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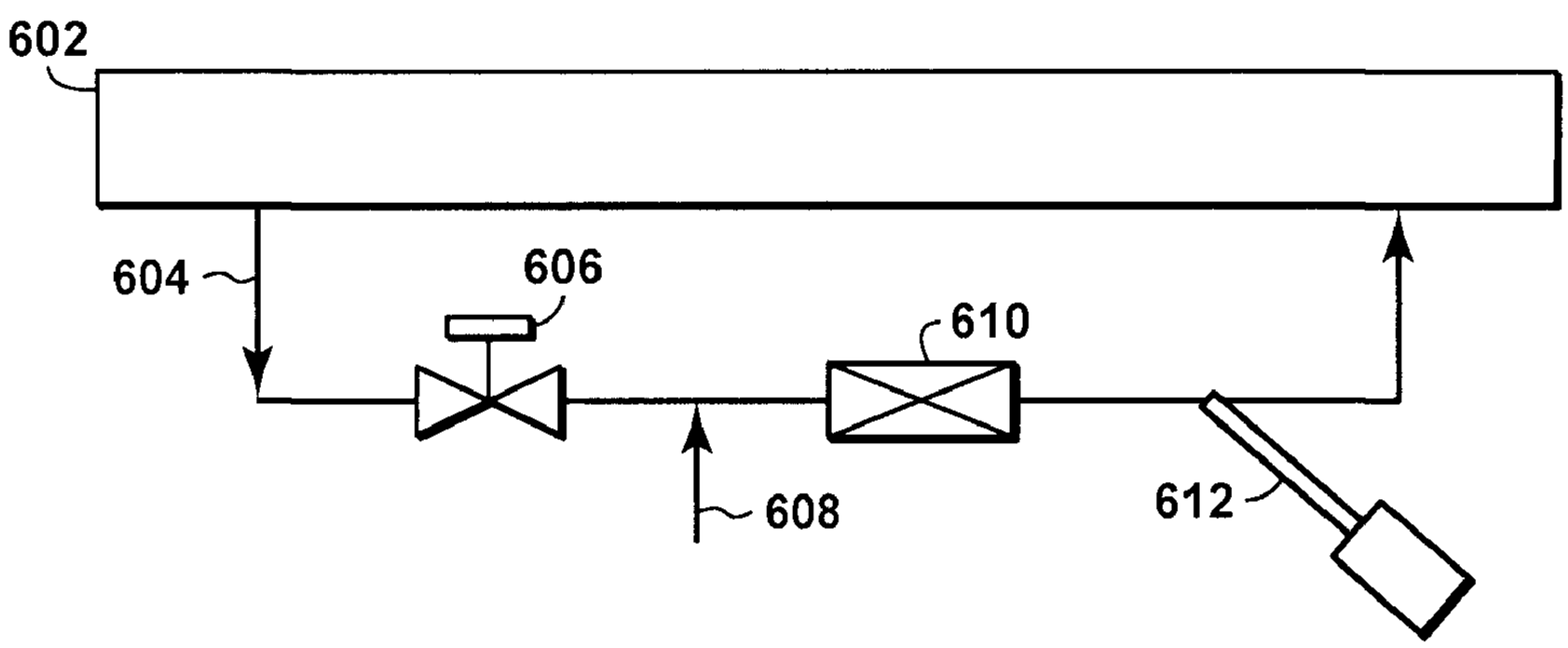
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(54) Titre : METHODE DE MESURE D'UN APPORT DE BOUE POUR UN PROCEDE DE SEPARATION SOLIDE-LIQUIDE

(54) Title: METHOD OF MEASURING A SLURRY FEED FOR A SOLID-LIQUID SEPARATION PROCESS



(57) Abrégé/Abstract:
Disclosed is a method comprising: a) providing a slurry intended as a feed to a solid-liquid separation process; b) removing a slip stream from the slurry; and c) measuring at least a portion of the slip stream at a plurality of additive dosage levels to obtain a characteristic indicative of a degree of flocculation, agglomeration, or aggregation for each of the plurality of additive dosage levels.

ABSTRACT

Disclosed is a method comprising: a) providing a slurry intended as a feed to a solid-liquid separation process; b) removing a slip stream from the slurry; and c) measuring at least a portion of the slip stream at a plurality of additive dosage levels to obtain a characteristic indicative of a degree of flocculation, agglomeration, or aggregation for each of the plurality of additive dosage levels.

