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(54) Title: METHOD FOR TREATING MINE WASTE

(57) Abrégé/Abstract:

A method for treating mine waste is described. The method includes forming a flocculated stream by adding a first flocculant to a waste stream derived from a water based extraction of bitumen from oil sands. The waste stream comprises fine particles and solids. The flocculated stream is transported to a disposal area. A reflocculated stream is formed by adding a second flocculant to the flocculated stream after transporting the flocculated stream. The reflocculated stream is deposited in a deposition area within the disposal area. The first flocculant and the second flocculant comprise a non-ionic polymer and an anionic polymer.



ABSTRACT

A method for treating mine waste is described. The method includes forming a flocculated stream by adding a first flocculant to a waste stream derived from a water based extraction of bitumen from oil sands. The waste stream comprises fine particles and solids. The flocculated stream is transported to a disposal area. A reflocculated stream is formed by adding a second flocculant to the flocculated stream after transporting the flocculated stream. The reflocculated stream is deposited in a deposition area within the disposal area. The first flocculant and the second flocculant comprise a non-ionic polymer and an anionic polymer.

METHOD FOR TREATING MINE WASTE

FIELD OF DISCLOSURE

[0001] The disclosure relates generally to the field of oil sands processing. More specifically, the present disclosure relates to a method for treating mine waste.

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] The harvesting of oil sands to remove heavy oil has become more economical. Hydrocarbon removal from oil sands may be performed by several techniques (i.e., bitumen extraction processes). 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 sands, which can be

treated with hot water, steam or solvents to extract the heavy oil. This other technique may be referred to as a water-based extraction (WBE) process. The WBE process is a commonly used process to extract bitumen from mined oil sands. Extracting hydrocarbons using hot water from oil sands creates waste. Treating and reducing waste presents a challenge to the industry.

[0005] A WBE process that uses hot water extraction may create waste streams, typically referred to as tailings. The hot water extraction may involve crushing oil sands ore and mixing the crushed oil sands ore with hot water to form a slurry. To optimize the efficiency of the hot water extraction, the ore may be conditioned into small particles, and dispersion agents may be added. Upon dispersion, fine particles (or “fines”), substantially comprised of clay, may be suspended in a waste stream to form an emulsion. Valuable products, such as hydrocarbons, may float to the surface of the waste stream and be extracted. The remaining materials that are not extracted, or tailings, are treated as waste streams which may be subjected to dewatering and drying in a deposition area. Fine particles in waste streams may take many years to settle. This results in tailings ponds, which are associated with environmental and operating cost concerns.

[0006] Current technologies for WBE processes involve thickening and in-line flocculation. The result of in-line flocculation (or “flocs”) can be sheared during transportation in which case the water entrained in a flocculated stream of liquid cannot be adequately released; the drying process proceeds too slowly to reach regulation requirements for transportation. Upon shearing, the rheology properties of flocs present challenges to slope regulation requirements in deposition areas. After releasing water from a flocculated stream, and settlement of flocs from the flocculated stream following transportation, a concentrated flocculated stream is formed, having a lower permeability than the flocculated stream. As a result, drainage of water from the deposition area is impeded.

[0007] Other technologies for WBE processes include layering, sand loading, chemically induced micro agglomeration (CIMA), and dewatering a slurry using electrolysis tubes, among others. For example, Canadian Patent Application No. 2,515,581 describes a

process for rigidifying an aqueous suspension of WBE waste by adding a water soluble polymer during transfer to a deposition area. U.S. Patent No. 6,077,441 describes a process in which aqueous waste is flocculated in a well of a sedimentation lagoon, following which thickened sediment is permitted to solidify by settling and evaporation. European Patent Publication EP 0388108 describes a process in which a water-swellaable water-insoluble polymer is added to an aqueous dispersion of particulate clay or mud solids to promote rigidification.

[0008] Another process for strengthening tailings from WBE is described in US Patent Publication 2013/0019780. The described process mixes geopolymers, such as fly ash or cement, with thickened fluid fine tailings with shear, to increase the yield strength of tailings deposits. The geopolymers act to absorb water present in the tailings and to form a gel, but water is not released from the gel.

[0009] Another WBE process is described in WO 2011/097367, which describes the use of superabsorbent polymers to modify the rheology or physical stability of composite slurry derived from oil sands tailings. However, in this method some of water absorbed by the superabsorbent polymers cannot be recovered or recycled back into the WBE process.

[0010] In addition to some of the aforementioned disadvantages described with respect to the aforementioned WBE processes, some of the aforementioned WBE processes used for handling waste streams face the challenge that water entrained in the waste stream following transportation is difficult to remove or drain from the waste stream.

[0011] In view of the aforementioned disadvantages, there is a need for alternative methods for treating mine waste. More specifically, there is a need for alternative methods for treating mine waste that allow water to be recovered following transportation to a deposition area.

SUMMARY

[0012] It is an object of the present disclosure to provide a process for treating a waste stream derived from water based extraction of oil sands.

[0013] A method for treating mine waste may comprise (a) forming a flocculated stream by adding a first flocculant to a waste stream from a water based extraction of bitumen from oil sands, the waste stream comprising fine particles and solids; (b) transporting the flocculated stream to a disposal area; (c) forming a reflocculated stream by adding a second flocculant to the flocculated stream after transporting the flocculated stream; and (d) depositing the reflocculated stream in a deposition area located within the disposal area. The first flocculant and the second flocculant may comprise a non-ionic polymer and an anionic polymer.

[0014] 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

[0015] 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.

[0016] **Figure 1** is a chart showing a method for treating mine waste.

[0017] **Figure 2** represents a system for treating mine waste.

[0018] **Figure 3** is a diagram representing the transportation and flow of streams involved in oil sands extraction from a mine site.

[0019] **Figure 4** is a chart illustrating peak shear stress for flocculated streams, over time.

[0020] 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

[0021] 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.

[0022] 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 methods are not limited by the usage of the terms shown below, as all equivalents, synonyms, new developments, terms, methods, or processes that serve the same or a similar purpose are considered to be within the scope of the present disclosure.

[0023] 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 sands. 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.

[0024] “Bitumen” is a naturally occurring heavy oil material. Generally, it is the hydrocarbon component found in oil sands. 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. %).

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.

[0025] The term “bituminous feed” refers to a stream derived from oil sands that requires downstream processing in order to realize valuable bitumen products or fractions. The bituminous feed is one that comprises bitumen along with undesirable components, notably: solids and water. Such a bituminous feed may be derived directly from oil sands, and may be, for example, raw oil sands ore. Further, the bituminous feed may be a feed that has already realized some initial processing but nevertheless requires further processing. Also, recycled streams that comprise bitumen in combination with other components for removal as described herein can be included in the bituminous feed. A bituminous feed need not be derived directly from oil sands, but may arise from other processes. For example, a waste product from other extraction processes which comprises bitumen that would otherwise not have been recovered may be used as a bituminous feed.

[0026] “Heavy oil” includes oils which are classified by the American Petroleum Institute (“API”), as heavy oils, extra heavy oils, or bitumen. The term “heavy oil” includes bitumen as well as lighter materials that may be found in a sand or carbonate reservoir. 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/m³ or 1 g/cm³). 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 quicker and therefore directly contributes to the recovery rate.

[0027] “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).

[0028] “Coarse particles” are generally defined as those solids having a size of greater than 44 microns (µm).

[0029] The term “mine waste” refers to a fraction derived from oil sand, which remains following one or more step in the mining, extraction, or refining of a desired bitumen-containing fraction. Many mining, extraction and refining steps result in mine waste which may go directly to disposal, or may go on to further processing, for example to remove remaining bitumen or other components. Mine waste may contain water. Mine waste may be treated to remove the water. Mine waste may be in the form of a solid of fine or coarse particles, a semi-solid, a liquid, or a combination of these. For example, mine waste may be in the form of a flowable suspension such as a stream containing solids, such as fine particulate solids, and liquid. A flowable stream of mine waste may be referred to herein as a “waste stream”.

[0030] The term “waste stream” as used herein denotes a flowable stream derived from an oil sands extraction process or method. The waste stream may be a suspension of solids. A waste stream is a flowable stream that remains following the removal of a bitumen-containing fraction of extracted oil sand. The bitumen content of the waste stream, when present, may be difficult to remove. Thus it may not be practical or cost effective to remove bitumen from the waste stream. Waste streams may conventionally be sent directly to disposal, or may be sent to further processing for removal of additional components such as

bitumen, water, solids, etc. prior to disposal. Waste streams may include flotation tailings (FT), fluid fine tailings (FFT), mature fine tailings (MFT) or a combination of FT and FFT/MFT, or tailings solvent recovery unit (TSRU) tailings. Waste streams to which one or more flocculants have been added (such as the first flocculant and the second flocculant) to form a flocculated stream or a reflocculated stream are also types of waste streams.

[0031] 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.

[0032] The term “exemplary” is used herein as an adjective to identify an example, but is not intended to imply that the example being described is superior or preferable.

[0033] 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.

[0034] Where two or more ranges are used, such as 1 to 5 or 2 to 4, any number between or inclusive of these ranges is implied.

