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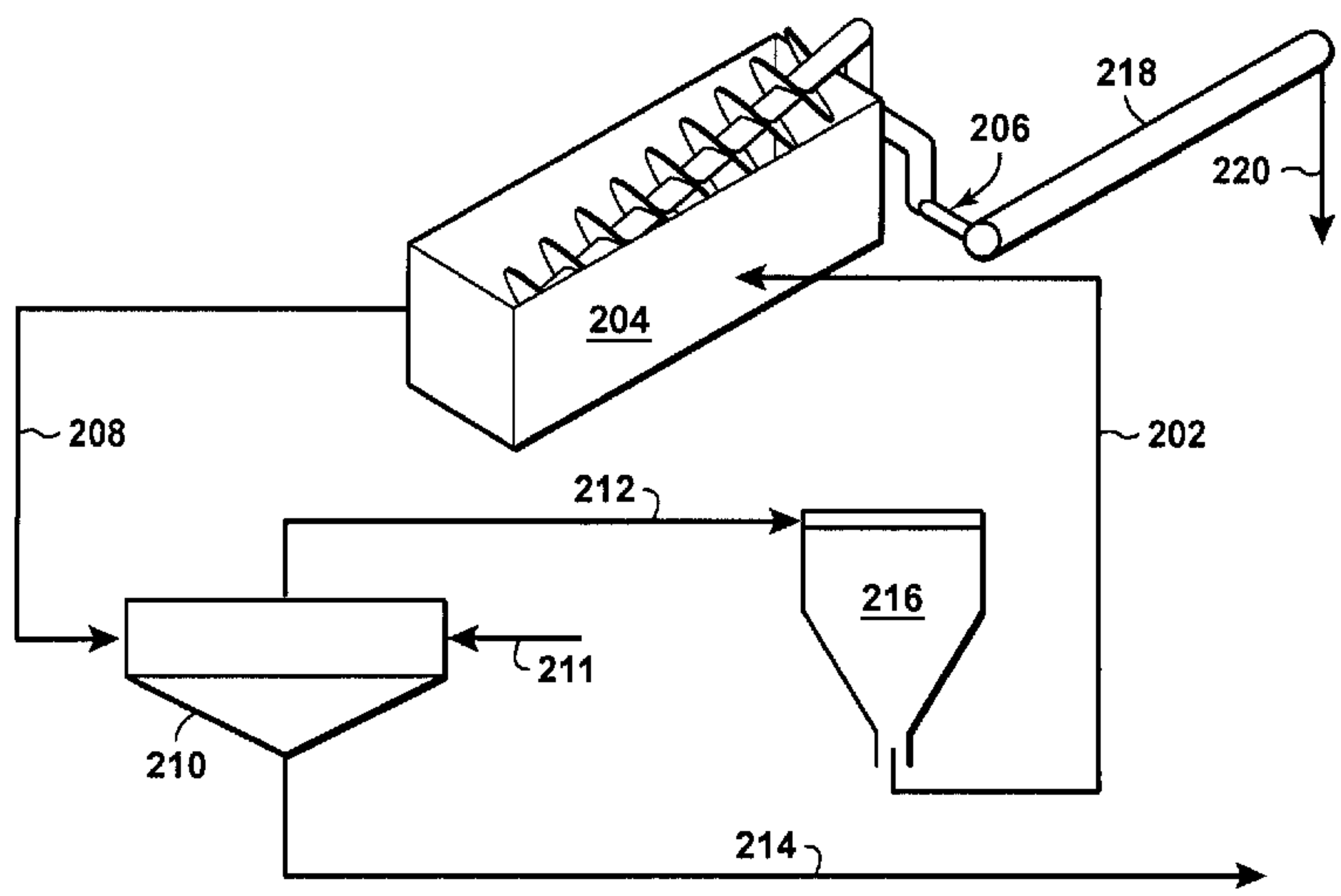

(57) Abrégé/Abstract:
A method including introducing an oil sand tailings stream into a classifier and producing a dewatered solids stream and a water-bitumen stream. By separating tailings in this way, it will be possible to increase fines capture or recover thermal energy or bitumen from the tailings.

ABSTRACT

A method including introducing an oil sand tailings stream into a classifier and producing a dewatered solids stream and a water-bitumen stream. By separating tailings in this way, it will be possible to increase fines capture or recover thermal energy or bitumen from the tailings.

