one of claims 1 to 21, wherein the shearing device comprises a cavitation tube, a cavitation pump, a jet pump, or a combination thereof.
23. The method of any one of claims 1 to 21, wherein the shearing device comprises a cavitation pump through which the tailings are passed prior to introduction into the flotation column.
24. The method of any one of claims 1 to 21, wherein the shearing device comprises a cavitation pump and subsequent cavitation tube and/or jet pump, arranged in series, through which a portion of the underflow from the flotation column are passed prior to recycling into the flotation cell.
25. The method of any one of claims 1 to 21, wherein the shearing device comprises a cavitation pump through which the water and gas are passed prior to introduction into the flotation column.

26. The method of any one of claims 1 to 25, wherein the sparging is provided by spargers distributed around the flotation column.

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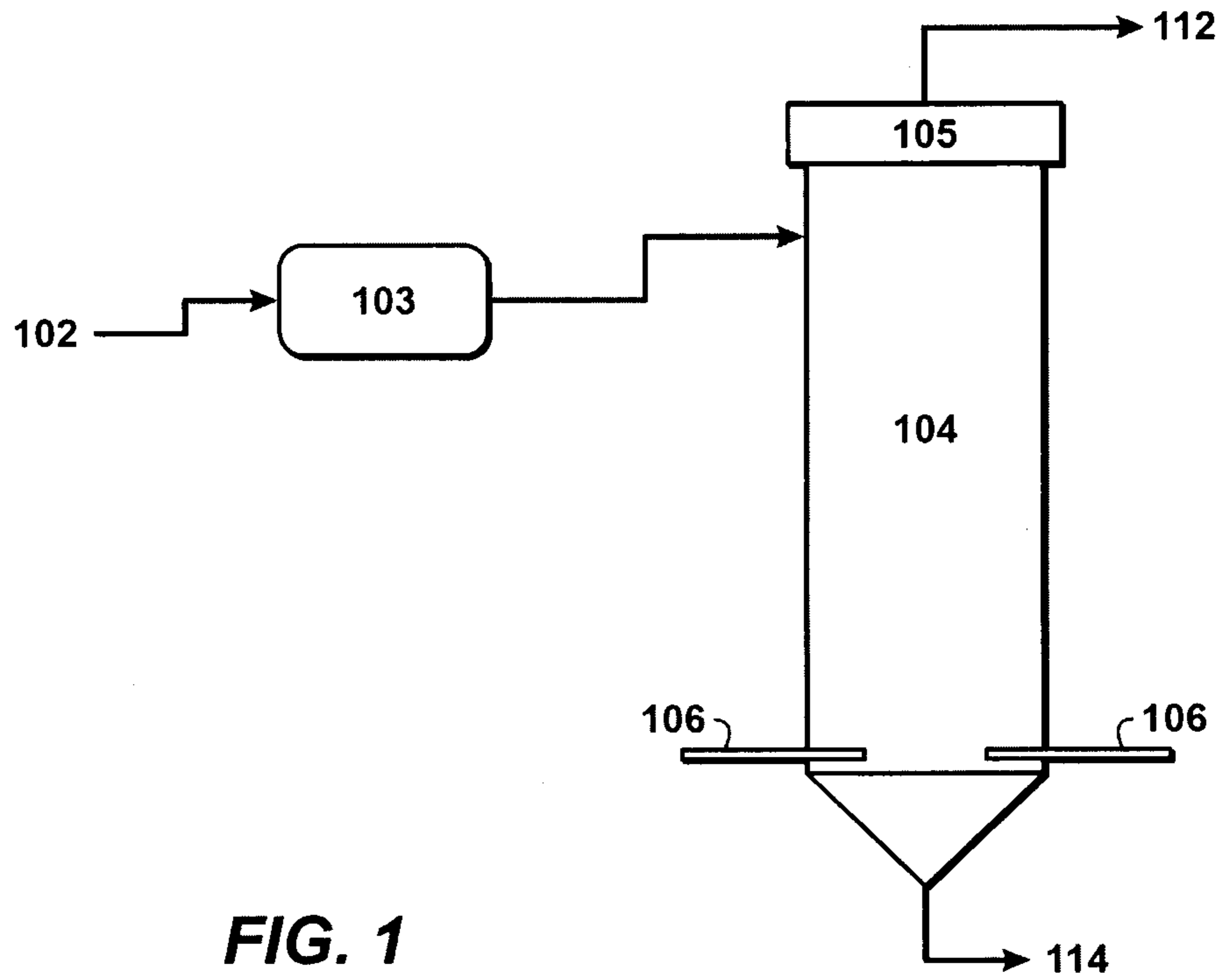