[0035] “Slope,” as discussed herein may be expressed as a percentage based on rise-over-run in distance per unit distance. Specifically, an elevational increase of a 5 m distance over a 100 m distance is a 5% slope. Slope may alternatively be considered in terms of the degree of slope relative to vertical (where vertical represents a 90 degree slope). To illustrate conversion between % slope and degrees: a 5% slope could equally be expressed as a 4.5 degree slope.

[0036] The present disclosure provides a method 100 and system 200 (**Figure 1-Figure 2**) for treating mine waste. More specifically, the present disclosure provides a

method 100 and system 200 for treating a waste stream. The system 200 may be referred to as a waste treatment system.

[0037] The method 100 and system 200 may comprise forming a flocculated stream 214 by adding a first flocculant 212 to a waste stream 211 from a WBE process of bitumen from oil sands, 102 (**Figure 1**). A flocculant, such as but not limited to the first flocculant 212, may be a component that permits aggregation of solids suspended in solution into aggregates referred to as “flocs”. In other words, the addition of the first flocculant 212 to the waste stream 211 may allow for the formation of a flocculated stream 214 in which fine particles and other solids come together to form flocs. A flocculated stream may be one in which suspended solids within a flowable stream of liquid aggregate or coalesce together to form masses of particles or flocs, which can precipitate within the stream. The first flocculant 212 may permit the suspended solids to aggregate or coalesce into aggregate masses of precipitate. The term “flocculated stream” as used herein refers to the waste stream upon addition of the first flocculant. The flocculated stream contains flocs as a result of the addition of the first flocculant. The amount of flocs present can vary in the flocculated stream. The extent to which the fine particles or solids within the flocculated stream are present can vary in the flocculated stream. The waste stream to which the first flocculant is added may itself have some amount of flocculation therein prior to the addition of the first flocculant.

[0038] The waste stream 211 may comprise fine particles and solids. The waste stream 211 may be thickened prior to adding the first flocculant 212. Prior to adding the first flocculant 212, water may be removed from the waste stream. Prior to adding the first flocculant 212 to the waste stream 211, fine tailings may be added to the waste stream. Removing the water from and/or adding the fine tailings to the waste stream may generate a concentrated waste stream to which the first flocculant 212 is added, thereby forming a flocculated stream that is more concentrated in solids, than if water is not removed from and/or fine tailings are not added to the waste stream before adding the first flocculant 212 to the waste stream, when transported to the disposal area.

[0039] The flocculated stream 214 may be allowed to settle. For example, the flocculated stream 214 may be allowed to settle in a gravity settling vessel from which underflow exits. Allowing the flocculated stream 214 to settle may concentrate flocs, thereby forming a concentrated flocculated stream. The concentrated flocculated stream may be further concentrated by being allowed to settle, for instance within a second gravity settling vessel.

[0040] The method 100 may comprise transporting the flocculated stream 214 to a disposal area 220, 104 (**Figure 1**). The disposal area 220 may be a region to which a flocculated stream 214 is transported. The disposal area 220 may define a location to which mine waste is directed after conducting bitumen extraction processes such as WBE. The disposal area 220 may be spaced away from a mining area from which the oil sand is derived. The disposal area 220 may be an External Tailings Area (ETA). The ETA may be an outdoor area to which coarse and fine tailings are directed for settling, such as but not limited to a tailings pond. The flocculated stream 214 may be transported to the disposal area 220 via any acceptable mode. For example, the flocculated stream 214 may be transported by pipeline 216 to the disposal area 220.

[0041] The method 100 may comprise forming a reflocculated stream by adding a second flocculant 218 to the flocculated stream 214 after transporting the flocculated stream 214, 106 (**Figure 1**). The second flocculant 218 may serve to coalesce suspended particles, such as but not limited to solids comprising coarse or fine particles, remaining suspended in the flocculated stream. The term “reflocculated stream” as used herein refers to the stream formed upon addition of the second flocculant to the flocculated stream. Reflocculation may refer to a second, subsequent, or additional flocculation (following the addition of the first flocculant), but does not necessarily imply that the previous flocculation has somehow become undone or reversed. The reflocculated stream may be subjected to further flocculation as a result of the addition of the second flocculant. The amount of flocs or the extent to which the flocs, fine particles or solids within the reflocculated stream are present can vary in the reflocculated stream.

[0042] The addition of the second flocculant 218 to the flocculated stream 214 may be done in any suitable manner, such as within a container or vessel, or by combining the flow of the flocculated stream 214 with the flow of a stream containing the second flocculant 218. For example, the second flocculant 218 may be added to the flocculated stream 214 in a vessel to form the reflocculated stream. The vessel may be at or near the end of a pipeline 216 if the flocculated stream 214 is transported via pipeline 216 to the disposal area 220. The vessel may be located near where the flocculated stream 214 exits the pipeline 216 in a deposition area 222 if the flocculated stream 214 is transported by pipeline 216 to the disposal area 220, and the reflocculated stream 219 can exit the vessel directly into the deposition area 222. A concurrent flow of the flocculated stream 214 with the second flocculant 218 can be used to form the reflocculated stream 219, for subsequently depositing the reflocculated stream directly in the deposition area 222, without mixing the reflocculated stream in a vessel.

[0043] The method 100 may comprise depositing the reflocculated stream 219 in the deposition area 222 108 (**Figure 1**). The depositing of the reflocculated stream 219 may permit release of water 224 from the reflocculated stream. Releasing water 224 from the reflocculated stream 219 may occur after adding the second flocculant 218 to the flocculated stream 214. The deposition of the reflocculated stream 219 in the deposition area 222 may allow precipitated flocs to settle. Allowing precipitated flocs to settle may lead to the release of water 224 from the reflocculated stream 219. Once the reflocculated stream 219 is deposited, water 224 may flow away from the precipitated flocs as a consequence of settling and/or gravity.

[0044] The disposal area 220 may include one or more deposition area 222. The deposition area 222 may be a specific location within the disposal area 220 where the reflocculated stream 219 is directly deposited. Thus, for example, a reflocculated stream 219 may be directed to the disposal area 220 by pipeline 216. The reflocculated stream 219 may be deposited in the deposition area 222; the deposition area 222 may be beneath or directly beneath a terminal end of the pipeline 216. When more than one deposition area 222 is present in the disposal area 220, a plurality of reflocculated streams may be directed to the disposal area 220 simultaneously. When more than one deposition area 222 is present in the

disposal area 220, the one or more deposition areas may receive the reflocculated streams at different times.

[0045] A deposition area may or may not have a slope. A deposition area 222 may have a slope of from 0.5% (percent) to 10%. A deposition area 222 may have a slope of from 1% to 4%. The slope of a deposition area 222 may be any number within or bounded by any of the preceding ranges. The deposition area may not initially have a slope. But the slope may form as the reflocculated stream 219 is deposited in the deposition area 222 because subsequent removal of water 224 from the deposition area 222 may form a pile having a centrally elevated portion, tapering downwardly toward the edges. The deposition area 222 may never have a slope.

[0046] The water 224 released at the deposition area 222 may be collected in the deposition area. The water 224 released at the deposition area 222 may be recycled for use in forming the first flocculant 212 and/or the second flocculant 218. The water released at the deposition area may be recycled for use in forming the first flocculant and/or the second flocculant by dissolving the anionic and non-ionic polymers in the water prior to adding the first flocculant to the waste stream and/or the second flocculant to the flocculated stream. The water 224 released at the deposition area 222 may drain out through a water-permeable material at the bottom of the deposition area. The water released at the deposition area may evaporate. The water released at the deposition area may be recycled to the WBE process. The water 224 released at the deposition area 222 may be collected from an end region of the deposition area.

[0047] The addition of a flocculant, such as but not limited to a first flocculant to a waste stream before or during transport of the waste stream, has the benefit that contact of flocculant with fine particles and/or solids in the waste stream occurs as the stream is agitated by the movement of transport. This agitation causes mixing of the flocculant with the fine particles and/or solids content of the waste stream. Thus, the mixing of flocculant with fine particles and/or solids may occur during transport to prepare a flocculated stream. During transport, flocs within the flocculated stream may aggregate and/or precipitate. Adding the

second flocculant after transporting the flocculated stream to a deposition area so as to form a reflocculated stream can assist in removing water from the waste stream due to the additional flocculation of fine particles and/or solids which remain in suspension in the flocculated stream following transport. Adding the second flocculant after transporting the flocculated stream to a deposition area so as to form a reflocculated stream, can assist in further aggregating and precipitating flocs formed during transport. The addition of the second flocculant after transport may have the effect of strengthening the flocs already aggregated, to form stronger aggregates or agglomerates of fine particles and solids. By adding the second flocculant to reflocculate the flocculated stream after transportation, any broken or sheared flocs may aggregate further into strengthened flocs from which water is readily released in the deposition area, as compared with the strength of flocs having no exposure to the second flocculant.