OIL SAND TAILINGS SEPARATION

BACKGROUND

Field of Disclosure

[0001] The disclosure relates generally to the field of oil sand tailings.

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.

[0005] 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.

[0006] 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.

[0007] 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.

[0008] 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 primary separation tailings or coarse sand tailings (CST)).

[0009] 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 a paraffinic solvent, and are called paraffinic froth treatment (PFT) processes, to produce pipelineable bitumen with low levels of solids and water. In the PFT process, a paraffinic solvent (for example, a mixture of iso-pentane and n-pentane) is used to dilute the froth before separating the product, diluted bitumen, by gravity. A portion of the asphaltenes in the bitumen is also rejected by design in the PFT process and this rejection is used to achieve reduced solids and water levels. In both the NFT and the PFT processes, the diluted tailings (comprising water, solids and some hydrocarbon) are separated from the diluted product bitumen.

[0010] Solvent is typically recovered from the diluted product bitumen component before the bitumen is delivered to a refining facility for further processing.

[0011] The PFT process may comprise at least three units: Froth Separation Unit (FSU), Solvent Recovery Unity (SRU) and Tailings SRU (TSRU). Mixing of the solvent with the feed bitumen froth may be carried out counter-currently in two stages in separate froth separation units. The bitumen froth comprises bitumen, water, and solids. A typical composition of bitumen froth is about 60 wt. % bitumen, 30 wt. % water, and 10 wt. % solids. The paraffinic solvent is used to dilute the froth before separating the product bitumen by gravity. The foregoing is only an example of a PFT process and the values are provided by way of example only. An example of a PFT process is described in Canadian Patent No. 2,587,166 to Sury.

[0012] 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).

[0013] 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.

[0014] It would be desirable to have an alternative method of separating oil sand tailings, for instance to then recover valuable components.

SUMMARY

[0015] It is an object of the present disclosure to provide an alternative method of separating oil sand tailings, for instance to then recover valuable components.

[0016] According to one aspect, there is provided a method including introducing an oil sand tailings stream into a classifier and producing a dewatered solids stream and a water-bitumen stream. By separating tailings in this way, it may be possible to increase fines capture or recover thermal energy or bitumen from the tailings. By separating tailings in this way, it may be possible to increase fines capture or recover thermal energy or bitumen from the tailings.

[0017] 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

[0018] 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.

[0019] Figure 1 is a schematic of a method of separating oil sand tailings.

[0020] Figure 2 is a schematic of a method of separating oil sand tailings including recycling a recovered stream into a bitumen extraction process.

[0021] Figure 3 is a schematic of the spiral classifier of Figure 2 with an incorporated bitumen collection system.

[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. %), based on a 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. %, based on a weight of the bitumen. 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. The recovery of heavy oils is based on the viscosity decrease of fluids with increasing temperature or solvent concentration. Once the viscosity is reduced, the mobilization of fluid by steam, hot water flooding, or gravity is possible. The reduced viscosity makes the drainage or dissolution quicker and therefore directly contributes to the recovery rate.

[0029] "Fine particles" are generally defined as those solids having a size of less than 44 microns (μm), that is, material that passes through a 325 mesh (44 micron).

[0030] "Coarse particles" are generally defined as those solids having a size of greater than 44 microns (μm).

[0031] "Macro-agglomeration" is the consolidation of both fine particles and coarse particles that make up the oil sand. Macro-agglomerates may have a mean diameter of 2 millimeters (mm) or greater.

[0032] "Micro-agglomeration" is the consolidation of fine particles that make up the oil sand. Micro-agglomerates may have a mean diameter of less than 2 millimeters (mm).

[0033] A "bitumen extract" is generally defined as bitumen that has been extracted from oil sand.

[0034] A "bitumen product stream" or "bitumen product" is generally defined as a high grade bitumen product that may be suitable for transport within pipelines and processing within downstream refineries. A high grade bitumen product stream may have a solids content of less than 1 wt. %, or less than 0.1 wt. %, on a dry bitumen basis.

[0035] The term "solvent" as used in the present disclosure should be understood to mean either a single solvent, or a combination of solvents.

[0036] 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.

[0037] 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.