METHOD OF MEASURING A SLURRY FEED FOR A SOLID-LIQUID SEPARATION PROCESS

BACKGROUND

Field of Disclosure

[0001] The disclosure relates generally to the field of solid-liquid separation of slurries, for instance oil sand streams.

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] Solid-liquid separation of slurries, such as mining slurries, is often desired. For instance, it is often desirable to separate solids from liquids in oil sand streams. Additional background on oil sand processes will now be provided.

[0004] 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.

[0005] Recently, the harvesting of oil sand to remove heavy oil has become more economical. Hydrocarbon removal from oil sand may be performed by several techniques.

For example, a well can be drilled to an oil sand reservoir and steam, hot air, solvents, or a combination thereof, can be injected to release the hydrocarbons. The released hydrocarbons may be collected by wells and brought to the surface. In another technique, strip or surface mining may be performed to access the oil sand, which can be treated with water, steam or solvents to extract the heavy oil.

[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. Other processes are non-aqueous solvent-based processes. An example of a solvent-based process is described in Canadian Patent Application No. 2,724,806 (Adeyinka *et al*, published June 30, 2011 and entitled "Process and Systems for Solvent Extraction of Bitumen from Oil Sands"). Solvent may be used in both aqueous and non-aqueous processes.

[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.

[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 Naphtha Froth Treatment (NFT) processes. Other processes use a paraffinic solvent, and are called Paraffinic Froth Treatment (PFT) processes, to produce pipelineable bitumen with low levels of solids and water. In the PFT process, a paraffinic solvent (for example, 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 Unit (SRU) and Tailings Solvent Recovery Unit (TSRU). Mixing of the solvent with the feed bitumen froth may be carried out counter-currently in two stages in separate froth separation units. The bitumen froth comprises bitumen, water, and solids. A typical composition of bitumen froth is about 60 wt. % bitumen, 30 wt. % water, and 10 wt. % solids. The paraffinic solvent is used to dilute the froth before separating the product bitumen by gravity. The foregoing is only an example of a PFT process and the values are provided by way of example only. An example of a PFT process is described in Canadian Patent No. 2,587,166 to Sury.

[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] As described above, solid-liquid separation of slurries is often desired. Successful solid-liquid separation depends heavily on the slurry feed to the solid-separation process. One or more additives are typically used to achieve physiochemical change in the slurry such as flocculation, agglomeration, or aggregation, to facilitate solid-liquid separation. One factor of interest is the amount of additive(s) that is required to achieve good process performance for a specific slurry feed. Additive dosage is typically determined offline and applied to a consistent slurry feed. However, when slurry feeds change quickly and frequently, such an approach may no longer be effective or practical.

SUMMARY

[0015] It is an object of the present disclosure to provide a method of measuring a slurry, intended as a feed to a solid-liquid separation process.

[0016] Disclosed is a method comprising:

a) providing a slurry intended as a feed to a solid-liquid separation process;

b) removing a slip stream from the slurry; and

c) measuring at least a portion of the slip stream at a plurality of additive dosage levels to obtain a characteristic indicative of a degree of flocculation, agglomeration, or aggregation for each of the plurality of additive dosage levels.

[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] Fig. 1 is a flow chart of a method of measuring a slurry.

[0020] Fig. 2 is a graph of median chord length as a function of additive dosage, as measured by FBRM.

[0021] Fig. 3 is a graph of average pixel value standard deviation as a function of additive dosage, as measured by PVM.

[0022] Fig. 4 is a graph of average pixel value standard deviation as function of flocculant dosage.

[0023] Fig. 5 is a graph of additive dosage as a function of slurry SFR.

[0024] Fig. 6 is a flow diagram of a method of measuring a slurry.

[0025] Fig. 7 is a flow diagram of a method of measuring a slurry.

[0026] Fig. 8 is a flow diagram of a method of measuring a slurry.

[0027] 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

[0028] 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.

[0029] 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.

[0030] Throughout this disclosure, where a range is used, any number between or inclusive of the range is implied.

[0031] 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.

[0032] "Bitumen" is a naturally occurring heavy oil material. Generally, it is the hydrocarbon component found in oil sand. Bitumen can vary in composition depending upon the degree of loss of more volatile components. It can vary from a very viscous, tar-like, semi-solid material to solid forms. The hydrocarbon types found in bitumen can include aliphatics, aromatics, resins, and asphaltenes. A typical bitumen might be composed of:

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

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

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

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

some amount of sulfur (which can range in excess of 7 wt. %), the weight % based upon total weight of the bitumen.