[0048] The method 100 may assist in the remediation of oil sand tailings. Dewatering can be accelerated by the addition of a first flocculant to a tailings stream and by transporting the flocculated stream via a pipeline to a disposal area, where a second flocculant is added to form a reflocculated stream before depositing the reflocculated stream on a deposition area. The method 100 may adjust rheological properties so that deposition of the flocculated stream, which may be thickened in consistency by the addition of the first flocculant and/or the second flocculant, permits drainage of water from the deposition area. The deposition of the reflocculated stream may occur on a slope to promote water to drain from or seep out of the reflocculated stream after the reflocculated stream is deposited in the deposition area. After depositing the reflocculated stream in the deposition area, the reflocculated stream may be referred to as a deposited reflocculated stream. The slope may be the slope of the deposition area. Permitting water removal by drainage or seepage from the deposited reflocculated stream may promote dewatering of the precipitated flocs in the reflocculated stream, so as to meet regulatory requirements. Permitting water removal by drainage or seepage from the deposited reflocculated stream may promote strength gain of the precipitated flocs in the reflocculated stream, so as to meet regulatory requirements.

[0049] Without being limited to theory, the addition of one or more flocculants, such as but not limited to the first flocculant and/or the second flocculant to the waste stream, may serve to neutralize the charges of fine particles (mostly clay) within the waste stream. The neutralization may promote release of water from the fine particles and sand particles for immediate recovery. During transportation, the flocculated stream can be broken apart due to, for example but not limited to, pump and/or pipeline shear. The addition of a second flocculant, after transporting the flocculated stream to the disposal area, may enhance the rheological properties of the waste stream. Enhancing the rheological properties of the waste stream may increase shear resistance. Enhancing the rheological properties of the waste stream may aid in slope formation of the deposited reflocculated stream in the deposition area. At the end of transporting the flocculated stream to the disposal area, flocs formed by the addition of the first flocculant to the waste stream can combine together further when the second flocculant is added to the flocculated stream. The further combination may restructure the mine waste stream to increase material permeability. The further combination may accelerate dewatering. The further combination may form a trafficable surface to allow for more rapid mine reclamation.

[0050] The method may assist in achieving regulatory requirements for strength gain in and water release from tailings. The water recycled from the waste stream can be up to 50%, or more as compared to other WBE process, which may help to reduce importation of fresh water to the WBE process. The method can enhance performance (for example, as assessed by peak shear stress) of tailings, relative to some of the other known WBE processes. The method may provide a reliable and cost effective technology for producing trafficable tailings from mine waste which meet regulatory requirements.

[0051] The first flocculant may be for use in flocculation of fine particles and/or other solids from the waste stream. The second flocculant may be for use in flocculation of fine particles and/or other solids from the waste stream.

[0052] The first flocculant and/or the second flocculant may comprise one or more polymers. The one or more polymers may act to flocculate fine particles. The one or more

polymers may include one or more polymers that act as coagulants. Having one or more polymers that act as coagulants may permit agglomeration of the fine particles and/or enhance particle settling.

[0053] The first flocculant and/or the second flocculant may include one or more polymers that are the same as, similar to, or different from each other. The one or more polymers included in the first flocculant and/or the second flocculant may be used to cause a restructuring, also known as “flocculation”, of the fine particles and solids present in the waste stream.

[0054] The first flocculant may comprise a non-ionic polymer and an anionic polymer. The second flocculant may comprise a non-ionic polymer and an anionic polymer. The second flocculant may be the same as or different than the first flocculant. The flocculant, such as but not limited to the first flocculant and/or the second flocculant, may comprise the non-ionic polymer and anionic polymer in a weight ratio of 25:75 or less. The weight ratio may be any number within and/or bounded by the preceding weight ratio range. The flocculant, such as but not limited to the first flocculant and/or the second flocculant, may be formed by dissolving anionic and non-ionic polymers in a water stream prior to adding the flocculant to the waste stream.

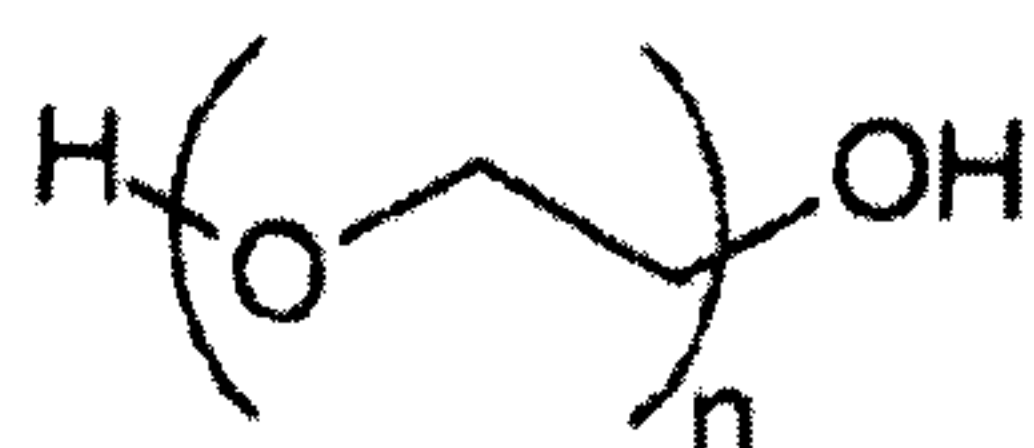
[0055] The anionic polymer may be a polyacrylamide copolymer comprising an anionic monomer. The anionic monomer may be acrylic acid. The anionic polymer may be in the form of an oil-in-water type emulsion. The anionic polymer may be a polyacrylamide copolymer of acrylic acid. The anionic polymer may be selected as a polymer having a charge density of 50% or less. For example, the anionic polymer may have a charge density of 30% or less. The charge density of the anionic polymer may be any density within and/or bounded by the preceding ranges of charge densities.

[0056] The non-ionic polymer may be a water soluble polymer. Examples of water soluble polymers include, but are not limited to, polyethylene oxide, polyacrylamide, methylcellulose, hydroxypropylcellulose, polygalactomannan, polyglycidol, polyvinyl acetate, polyvinyl methyl ether, or polyvinyl pyrrolidone. The non-ionic polymer may be one

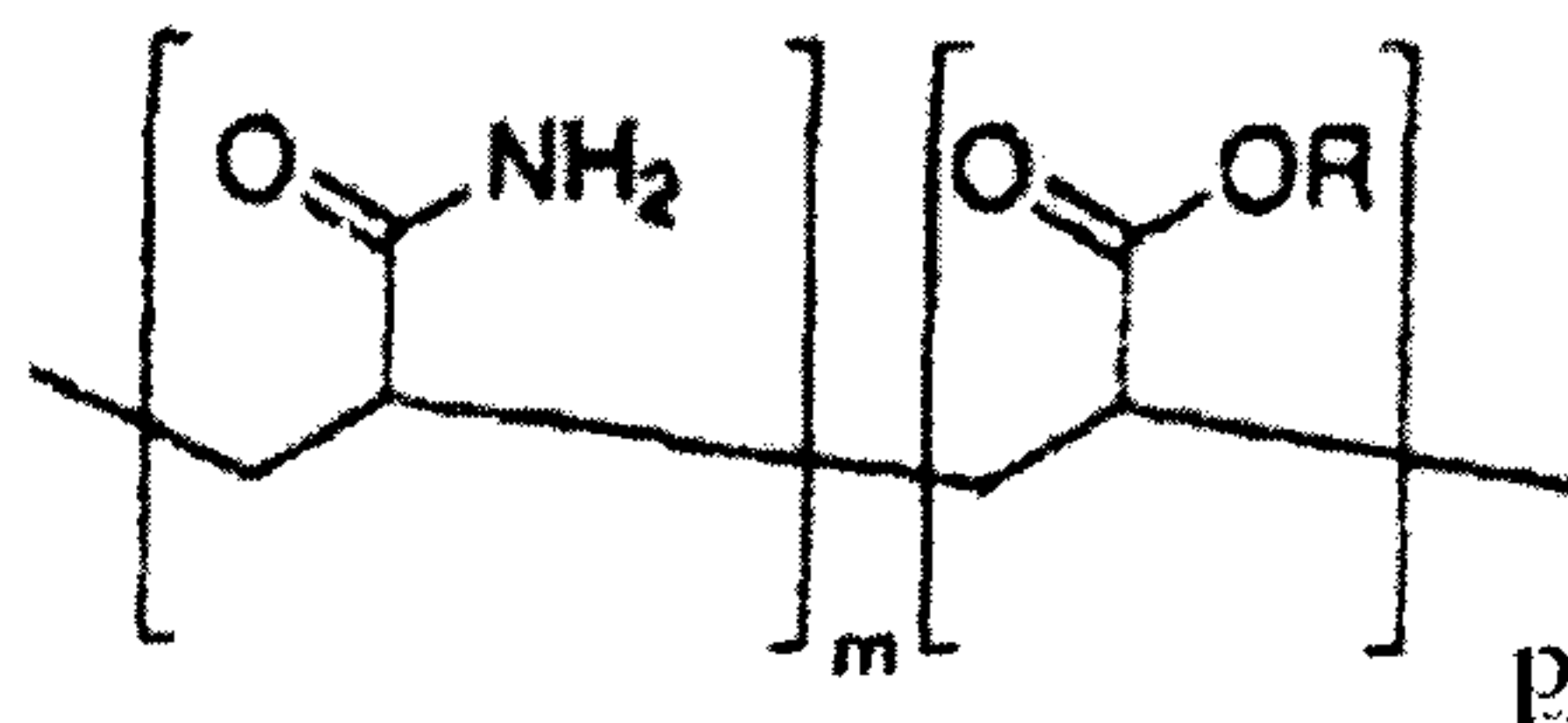
having a molecular weight of 400,000 g/mol or less. The non-ionic polymer may be a polyethylene oxide.