[0038] "At least one," in reference to a list of one or more entities should be understood to mean at least one entity selected from any one or more of the entity in the list of entities, but not necessarily including at least one of each and every entity specifically listed within the list of entities and not excluding any combinations of entities in the list of entities. This definition also allows that entities may optionally be present other than the entities specifically identified within the list of entities to which the phrase "at least one" refers, whether related or unrelated to those entities specifically identified. Thus, as a non-limiting example, "at least one of A and B" (or, equivalently, "at least one of A or B," or, equivalently "at least one of A and/or B") may refer, to at least one, optionally including more than one, A, with no B present (and optionally including entities other than B); to at least one, optionally including more than one, B, with no A present (and optionally including entities other than A); to at least one, optionally including more than one, A, and at least one, optionally including more than one, B (and optionally including other entities). In other words, the phrases "at least one," "one or more," and "and/or" are open-ended expressions that are both conjunctive and disjunctive in operation. For example, each of the expressions "at least one of A, B and C," "at least one of A, B, or C," "one or more of A, B, and C," "one or more of A, B, or C" and "A, B, and/or C" may mean A alone, B alone, C alone, A and B together, A and C together, B and C together, A, B and C together, and optionally any of the above in combination with at least one other entity.

[0039] Heat loss from tailings, for instance from coarse sand tailings (CST) and TSRU tailings may be significant. A commercial process to recover some of this heat has eluded the industry, possibly because of at least three challenges, namely erosion of heat exchange equipment by solids in the tailings, plugging of heat transfer internals because of large solids in the tailings, and fouling due to residual bitumen and clays in the tailings.

[0040] In addition to heat loss, bitumen loss is of course undesirable. Bitumen loss in tailings, for instance in coarse sand tailings (CST,) may be significant.

[0041] A method may comprise providing an oil sand tailings stream, introducing the oil sand tailings stream into a classifier and producing a dewatered solids stream and a bitumen-water stream. By separating tailings in this way, it may be possible to increase fines capture or recover thermal energy or bitumen from the tailings.

[0042] The oil sand tailings stream may be any suitable stream stemming from oil sand. Examples include, but are not limited to, coarse sand tailings (also known as primary separation tailings and CST), middlings, fine tailings (FT), 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 comprise coarse sand tailings (CST), tailings solvent recover unit (TSRU) tailings, fine tailings (FT), or a combination thereof. The oil sand tailings stream may be at a temperature of at least 30°C, at least 60°C, between 30°C and 100°C, between 30°C and 70°C, or between 60°C and 100°C. The oil sand tailings stream may comprise coarse sand tailings (CST) at a temperature of at least 35°C, or between 35°C and 70°C. The oil sand tailings stream may comprise tailings solvent recover unit (TSRU) tailings at a temperature of at least 70°C, or between 70°C and 100°C. The oil sand tailings stream may stem from solvent based extraction. The tailings may comprise fine tailings (FT) at a temperature of at least 30°C, or between 30°C and 60 °C. The oil sand tailings stream may comprise CST and FT.

[0043] In the processes herein, the classifier may be any suitable classifier and may preferably be a spiral classifier. The spiral classifier may comprise an auger disposed at an angle from horizontal and for moving the dewatered solids stream up in the classifier. The classifier may be a spiral/screw, rotary high weir, hydraulic, rake, cross- flow, cone, pyramid, or Allen cone classifier. The classifier may include a material that mitigates bitumen coating or deposition. In preferred embodiments herein, the internals of the classifier may be coated with a hydrophilic, oleophobic coating. Additionally, an additive may be introduced into the tailings line to reduce bitumen coating on the classifier.

[0044] The dewatered solids stream herein is a stream with a reduced water content, a reduced bitumen content, and an increased solids content, as compared to the oil sand tailings stream. By way of example only, the dewatered solids streams may have a solids content of 60 to 100%. The term "dewatered" do not imply any particular quantitative water reduction or water level and certainly does not mean that no water remains in the dewatered solids stream.

[0045] Conversely, the bitumen-water stream herein is a stream with an increased water content, an increased bitumen content, and a decreased solids content, as compared to the oil sand tailings stream. The bitumen-water stream may comprise fines and, as practical matter, will inevitably include some fines.

[0046] In an embodiment, a chemical reagent may be added to the classifier for increasing fines removal via flocculation in the dewatered solids stream. Unsettled fines may be removed from the classifier as a fines rich stream. A chemical reagent may be added to the fines rich stream to form a flocculated fines stream, and the flocculated fines stream may be recycled to the classifier for increasing fines removal in the fines rich stream. The chemical reagent may comprise a flocculent, a coagulant, or a combination thereof.