In addition, bitumen can contain some water and nitrogen compounds ranging from less than 0.4 wt. % to in excess of 0.7 wt. %. The percentage of the hydrocarbon found in bitumen can vary. The term "heavy oil" includes bitumen as well as lighter materials that may be found in a sand or carbonate reservoir.

[0033] "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.

[0034] The term "bituminous stream" refers to a stream derived from oil sand that requires downstream processing in order to realize valuable bitumen products or fractions. The bituminous stream is one that comprises bitumen along with undesirable components. Undesirable components may include but are not limited to clay, minerals, coal, debris and water. The bituminous stream may be derived directly from oil sand, and may be, for example, raw oil sand ore. Further, the bituminous stream may be a stream 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 stream. A bituminous stream need not be

derived directly from oil sand, but may arise from other processes. For example, a waste product from other extraction processes which comprises bitumen that would otherwise not have been recovered may be used as a bituminous stream.

[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] The term "paraffinic solvent" (also known as aliphatic) as used herein means solvents comprising normal paraffins, isoparaffins or blends thereof in amounts greater than 50 wt. %. Presence of other components such as olefins, aromatics or naphthenes may counteract the function of the paraffinic solvent and hence may be present in an amount of only 1 to 20 wt. % combined, for instance no more than 3 wt. %. The paraffinic solvent may be a C_4 to C_{20} or C_4 to C_6 paraffinic hydrocarbon solvent or a combination of iso and normal components thereof. The paraffinic solvent may comprise pentane, iso-pentane, or a combination thereof. The paraffinic solvent may comprise about 60 wt. % pentane and about 40 wt. % iso-pentane, with none or less than 20 wt. % of the counteracting components referred above.

[0039] With reference to Figure 1, disclosed is a method comprising:

a) providing (102) a slurry intended as a feed to a solid-liquid separation process;

b) removing (104) a slip stream from the slurry; and

c) measuring (106) at least a portion of the slip stream at a plurality of additive dosage levels to obtain a characteristic indicative of a degree of flocculation, agglomeration, or aggregation for each of the plurality of additive dosage levels.

[0040] SLURRY COMPOSITION AND SOLID-LIQUID SEPARATION

[0041] The slurry is intended as a feed to a solid-liquid separation process. Any suitable slurry may be used. For instance, in addition to the oil sand streams discussed below, other mining streams may be used. The solid-liquid separation may alternatively be water clarification. The slurry may alternatively be a solid-liquid slurry stream, waste stream, or drilling mud from a drilling operation.

[0042] As described above in the background section, it is often desirable to separate solids from liquids in oil sand streams.

[0043] An "oil sand stream" is any suitable stream stemming from oil sand. Examples include, but are not limited to, oil sand, a bituminous stream, a bitumen froth, oil sand tailings, a stream from aqueous based extraction, a stream from solvent based extraction, a solvent diluted bitumen froth, a hydrotransport slurry, a solvent-ore slurry, or a combination thereof.

[0044] The oil sand tailings stream may stem from aqueous based extraction or solvent based extraction. The oil sand tailings stream may comprise coarse tailings, middlings, flotation tailings, froth separation tailings, tailings solvent recovery unit (TSRU) tailings, fluid fine tailings (FFT), mature fine tailings (MFT), thickened tailings, thickener overflow, centrifuged tailings, hydrocycloned tailings, or a combination thereof. The oil sand tailings stream may include at least one of a feed stream to a thickener, a thickener overflow, and a thickener underflow. The oil sand tailings stream may include a feed stream to a centrifuge, filter, or inline mixer. Oil sands tailings streams are a subset of what may be called a "slurry", which is a flowable liquid/solids mixture.

[0045] An example of a solid-liquid separation process in the oil sands field involves introducing an oil sand tailings stream, which in this example is a feed stream to a thickener (or "thickener feedstream"), into a thickener along with a flocculant and/or a coagulant to facilitate solid-liquid separation and thus water recovery and tailing disposal. Flocculant dosage may be adjusted to improve flocculation for a given thickener feedstream. When the thickener feedstream being introduced into the thickener is highly variable, flocculant dose adjustment in real-time based on changing slurry feed to improve flocculation is important to thickener operation and performance. Floc formation can be affected by multiple factors, such as thickener feedstream composition, water chemistry, flocculant quality, and impurity content. For example, a floc size that is too small may lead to a lower settling rate, higher fines loss, thickener bed expansion, or flooding. A floc size that is too large (and therefore too heavy), may lead to higher bed rheology, poor dewatering, thickener rake operation difficulty, or rat-holing. Sub-optimal or poor additive dosage may lead to sub-optimal or poor thickener performance or a reduction in thickener availability, which may lead to lower fines recovery efficiency, a more challenging deposition operation, or decreased process water availability.