[0057] The first flocculant and/or the second flocculant may comprise polyethylene oxide, acrylamide copolymers comprising acrylic acid, acrylic acid sodium salt-acrylamide copolymer, acrylic acid sodium salt, 1-vinyl-2-pyrrolidinone, and/or water-soluble sulfonate-containing monomers.

[0058] Polyethylene oxide may be used in a wide range of molecular weights. Polyethylene oxide can be represented by Formula II in which n represents the repeating unit.

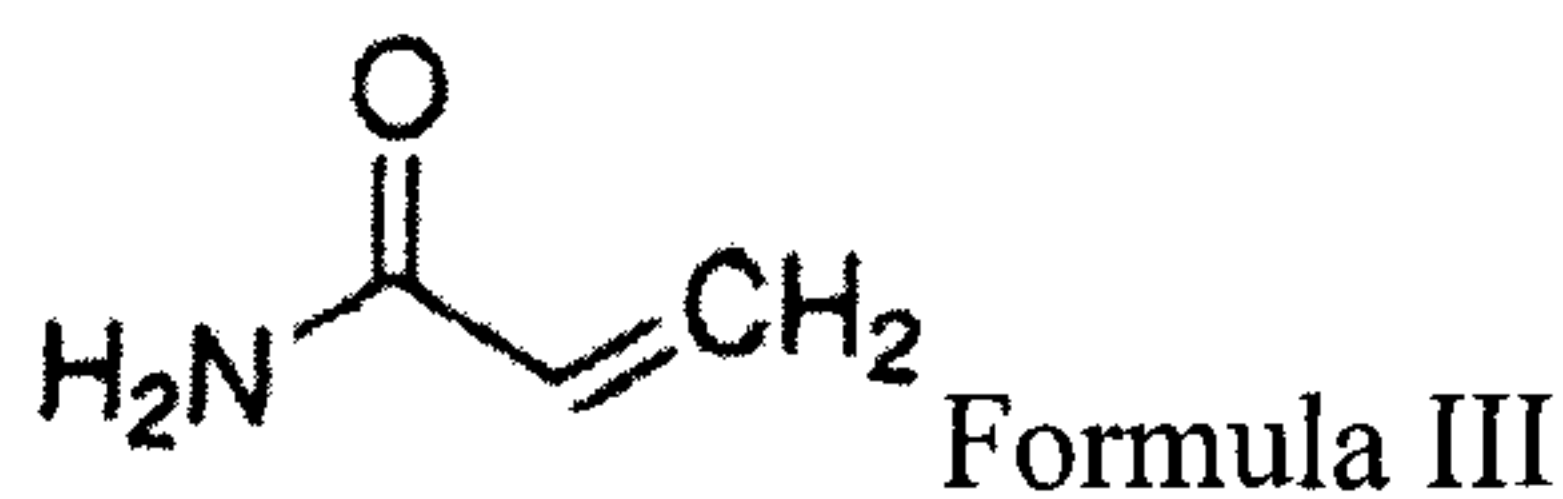


[0059] Formula II In an acrylic acid sodium salt-acrylamide copolymer, the repeating unit can be represented by general Formula I, in which R is H or Na, and m and p represent the number of monomer units within the repeating unit of Formula I ($m \geq 1$ and $p \geq 1$). For this and other repeating units described herein, the number of repeating units (referred to as "n", when shown) may be from 100 to 100,000, depending on the desired molecular weight of the macromolecule.



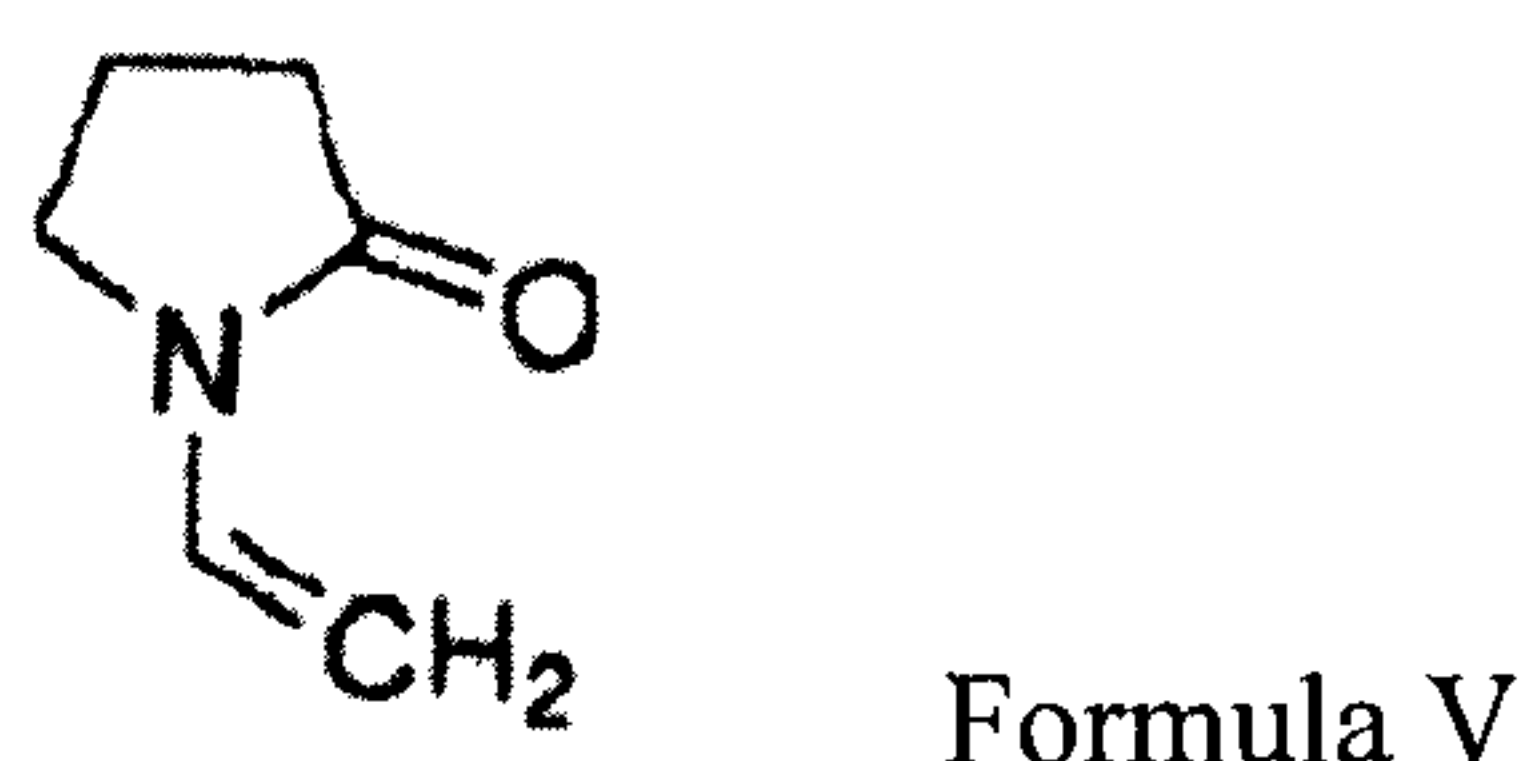
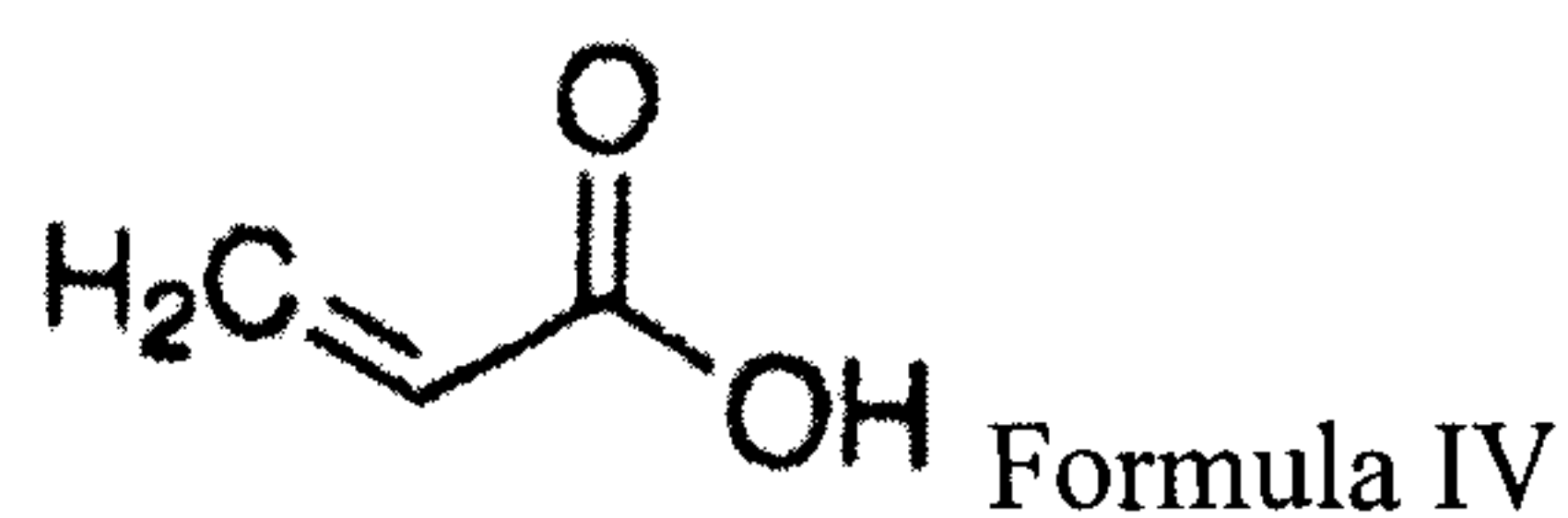
Formula I

[0060] A polyacrylamide-based polymer, such as a polyacrylamide copolymer may have acrylamide (Formula III) as the primary monomeric repeating unit.