FIG. 1

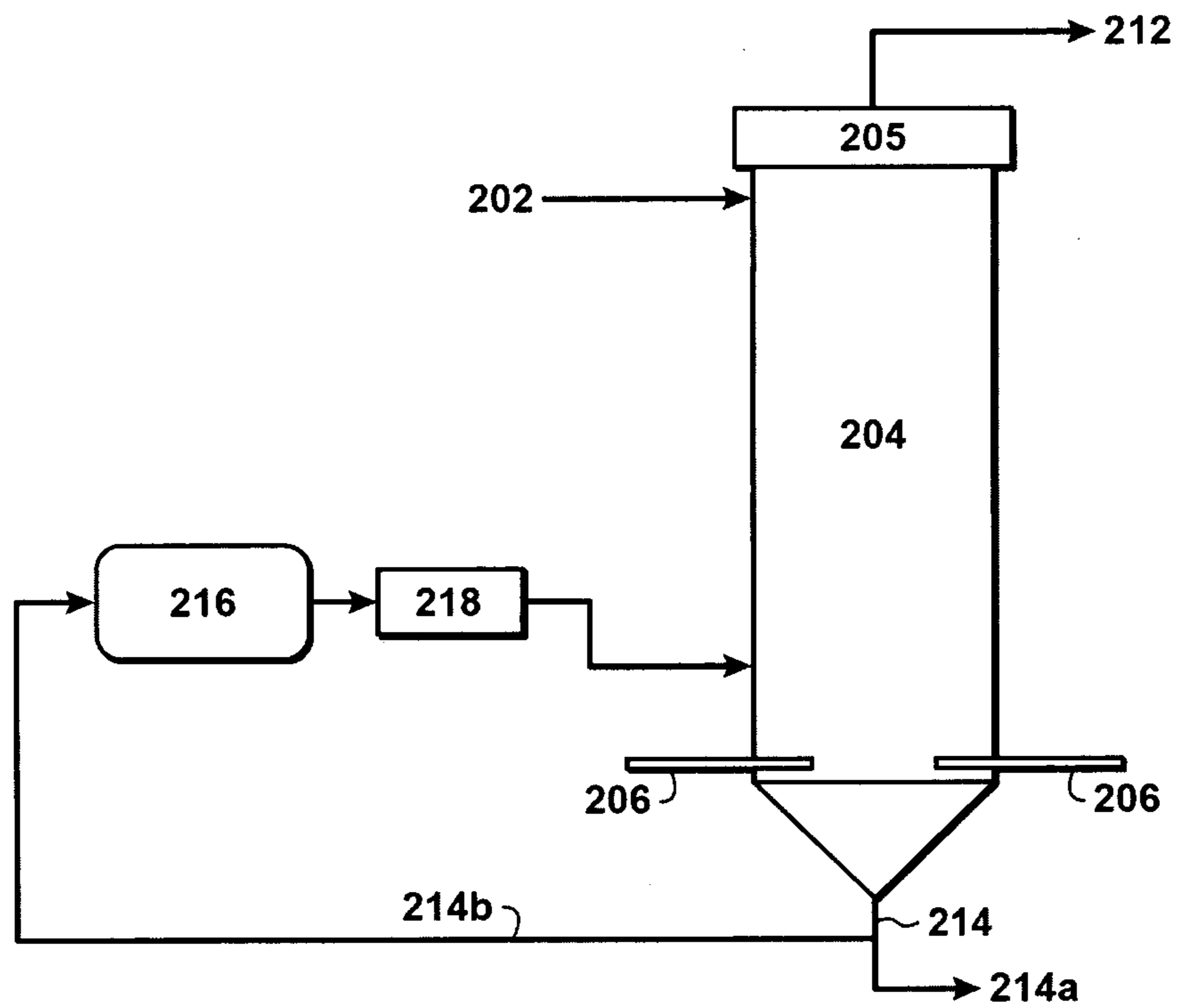