[0047] Figure 1 is a schematic of a method of separating oil sand tailings. An oil sand tailings stream (102) may be introduced into a classifier (104), producing a dewatered solids stream (106), a bitumen-water stream (108), and a fines rich stream (110). The fines rich stream (110) may be combined with a chemical reagent (112) to form a flocculated fines stream (114), which may then recycled to the classifier for increasing fines removal in the dewatered solids stream.

[0048] The bitumen-water stream may be introduced into a thickener and a thickener overflow and a thickened tailings stream may be produced. The thickener may be any suitable thickener or may be another classifier. Alternatively, the bitumen-water stream may be introduced into another part of the extraction process.

[0049] The thickener overflow may be introduced into a bitumen extraction process, for instance into a primary separation cell (PSC), for recovering thermal energy, bitumen, or both, from the oil sand tailings stream. The coarse sand tailings (CST) from the bitumen extraction process may be used as the oil sand tailings stream.

[0050] A dispersant or air may be added to the oil sand tailings stream or to the classifier for assisting bitumen recovery.

[0051] The dewatered stream may be used as construction material, or blended with aggregates for use as construction sand. The dewatered solids stream may be transported to a discharge area, for instance by conveyor belt.

[0052] Figure 2 is a schematic of a method of separating oil sand tailings including recycling a recovered stream into a bitumen extraction process. Coarse sand tailings (CST) (202) may be introduced into a spiral classifier (204) with an auger, producing a dewatered solids stream (206) and a bitumen-water stream (208). The bitumen-water stream (208) may be introduced into a thickener (210) and a thickener overflow (212) and a thickened tailings stream (214) may be produced. A tailings stream (211), for instance fine tailings or fluid fine tailings may also be added to the thickener (210). The thickener overflow (212) may be introduced in a primary separation cell (PSC) (216) forming coarse sand tailings (CST) (202). The dewatered solids stream (206) may be transported to a discharge area, for instance by conveyor belt (218), to deposit the conveyed CST (220). The solid content of dewatered solids stream (206) may be adjusted by the speed of auger of the classifier, with the higher the RPM, the lower solid content.

[0053] Figure 3 is a schematic of the spiral classifier (204) of Figure 2 with an incorporated bitumen collection system. As shown in Figure 3, in an embodiment, a bitumen collection system may be used to collect a bitumen-rich (302) stream from the top of the classifier. The classifier may comprise a weir (304) for mitigating bitumen contact of floating bitumen with an auger section of the classifier.

[0054] Mature fine tailings (MFT) may be added to the dewatered solids stream to provide a flowable tailings stream while increasing fines content of the dewatered solid stream. The flowable tailings stream may be transported to a point of discharge using pumps. The pumps may comprise positive displacement pumps or centrifugal pumps. The dewatered solids stream may be blended with mature fine tailings (MFT). The dewatered solids stream may be blended with mature fine tailings (MFT) in a weight ratio of dewatered solids stream to MFT of 7:1 to 3:1.

[0055] 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 an oil sand tailings stream;
   b) introducing the oil sand tailings stream into a classifier;
   c) adding a chemical reagent to the classifier for increasing fines removal via flocculation;
   d) removing unsettled fines from the classifier as a fines rich stream;
   e) producing a dewatered solids stream and a water-bitumen stream from the classifier;
   f) adding the chemical reagent to the fines rich stream to form a flocculated fines stream; and
   g) recycling the flocculated fines stream to the classifier for increasing fines removal in the fines rich stream.

2. The method of claim 1, further comprising introducing the water-bitumen stream into a thickener and producing a thickener overflow and a thickened tailings stream.

3. The method of claim 2, further comprising recycling the thickener overflow into a bitumen extraction process for recovering thermal energy, bitumen, or both from the oil sand tailings stream.

4. The method of claim 2, further comprising recycling the thickener overflow into a primary separation cell (PSC) of a bitumen extraction process for recovering thermal energy, bitumen, or both from the oil sand tailings stream.

5. The method of claim 1, wherein the chemical reagent comprises a flocculent, a coagulant, or a combination thereof.

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6. The method of any one of claims 1 to 5, further comprising adding a dispersant or air to the oil sand tailings stream or to the classifier for assisting bitumen recovery.