Formula III

[0061] Acrylic acid monomers (Formula IV), and 1-vinyl-2-pyrrolidinone monomers (Formula V) may be present in the polyacrylamide copolymers described herein.



[0062] A polyacrylamide based polymer may be a high molecular weight water soluble or swellable polymers obtained from water soluble monomers, such as acrylamide, acrylic acid, and adam-methyl chloride.

[0063] A polyacrylamide-based emulsion may be used as the anionic polymer component of the first flocculant and/or the second flocculant. Polyacrylamide-based emulsions are dispersions or suspensions of a hydrogel of water-soluble polymer in an oil. They may be two-phase heterogeneous systems, which may comprise other components. The hydrated polymer may be in the shape of microbeads of 1 micron average diameter. Such microbeads may be dispersed in the hydrocarbon (oil) and may be stabilized by surfactants for protection against coagulation or agglomeration.

[0064] The water content of a polyacrylamide-based emulsion may vary from about 20% to about 40% of the final weight of the emulsion. Water composition of a polyacrylamide-based emulsion may depend on the grade. The water content may include not only free water in the emulsion, but also may represent water present as a component of the emulsion, which may take the form of a gel.

[0065] Polyacrylamide-based emulsions may be self-inverting emulsions. This is a type of emulsion having the property that the polymer can be released in a short period of

time by the addition of water (or other aqueous solutions) without the need for addition of another chemical.

[0066] When preparing a first flocculant and/or a second flocculant from a polyacrylamide-based emulsion such as described above, phase inversion and dissolution may take place under certain circumstances. When the emulsion comes into contact with water, the inverting surfactant dissolves and emulsifies the oil in the water, which is referred to as “inversion”. Beads of the gel come in contact with water and dissolve (dissolution).

[0067] The first flocculant and/or the second flocculant may comprise a mixture of polyethylene oxide, a water-soluble non-ionic polymer, and a polyacrylamide-based polymer in the form of an emulsion. The emulsion may comprise a water-in-oil type emulsion in which the polymer is dissolved in an aqueous droplet phase.

[0068] The addition of the first flocculant may be in the form of a solution which may contain other components, such as a coagulant. The first flocculant and/or the second flocculant may be anionic, cationic and/or non-ionic. An example of a non-ionic polymer is polyethylene oxide (PEO). The majority of the cationic groups of polyelectrolytes are derived by introducing quaternary ammonium groups onto the polymer backbone, although polymers containing sulfonium and phosphonium groups may be used. The most commonly used cationic polyelectrolytes are polydiallyldimethyl ammonium chloride (polyDADMAC). In the anionic group of polyelectrolytes, two main types of polymers may be used: polymers containing carboxyl functional groups and polymers containing sulfonic acid groups. A representative of the former type is polyacrylic acid and its derivatives. A representative of the latter type is polystyrene sulfonic acid (PSSA). Possible coagulants may be metallic salts (such as alum, ferric, calcium, sodium aluminate, sodium silicate) or cationic, anionic and nonionic polymers.

[0069] The first flocculant and/or the second flocculant may include synthetic polymers, which can be tailor-made by controlling the molecular weight, molecular weight distribution, and/or chemical structure. Thus, due to this tailorability, synthetic polymers can

be used to bridge the formation of aggregates of flocs from individual flocs, thereby enhancing permeability. Thus, dewatering is accelerated when a tailings stream is deposited.

[0070] The waste stream may comprise a tailings slurry generated during a WBE process. The tailings slurry may comprise flotation tails (FT), for example FT from a primary separation vessel (PSV), fluid fine tailings (FFT), mature fine tailings (MFT), a combination of FT and FFT/MFT, tailings solvent recovery unit (TSRU) tailings, and/or a waste stream from paraffinic froth treatment (PFT). The waste stream from the PFT may be the PFT underflow. The waste stream may comprise fine tailings. The fine tailings may come from ETA to which coarse and fine tailings formed in a WBE process have already been directed for settling. The solids content of the fine tailings may be from 5 to 40%. The solids content may be any number within or bounded by the solids content range. The tailings may be thickened prior to flocculation, such as by de-watering, adding thickeners, adding fine particles or solids, or adding water-absorbing polymer particles to form a thickened tailings slurry. The thickened tailings slurry may then be treated as the waste stream according to the method 100. The thickened tailings slurry may have a solids content of 10 wt% (weight percent) or greater, for example 30 wt% or greater. The weight percent of the thickened tailings slurry may be any number within or bounded by the preceding range.

[0071] The first flocculant may be mixed with the waste stream by entry within an input area of a settling vessel or any unit that provides shear or turbulent flow. The amount of first flocculant added to the waste stream may be any appropriate level, for example in the range from 50 g/ton (dry solids) to 2000 g/ton (dry solids), for example in the range of from 50 g/ton (dry solids) to 300 g/ton (dry solids), or from about 50 g/ton to about 100 g/ton (dry solids) may be used. The addition of the first flocculant to the waste stream may be by injecting the first flocculant in a pipeline including the waste stream, by combining the first flocculant with the waste stream prior to pipeline entry, or by any other method that permits addition of the first flocculant to the waste stream before or during transport.

[0072] When the second flocculant is added to the flocculated stream, the amount of second flocculant added to the flocculated stream may be the same or different from the

amount of the first flocculant added to the waste stream. The amount and type of second flocculant added to the flocculated stream may be selected independently of the amount and type of first flocculant. Any appropriate level, for example in the range from 50 g/ton (dry solids) to 2000 g/ton (dry solids), in the range of from 50 g/ton (dry solids) to 300 g/ton (dry solids), or from about 50 g/ton to about 100 g/ton (dry solids) may be used.

[0073] Once deposited in the deposition area, water in the reflocculated stream can be released and collected over 5 days following deposition, allowing the deposited reflocculated stream to dry. After drying, another layer of the reflocculated stream may be deposited on the previously deposited layer. The process may continue until a desired height is reached. A desired height may be in the range of 5-20 meters, for example, 7-10 meters per year. When the reflocculated stream deposition at the deposition area is complete, loading may be conducted. Loading may involve capping one or more layers of the deposited reflocculated stream with a coarse sand layer to promote further settling, water removal, and consolidation of fines. The height of sand cap involved in loading can be 2-20 meters, for example 5-10 meters. Water may be released and collected in the first 3 – 5 days following discharge of the reflocculated stream to the deposition area. With loading, water can be continuously released as the solids consolidate. With water release, the deposit volume of the reflocculated stream is eventually reduced. The volume reduction of the reflocculated stream can be from 10% to 60%, for example from 30% to 50%. The released water may migrate to the top, bottom, or sides of deposition area. The released water may drain out through a water-permeable material at the surface (or “base”) of the deposition area upon which the reflocculated stream is deposited, in which case, water could then flow by gravity to a water collection area. Some released water may evaporate.

[0074] The extent to which fine particles flocculate can be adjusted by altering the conditions of the method described in the present disclosure, including the nature and concentration of the fine particles or other solids in the waste stream, the concentration and composition of the polymers within the first and/or second flocculant, the extent of shear and/or mixing, or the length of the pipeline for situations in which the stream travels via pipeline to the deposition area. Flocculation may be adjusted in order to alter the size of the

flocs or aggregates. Settling rate and water release may vary proportionally with the increased size of the flocs or aggregates formed in the reflocculated stream. The larger the flocs or aggregates, the faster the settling rate and more extensive the release of water may be.

[0075] **EXAMPLE**

[0076] Anionic and Non-ionic Polymer Combination Flocculant

[0077] The example described permits dewatering of a waste stream 211, such as a tailings slurry, using an anionic and a non-ionic polymer combination as the first flocculant 212. The polymer combination is used as the first flocculant 212 at the beginning of a tailings dewatering process and as the second flocculant 218 at the end of a transportation process. Transportation by pipeline 216 is used, before the flocculated stream 214 enters the disposal area 220 and is combined with the second flocculant 218. The addition of the second flocculant 218 (referenced interchangeably herein as “reflocculation”) for treating tailings allows deposited tailings to increase in deposition strength at an early stage in deposition, which optimizes the release and recycling of water 224. Further, the reflocculation produces trafficable tailings to meet regulatory requirements. Water 224 is recovered from the deposition area and can subsequently be recycled back into the WBE process to reduce overall water consumption.