FIG. 2

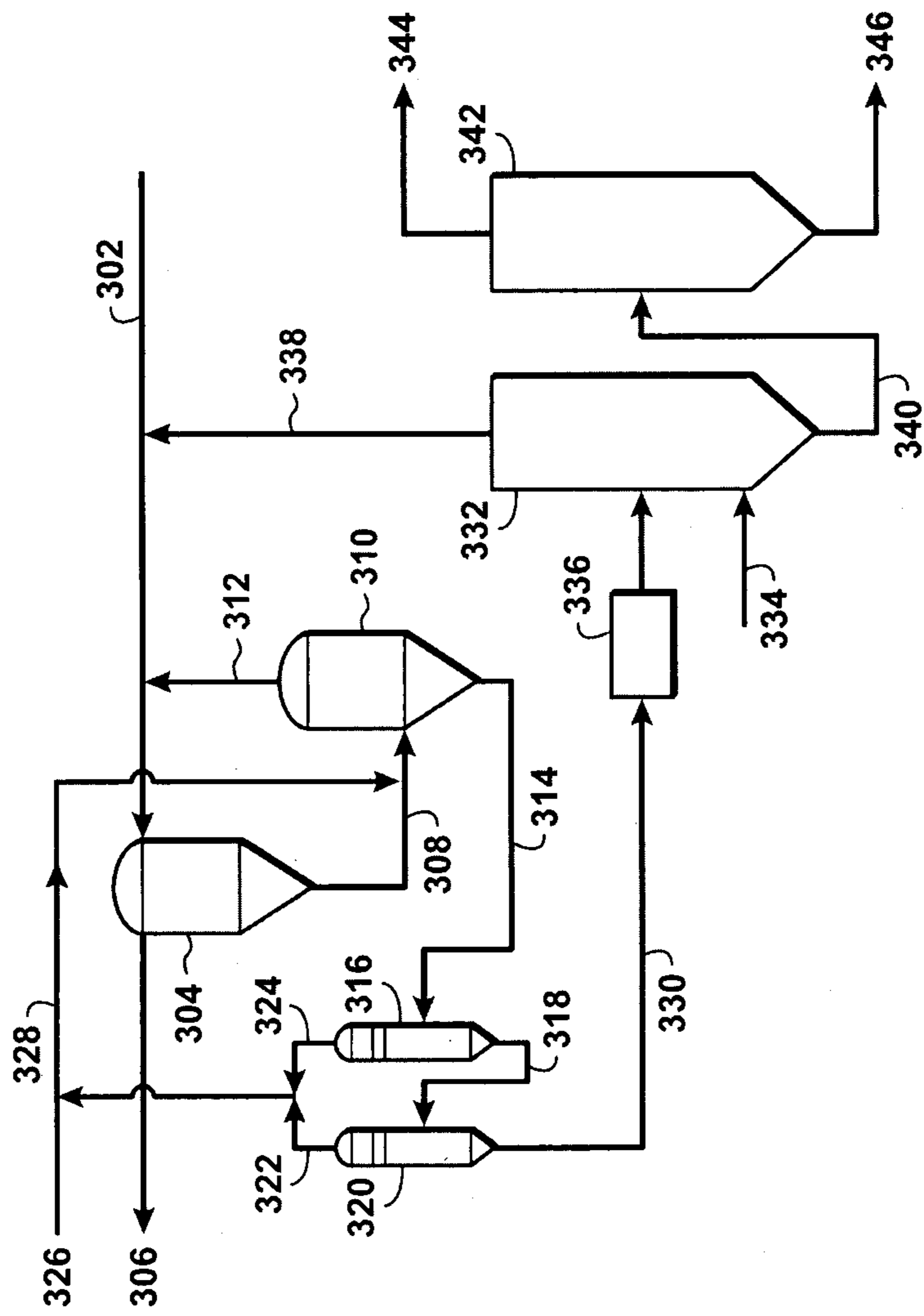


FIG. 3