7. The method of any one of claims 1 to 6, wherein the classifier is a spiral classifier.

8. The method of claim 7, wherein the spiral classifier comprises an auger disposed at an angle from horizontal and for moving the dewatered solids stream up in the classifier.

9. The method of any one of claims 1 to 8, wherein the oil sand tailings stream comprises aqueous extraction tailings.

10. The method of any one of claims 1 to 8, wherein the oil sand tailings stream comprises coarse sand tailings (CST), fine tailings (FT), tailings solvent recovery unit (TSRU) tailings, or a combination thereof.

11. The method of any one of claims 1 to 8, wherein the oil sand tailings stream comprises coarse sand tailings (CST).

12. The method of any one of claims 1 to 8, wherein the oil sand tailings stream comprises tailings solvent recovery unit (TSRU) tailings.

13. The method of any one of claims 1 to 8, wherein the oil sand tailings stream comprises coarse sand tailings (CST) and is at a temperature of at least 35°C.

14. The method of any one of claims 1 to 8, wherein the oil sand tailings stream comprises tailings solvent recovery unit (TSRU) tailings and is at a temperature of at least 70°C.

15. The method of any one of claims 1 to 8, wherein the oil sand tailings stream comprises fine tailings (FT) and is at temperature of at least 30°C.

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16. The method of any one of claims 1 to 8, wherein the oil sand tailings stream comprises coarse sand tailings (CST) and fine tailings (FT).

17. The method of claim 4, further comprising using coarse sand tailings from the bitumen extraction process as the oil sand tailings stream.

18. The method of any one of claims 1 to 17, wherein the dewatered solids streams has solids content of 60 to 100%.

19. The method of any one of claims 1 to 18, further comprising using the dewatered stream as construction material.

20. The method of any one of claims 1 to 19, further comprising blending the dewatered solids stream with aggregates for use as construction sand.

21. The method of any one of claims 1 to 20, further comprising transporting the dewatered solids stream to a discharge area.

22. The method of claim 21, wherein the transporting is by conveyor belt.

23. The method of any one of claims 1 to 22, further comprising adding mature fine tailings (MFT) to the dewatered solids stream to provide a flowable tailings stream while increasing fines content of the dewatered solid stream.

24. The method of claim 23, further comprising transporting the flowable tailings stream to a point of discharge using pumps.

25. The method of claim 24, further comprising blending the dewatered solids stream with mature fine tailings (MFT).

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26. The method of claim 25, wherein the dewatered solids stream is blended with mature fine tailings (MFT) in a weight ratio of dewatered solids stream to MFT of 7:1 to 3:1.

27. The method of claim 26, wherein the pumps comprise positive displacement pumps or centrifugal pumps.

28. The method of any one of claims 1 to 27, further comprising adjusting a speed of an auger of the classifier for adjusting a solids content of the dewatered solids stream.

29. The method of any one of claims 1 to 28, wherein the classifier comprises a weir for mitigating floating bitumen from contacting an auger section of the classifier.

30. The method of any one of claims 1 to 29, further comprising wherein the classifier comprises a bitumen collection system and collecting a bitumen-rich stream from the classifier.