[0078] Following the addition of the second flocculant 218 (or “reflocculation”) at the end terminal of the pipeline 216 to a disposal area 220, the reflocculated stream 219, now in the form of a dewatered slurry can then be deposited in a deposition area 222. Strength gain of the tailings in the tailings slurry is enhanced with this method. Extra release of water permits the reflocculated stream 219 to achieve a thick consistency when deposited at the deposition area 222. The recycled water 224 can be reused in the extraction process to reduce overall water consumption. A trafficable surface may be formed to allow more rapid mine reclamation activities and to meet regulatory requirements.

[0079] In an initial step, generating flotation tailings (FT) or combining flotation tailings with fluid fine tailings (FFT) and/or mature fine tailings (MFT) form a fine tailings stream with solids content 5%/wt -30%/wt, preferably in the range of 10-25%/wt.

[0080] In this example, a fine tailings slurry is used as the waste stream 211. The waste stream 211 is mixed with a composition including a water soluble polymer, the first flocculant 212, and may contain one or more coagulants, to bond (or “bridge”) the fine and coarse components together, recovering 50-60%/wt water and forming a more dense tailings slurry (the flocculated stream 214), which may be interchangeably referred to in this example as thickened tailings (TT).

[0081] Thickened tailings are transported by pipeline 216, and the second flocculant 218 is added. In this example, the second flocculant is added at the end of the pipeline 216 to a disposal area 220, which contains the deposition area 222. The flocculated stream 214, containing flocculated fine tailings, is transported to a disposal area 220, where the addition of the second flocculant 218 occurs forming a reflocculated stream 219, referred to in this example interchangeably as a “reflocculated tailings stream”. The reflocculated tailings stream is deposited on the deposition area 222 may form a slope to permit release of water 224 by drainage.

[0082] The reflocculated tailings stream may be continually deposited in one deposition area (alternatively referred to as a “deposition cell” or “deposition bed”) over about 7-21 days, evaporating and setting the tailings, following which there can be a switch in which the reflocculated tailings stream is directed to a different deposition area.

[0083] In this example, the reflocculated tailings stream is dewatered on a deposition bed with a base slope of 0.5%-10%, for example 0.5-2%. The deposition bed may have a water-permeable material at the bottom, as a base on which the reflocculated tailings stream is deposited. Released water may either migrate upward (to the top of the pile formed at the deposition area) or downward (to the bottom of pile formed at the deposition area). Water that flows to the end of the deposition bed by gravity may be collected at a water storing area and pumped back into the mining or bitumen extraction process for reuse.

[0084] After drying, another layer of the reflocculated tailings stream is deposited on a previously deposited layer. The process continues until the desired height of from 5-20 meters is reached. When reflocculated tailings stream deposition at the deposition area is complete,

loading may be conducted by capping the top of the deposited tailings in the deposition area with a coarse sand layer to a height of 2-20 meters.

[0085] An aqueous feed from an aqueous oil sands extraction process may be directed to a primary separation vessel (PSV). A variety of waste streams from the aqueous extraction and froth treatment process can be included in an external tailings area for water removal. Utilizing the method described herein, the waste streams containing flocs can be reflocculated at the disposal area to advantageously promote rigidity and /or permit removal of water in the deposition area.

[0086] In the method, a bitumen-containing feed may be directed to the PSV, and bitumen floats to the surface as froth, while sand settles out, and an underflow stream is directed to further tailings recovery. For example, underflow from the primary separation vessel (PSV) which may contain coarse sand tailings may be directed to an external tailings area. Fine tailings derived from flotation may also be directed to an external tailings area so as to allow further settling to remove water.

[0087] Froth from the primary separation vessel may be processed further using paraffinic froth treatment (PFT) from which the froth goes on to purification. Flotation tails can be included in an external tailings area for settling, and may be directed to the ETA before or after thickening. Froth treatment tailings derived from PFT, following paraffinic solvent removal in a tailings solvent recovery unit (TSRU), may be flocculated and reflocculated in the method described herein, and directed to an external tailings area for deposition.

[0088] **Figure 3** is a diagram representing the transportation and flow of streams involved in oil sands extraction from a mine site, according to the method 100 of **Figure 1**, including locations at which addition of first and second flocculants occur. The first flocculant and the second flocculant may be used to thicken flotation tailings or to thicken TSRU tailings.

[0089] A bitumen feed 300 may be sent to a primary separation vessel 302. Bitumen froth 304 may be sent to paraffinic froth treatment (PFT) 306. Middlings 308 may be sent to flotation cells 310. Coarse sand tailings 312 may be sent to an External Tailings Area (ETA)

314 for use as a building material to contain tailings ponds of tailings with lower solids content. The ETA 314 may include at least one area. For example, the ETA 314 may include two areas. The two areas may comprise a west ETA 314a and an east ETA 314b. The west ETA 314a may have a higher water content than the east ETA 314b.

[0090] The PFT 306 may produce bitumen 317 and PFT tailings 318. The PFT tailings 318, may be directed to a thickener 320 from which water may be released. Addition of a first flocculant 322 to a waste stream 323 derived from the thickener 320 produces a flocculated stream 326 which is directed to transportation, for example by pipeline 327, to a disposal area 328. Upon arrival at the disposal area, a second flocculant 330 is added to the flocculated stream 326 to form a reflocculated stream 331a for deposition on a deposition area 360. The addition of the second flocculant 330 acts to reflocculate flocs, fine particles, and other solids further following shear of the flocculated stream 326 caused by transportation and pumping. PFT tailings 318 may be sent to the ETA 314.

[0091] Flotation tailings (FT) 332 may be used as the waste stream. FT 332 may be directed to a thickener 336 where a first flocculant 322 is added to the FT 332, thereby creating a flocculated stream 342. The flocculated stream 342 may be sent to the disposal area 328 via pipeline 343 following which a second flocculant 330 may be added to form a reflocculated stream 331b.

[0092] Coarse sand tailings 312 from PSV 302 may be directed to ETA 314, such as the West ETA 314a. Fine tailings 349, which may be derived from PFT 306, may be sent to West ETA 314a. Fine tailings 350 for recycling may be derived from West ETA 314a for combining with other waste streams for flocculation, such as for combination with flocculated stream 342 at pipeline 343.

[0093] Once the flocculated stream 326 arrives at the disposal area 328, it is combined with the second flocculant 330 to form a reflocculated stream 331a and deposited in a deposition area 360 to release water.

[0094] Following the first flocculant 322 and second flocculant 330 additions, the reflocculated streams 331a and/or 331b, may be allowed to flow into the deposition area 360

having a slope of from 0.5 to 10%, for example from about 2 to about 4% slope, if no slope is formed in advance of depositing the reflocculated streams 331a and/or 331b in the deposition area 360. The reflocculated stream 331a and/or reflocculated stream 331b may form a slope as more of the reflocculated stream accumulates upon the reflocculated stream initially deposited. Slope formation from the deposition of the reflocculated stream 331a or reflocculated stream 331b in the deposition area 360 may permit water to be released faster from the reflocculated stream. One or more reflocculated streams may be formed. Two reflocculated streams are illustrated in **Figure 3** in order to depict, simultaneously, the way in which two different waste streams may be utilized in the method. Only one waste stream need be utilized, which may lead to formation of one reflocculated stream, or more than one reflocculated stream.

[0095] **Figure 4** is a chart illustrating peak shear stress for different polymers over a period of seven days. Notably, the peak shear stress of the PEO and polyacrylamide combination (-+-) reached about 4400 Pa by day 7, compared with using polyacrylamide alone (-□-) at about 3100 Pa by day 7, PEO alone (-Δ-) at about 400 Pa on day 7, and the control (-◇-) at only a minor change in peak shear stress over time, of about 100 Pa.

[0096] The data in **Figure 4** shows that the use of a flocculant comprising a non-ionic polymer (PEO) and an anionic polymer (polyacrylamide) together results in strengthened flocs. The use of PEO and the polyacrylamide together showed better results with regard to peak shear stress over the 7 day period, which was more than simply an additive effect. The higher peak shear stress of the PEO + Polyacrylamide flocculant shows strengthened flocs from which water can be released when a reflocculated stream is deposited in a deposition area in the described method 100.