[0046] Another suitable solid-liquid separation process is the re-flocculation of a thickener underflow (i.e. a slurry). In this process, a flocculant is added to the sheared underflow from a thickener such as described in the preceding paragraph. In this way, a second flocculation occurs to repair broken or partial flocs due to shearing before discharging to facilitate solid-liquid separation of the thickener underflow in a deposition area.

[0047] Some processes have lower feed variability, for instance because their tailings are conditioned with hydrocyclones or are processing Mature Fine Tailings (MFT), which have matured to a narrow compositional range in a tailings pond. The additive dosage adjustment described herein may nonetheless be useful in such processes. In particular, despite lower feed variability or narrower fine content variation, the additive dosage also depends on other variability, such as clay mineralogy, water chemistry, feed rheology, etc. Proper and timely dosage adjustment to account for process variability for desired process performances is useful.

[0048] The solid liquid separation may involve re-flocculation of shared thickened tailings, inline flocculation of MFT, or MFT centrifuging. In solvent-based extraction and agglomeration of oil sands, the subject additive may be the bridging liquid used.

[0049] SLIP STREAM MEASUREMENT

[0050] By using a slip stream for measurement, smaller volumes of slurry may be removed from the main process for measurement. Using a slip stream is distinct from grab sampling methods where small samples are taken from a slurry and are analyzed. Grab sampling can be slow as the lab analysis can take significant time and therefore adjustments are necessarily based on dated measurements which can limit their effectiveness. Additionally, a grab sampling sample may not be a good representation of the slurry due to its size and sampling location in what may be a heterogeneous slurry.

[0051] The slip stream may be returned to the slurry or may be sent for waste treatment. Alternatively, an inline mixer may be disposed upstream of the slip stream exit or the slip stream may be taken from an area of turbulent flow, such as after a piping elbow or flow meter to assist homogeneous sampling.

[0052] The measurement of the slip stream may be performed by any suitable instrument or technique capable of obtaining the characteristic indicative of a degree of flocculation, agglomeration, or aggregation, with sufficient accuracy.

[0053] The characteristic indicative of a degree of flocculation, agglomeration, or aggregation (also referred to herein simply as "characteristic") may include a measure of flocculent, agglomerate, or aggregate size; a measure of flocculent, agglomerate, or aggregate settling rate; a measure of supernatant tubidity; a measure of flocculent, agglomerate, or aggregate compaction density; or a measure of flocculent, agglomerate, or aggregate filtration rate.

[0054] The "characteristic" may be obtained by measuring particle size, for instance using particle size analyzers, for instance focused beam reflectance measurement (FBRM) probes or particle vision measurement (PVM) probes. Both FBRM and PVM probes may be inserted directly into the slip stream to measure the degree of flocculation, agglomeration, or

aggregation. Bench testing has indicated that both FBRM and PVM probes are capable of determining underdose for flotation tailings and mature fine tailings flocculation. However, as shown in Figures 2 (which is based on measurement obtained from an FBRM probe) and 3 (which is based on measurement obtained from an PVM probe), these probes cannot distinguish between an optimal state and an overdose state.

[0055] The obtained characteristics may be used to determine a recommended additive dosage level of the slurry, as illustrated below. Additionally, the obtained characteristics may be used with correlation reference data to determine a compositional parameter of the slurry. Examples of composition parameters are fines content and clay content. Where the determined compositional parameter falls outside of an operation window of the solid-liquid separation process, one may bypass the solids-liquid separation process and pass the slurry to a designated area as an untreated slurry.

[0056] For Figures 2 to 5, the following setup was used. FBRM and PVM were mounted and directly inserted into a one liter slurry pail under agitation with a stand mixer which provides the mixing needed for solid particle suspension and flocculation. Multiple FT (Floatation Tailings) and FT/MFT (Floatation Tailing/Mature Fine Tailings) mixtures with different SFRs (Sand to Fines Ratios), solid content (SC), and bitumen content (Bit) were tested with the setup. For each testing feed, chord length distribution and images were captured, after the addition of variant polymer dosages, by FBRM and PVM, respectively.