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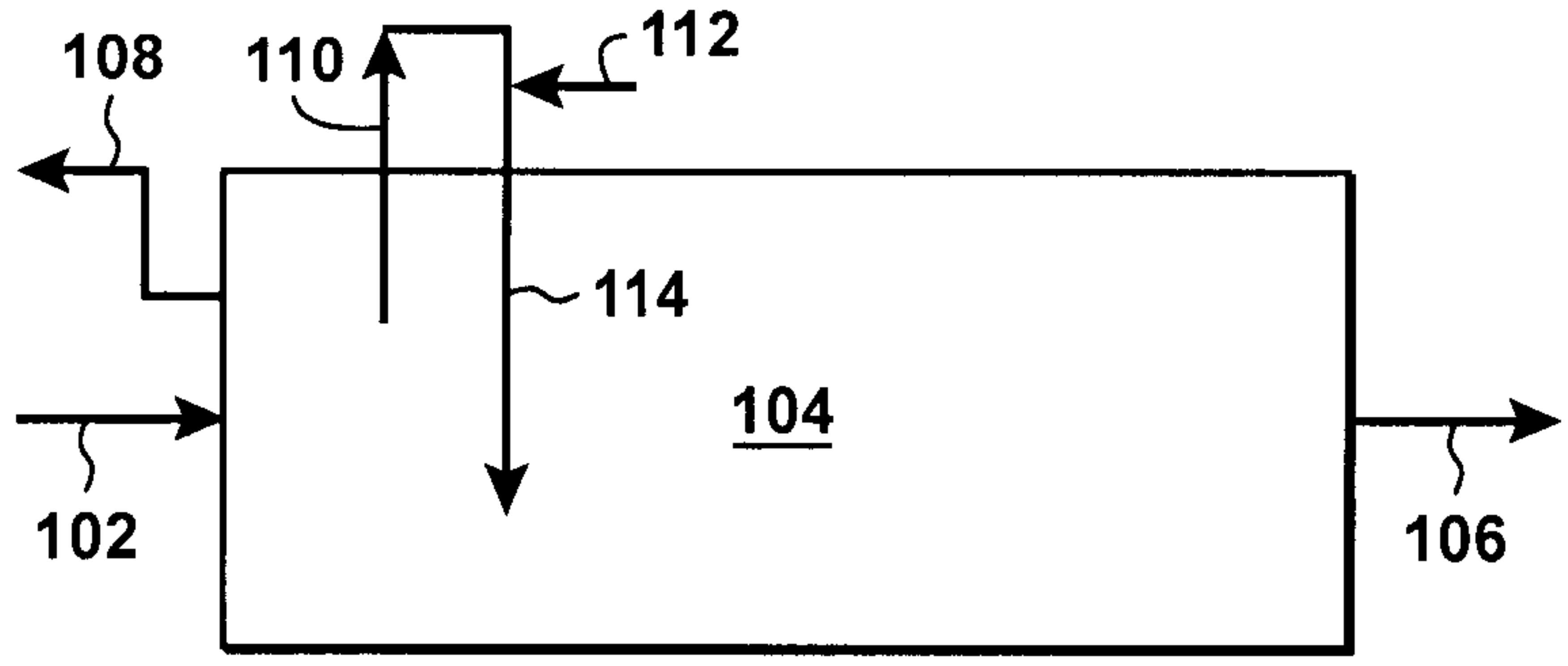