[0097] 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

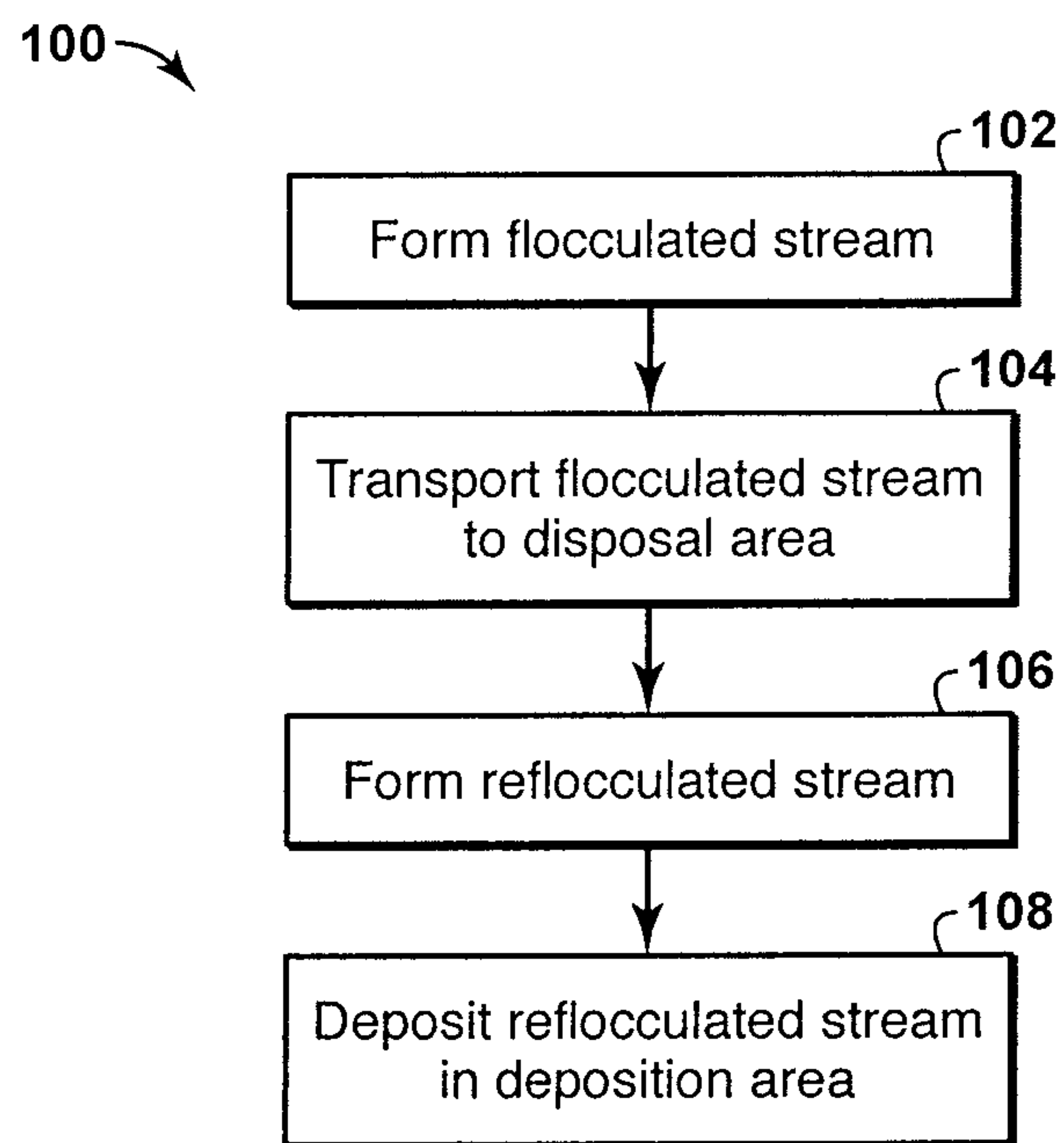
equivalents. It is also contemplated that structures and features in the present examples can be altered, rearranged, substituted, deleted, duplicated, combined, or added to each other.

CLAIMS:

1. A method for treating mine waste comprising:
 - (a) forming a flocculated stream by adding a first flocculant to a waste stream from a water based extraction of bitumen from oil sands, said waste stream comprising fine particles and solids;
 - (b) transporting the flocculated stream to a disposal area;
 - (c) forming a reflocculated stream by adding a second flocculant to the flocculated stream after transporting the flocculated stream; and
 - (d) depositing the reflocculated stream in a deposition area within the disposal area;
 wherein the first flocculant and the second flocculant comprise a non-ionic polymer and an anionic polymer.
2. The method of claim 1, wherein said anionic polymer is a polyacrylamide copolymer comprising an anionic monomer.
3. The method of claim 2, wherein the anionic monomer comprises acrylic acid.
4. The method of claim 1, wherein the non-ionic polymer comprises a polyethylene oxide and the anionic polymer comprises a polyacrylamide copolymer of acrylic acid.
5. The method of any one of claims 1-4, wherein the anionic polymer is in the form of an oil-in-water type emulsion.
6. The method of claim 1 or claim 2, wherein the non-ionic polymer comprises a water soluble polymer.
7. The method of claim 6, wherein the water soluble polymer comprises polyethylene oxide, polyacrylamide, methylcellulose, hydroxypropylcellulose, polygalactomannan, polyglycidol, polyvinyl acetate, polyvinyl methyl ether, polyvinyl pyrrolidone, or mixtures thereof.

8. The method of any one of claims 1-7, wherein transporting the flocculated stream comprises transportation by a pipeline.
9. The method of any one of claims 1-8, wherein the deposition area has a slope of from 0.5% to 10%.
10. The method of claim 9, wherein the deposition area has a slope of from 1% to 4%.
11. The method of any one of claims 1-10, wherein the first flocculant and/or the second flocculant comprises the non-ionic polymer and the anionic polymer in a weight ratio of 25:75 or less.
12. The method of any one of claims 1-11, wherein the non-ionic polymer has a molecular weight of 400,000 g/mol or less.
13. The method of any one of claims 1-12, wherein the anionic polymer has a charge density of 50 percent or less.
14. The method of claim 13, wherein the anionic polymer has a charge density of 30 percent or less.
15. The method of any one of claims 1-14, further comprising forming the first flocculant by dissolving the non-ionic polymer and the anionic polymer in a water stream prior to adding the first flocculant to the waste stream.
16. The method of any one of claims 1-15, wherein the waste stream comprises flotation tails from a primary separation vessel.
17. The method of claim 16, wherein the waste stream further comprises fine tailings.

18. The method of any one of claims 1-17, further comprising generating a concentrated waste stream by removing water from the waste stream and/or adding fine tailings to the waste stream, before adding the first flocculant to the waste stream.
19. The method of any one of claims 1-18, wherein the waste stream is from paraffinic froth treatment.
20. The method of claim 17, wherein the fine tailings are recycled from an external tailings area.
21. The method of any one of claims 1-20, further comprising forming released water by releasing water from the reflocculated stream deposited in the deposition; and collecting the released water in the deposition area.
22. The method of claim 21, wherein at least a portion of the released water is recycled for use in forming the first flocculant and/or the second flocculant, by dissolving the anionic polymer and the non-ionic polymer in the released water prior to adding the first flocculant to the waste stream and/or adding the second flocculant to the reflocculated stream.
23. The method of claim 21, further comprising draining the released water through a water-permeable material at a bottom of the deposition area.

1/4**FIG. 1**

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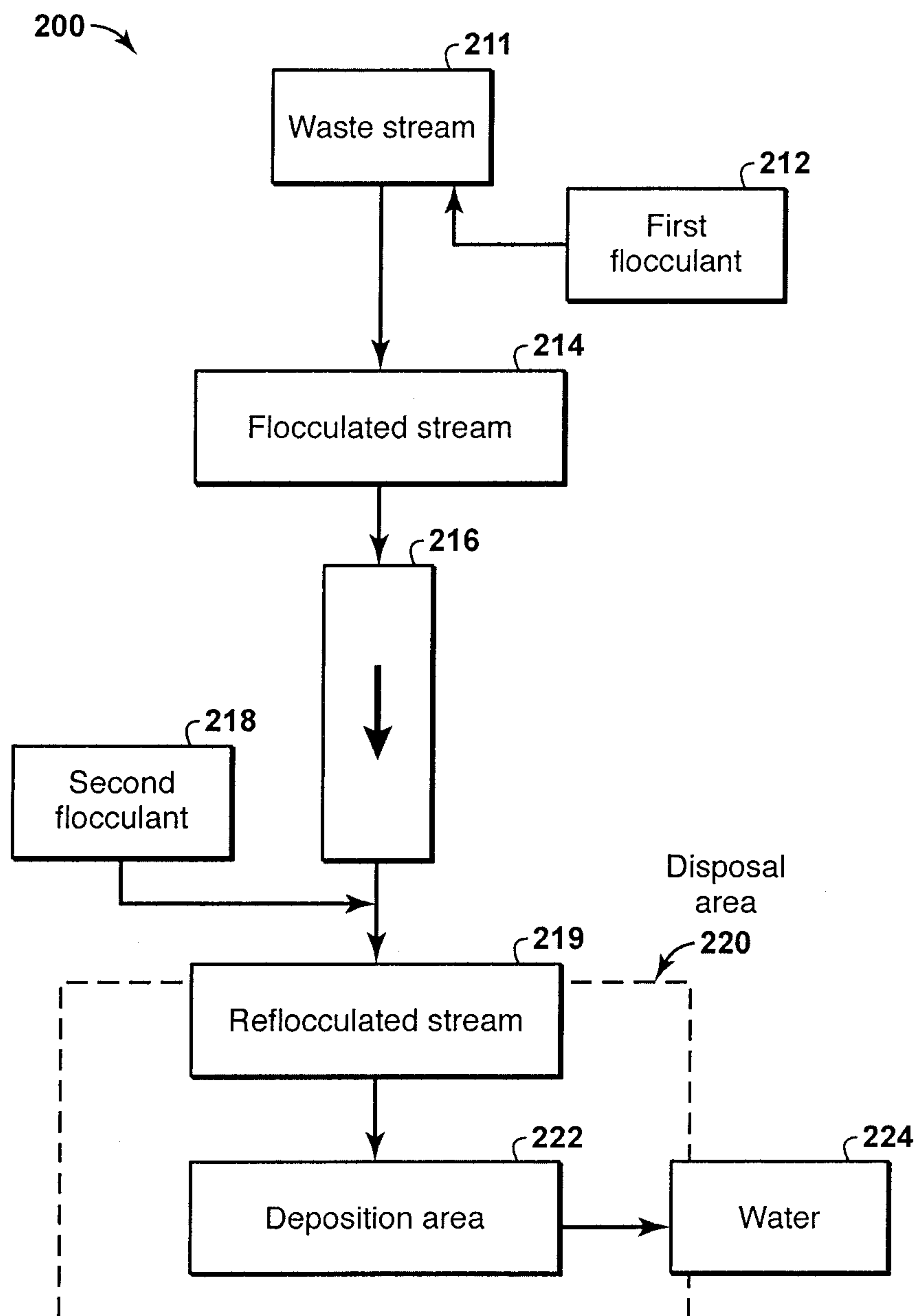