[0057] FBRM is scanning laser microscopy, developed in the 1990's and commercially available from Mettler Toledo. In FBRM, a rotating lens provides a focused laser beam at an external surface of a sapphire window in a circular mode at a fixed rate. When the beam meets a particle, backscattered light is generated, a time lag between the laser emission and the reflection times' scanning velocity is measured, and a chord length is generated. Chord length is on scanning path from one endpoint to the other. Thousands of chords are measured during single duration (2 sec), generated chord length distribution.

[0058] PVM ((Particle Vision and Measurement) is a probe-based video microscope that visualizes particles sizes, shapes and concentrations. PVM continuously generates 1090x820 μm greyscale images of slurry in real time.

[0059] As flocculation takes places, fine particles were captured and aggregated into larger flocs, displaying more longer chords and fewer shorter chords in FBRM output while presenting water channels (i.e. dark area) in PVM images. Statistical analysis of FBRM chord length distributions and image analysis of PVM can thus be used to quantify flocculation level. For example, FBRM square-weighted mean chord length (sq MCL) and average standard deviation of the pixel values of PVM images can track the degree of flocculation. FBRM sq MCL relates to aggregate size; the higher MCL value, the larger the aggregate size. A low standard deviation of PVM image indicates the pixel colors are relatively uniformly grey, as is typical with underflocculated fines or a low or no flocculation level. A high standard deviation indicates that flocs are present, with bright flocs and darker water channels.

[0060] The gray areas at the left at each of Figures 2 and 3 show the approximate levels of underdosing of the additive. As can be seen in Figures 2 and 3, utilizing either of these detection methods (FBRM in Figure 2 or PVM in Figure 3) that for a given slurry stream condition, there is an optimum dosage amount which for dosages above that amount either 1) additional additive dosage is wasted with little or no optimization of the desired effect, or 2) additional additive dosage begins to result in a decrease in the optimal desired effect.

[0061] The "characteristic" is also a function of both slurry sand-to-fines ratio (SFR) and solids content. Therefore, placing FBRM or PVM probes into a thickener feedwell for feedback control, as opposed to using a slip stream, may be challenging or impractical when faced with feed variability.

[0062] On the other hand, as illustrated in Figure 4, for a given slurry, recommended additive dosage levels can be determined with measurements at a plurality of additive dosage levels. When the measurements at these additive dosage levels are taken off one or more slip streams from the slurry, where the slip stream(s) are representative of the slurry, the information can be used to inform processing decisions to the slurry in real-time, thereby realizing feed forward control. For a wide range of slurry variability, integration of an operation strategy such as illustrated in Figure 5, may not only facilitate additive dosage recommendation against a changing slurry but may also infer compositional range, providing

guidance on upstream or downstream operation, such as changing a tailing stream(s) blending ratio, recycling FFT, or changing bed residence time. In Figure 5, each of the four dosage levels, e.g. (n-1) to (n+2), can be used to operate a corresponding range of feed SFR to maintain sustained dynamic thickener operation at design hydraulic rate without incurring bed flooding and rat-holling, respectively. Instead of SFR, another compositional characteristic may be used.

[0063] Measurements at a plurality of additive dosage levels off slip stream(s) may be taken cyclically, sequentially, simultaneously, or any combination thereof. Figures 6 to 8 illustrate installation scheme examples that may be used to realize real-time process control. Where the plurality of additive dosage levels are termed n-y, n, n+z, and the obtained characteristics at the plurality of additive dosage levels are termed signal (n-y), signal (n), and signal (n+z), where y and z are predetermined incremental additive dosage levels, where y and z are the same or different, one can record the relationship of the three signals and determine a dosage level recommendation according to the following rules:

- if signal (n-y) < signal (n) < signal (n+z), then signal for additive dosage level of (n+z) to the slurry and increase dosage level in next slip stream dosing;
- if signal (n-y) < signal (n) = signal (n+z), then signal for additive dosage level of (n) to the slurry; and
- if signal (n-y) = signal (n) = signal (n+z), then signal for additive dosage of (n-y) to the slurry and lower additive dosage level in next slip stream dosing.

[0064] Figure 6 is an example of a "cyclic" scheme. A slip stream (604) is taken from a slurry (602) and may be passed through a flow meter and/or a density meter (606). The flow meter may be used to measure and/or regulate flow while the density meter may be used to measure slip stream density. An additive (608) is injected into the slip stream (604) which is then passed through an inline or dynamic mixer (610). An analyzer (612) measures the slip stream at the n-y dosage level to obtain a characteristic indicative of a degree of flocculation, agglomeration, or aggregation at the n-y dosage level. The method is repeated for dosage levels of n and n+z and the method continues according to the above rules.