FIG. 1

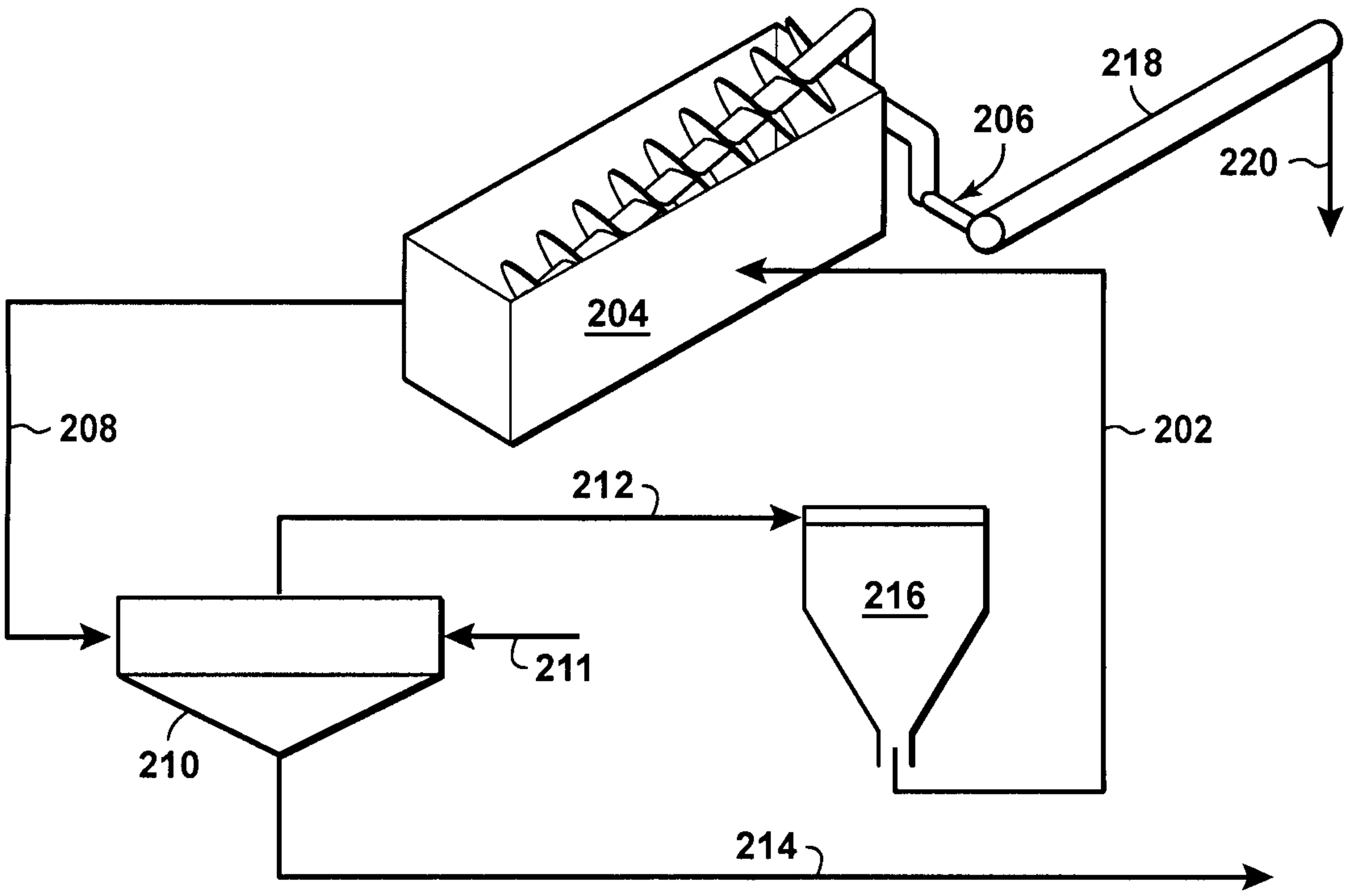


FIG. 2

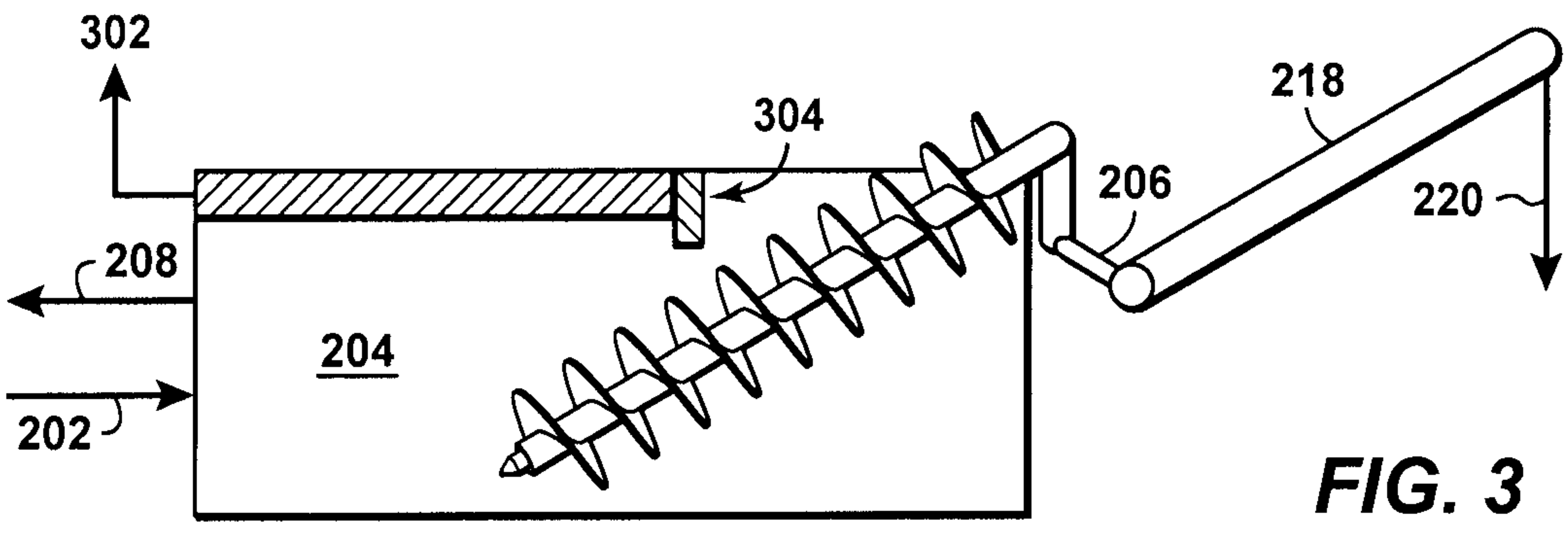