FIG. 2

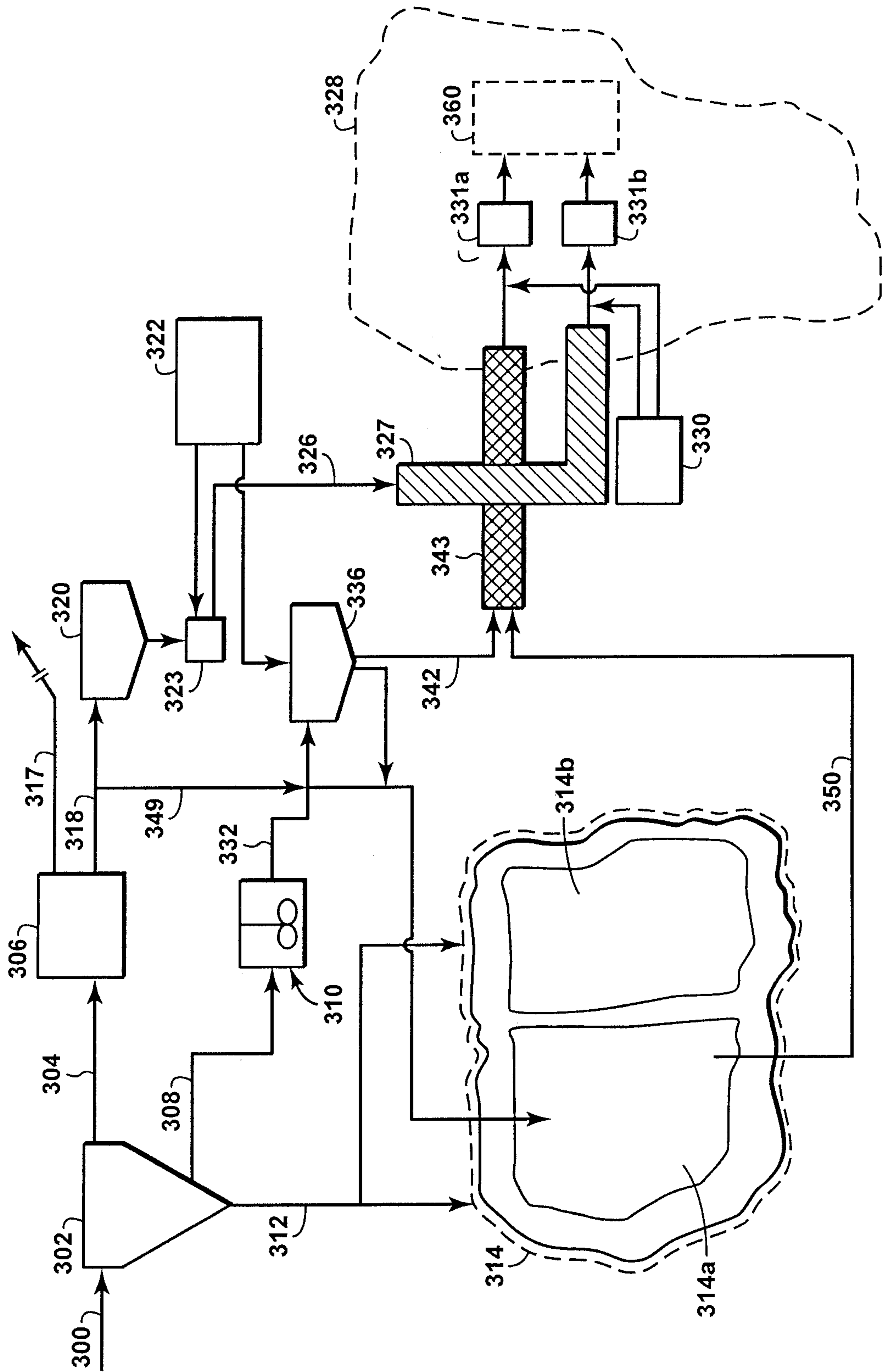
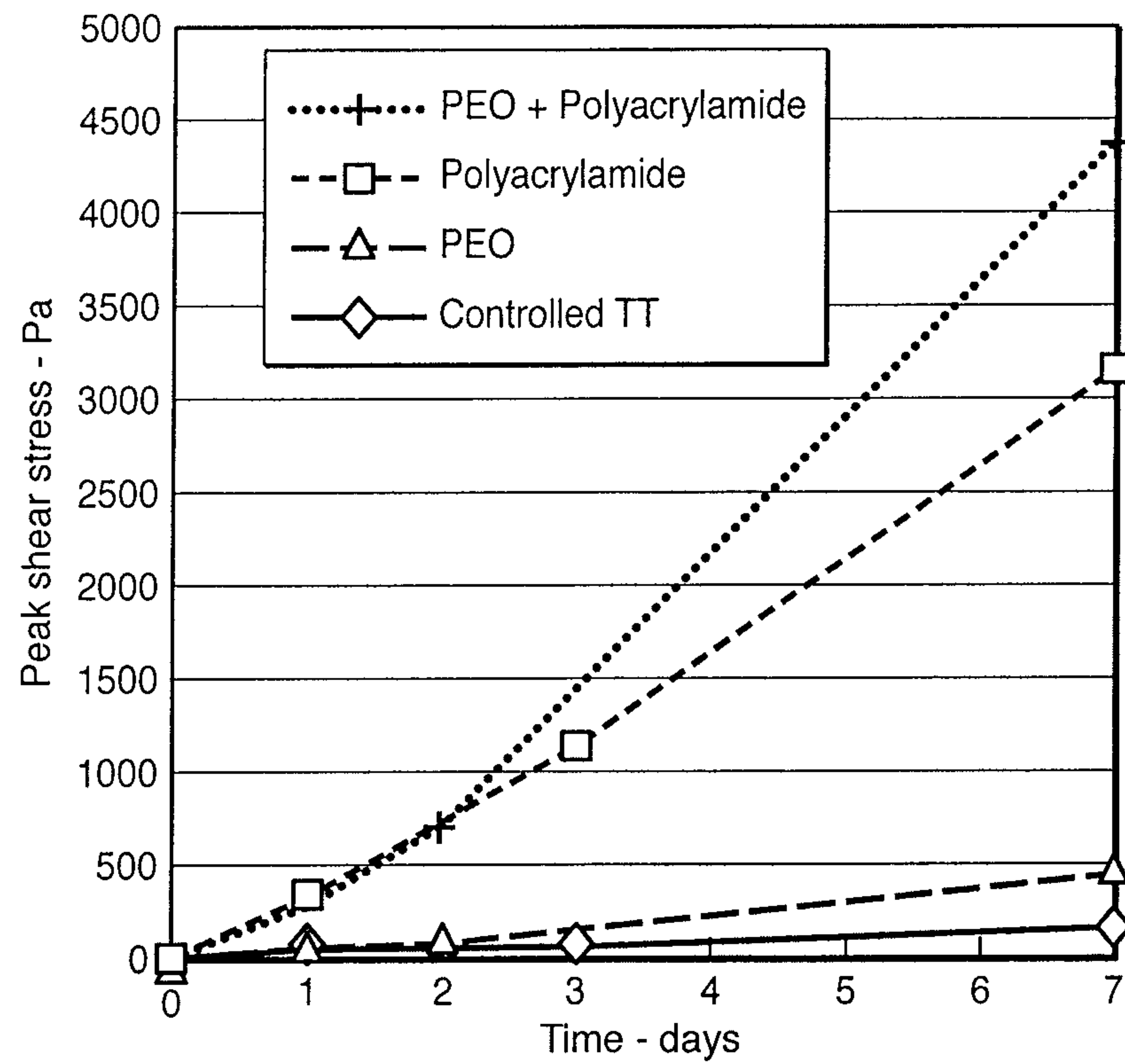


FIG. 3

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**FIG. 4**