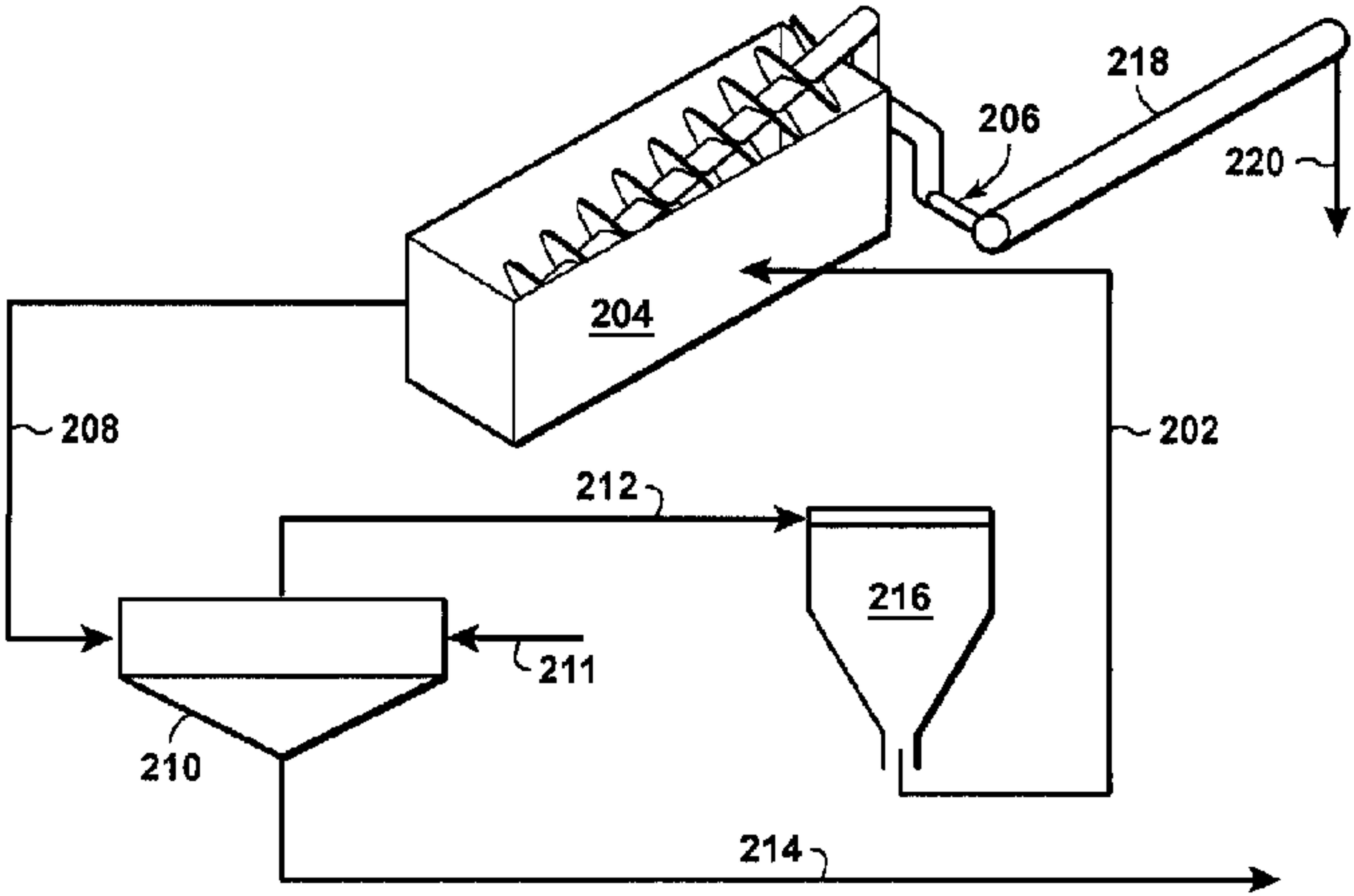


FIG. 3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