[0065] Figure 7 is an example of an "in series" or sequential scheme. A slip stream (704) is taken from a slurry (702) and is passed through a flow meter and/or density meter (706). An additive (708a) is injected into the slip stream (704), to achieve an n-y dosage, and the slip stream is then passed through an inline or dynamic mixer (710a). An analyzer (712a) measures the slip stream at the n-y additive dosage to obtain a characteristic indicative of a degree of flocculation, agglomeration, or aggregation for the n-y additive dosage. The method is repeated with incrementally more additive (n and n+z) using additional additive (708b and 708c), additional inline or dynamic mixers (710b and 710c), and additional analyzers (712b and 712c). The method then continues according to the above rules.

[0066] Figure 8 is an example of an "in parallel" or simultaneous scheme. One slip stream (804) is taken from a slurry (802), and separated into three sub slip streams (804a, 804b, and 804c) (which may also be referred to as portions of the slip stream) which are passed through flow meters and/or density meters (806a, 806b, and 806c), respectively. Additive (808a, 808b, and 808c) is added to the sub slip stream to achieve dosage levels of n-y, n, and n+z, respectively, followed by inline or dynamic mixers (810a, 810b, and 810c), respectively and the sub slip streams are analyzed by analyzers (812a, 812b, and 812c), respectively. The method then continues according to the above rules.

[0067] Figures 6 to 8 merely illustrate three of a myriad of possible configurations. Ancillary instrumentation or equipment in the slip stream(s) may be added to improve stabilization or accuracy, depending, for instance, on slurry variability. Ancillary instruments may include, but are not limited to, a density meter, a buffering tank, and a dynamic mixer.

[0068] Density meter(s) may be installed in the main slip stream(s) or in a portion of the slip stream(s) to measure the density of the slip stream(s) or portions thereof.

[0069] Static or dynamic mixing unit(s) may be installed in slip stream(s) to induce the flocculation, agglomeration, or aggregation at different additive dosage levels.

[0070] The additive may be injected via one or multiple injection ports. The additive(s) may be introduced to the slip stream(s) at pre-determined level(s) and frequency prior to the mixing unit(s).

[0071] Flow meter(s) may be installed in the main slip stream or a portion of the slip stream(s) to measure and/or regulate the flow rate(s) of the slip stream(s) or portions thereof.

[0072] A dilution stream may be introduced to slip stream(s) in conjunction with flow meter(s) and density meter(s) in slip stream(s) or stream(s) between the slurry(ies) and the slip stream(s) to regulate density or solid content of the slip stream(s) prior to additive injection.

[0073] A buffering unit such as continuous flow stirred-tank reactor (CSTR) may be installed between the slurry and slip stream(s) to buffer the flow, that is, to reduce the fluctuation of the slurry prior to additive injection.

[0074] The slip stream(s) may be heated prior to being exposed to the analyzer(s).

[0075] There may be one slip stream off each main feed line to each analyzer unit. Alternatively, there may be multiple slip streams off each slurry line to each solid-liquid separation unit.

[0076] Certain main slurry lines may have a single slip stream and certain main slurry lines have multiple slip streams.

[0077] There may be one online analyzer in each slip stream or there may be multiple analyzers in each slip stream.

[0078] There may be one analyzer in each of some slip stream(s) and multiple analyzer(s) in each of other slurry line(s) to a solid-liquid separation unit.

[0079] PROCESS ADJUSTMENT

[0080] Based on the obtained characteristic, the slurry or the solid-liquid separation process may be adjusted. For instance, the following may be adjusted: additive dosage level, flocculant dosage level, coagulant dosage level, agglomerant dosage level, or flocculant mixing. The adjustment may include combining the slurry with another stream in a proportion to satisfy operational specifications of the solid-liquid separation process. The adjustment may be of an operating parameter of a thickener in the solid-liquid separation process. For instance, the operating parameter of the thickener may include a bed height of the thickener, a feed rate to the thickener, an underflow rate from the thickener, a residence

time in the thickener, or a rake torque. The adjustment may include adjusting an operating parameter downstream of a thickener in the solid-liquid separation process. For instance, the operating parameter downstream of the thickener may include dilution of a thickener underflow or additional additive addition to the thickener underflow.

[0081] Adjustments may be performed in real-time. "Real-time" as used herein may include some delays such as processing delays but is distinct from, for example, off line measurement, analysis, and adjustment.

[0082] Adjustment may also include:

- adjusting the rate at which one or more flocculant(s) are added to a thickener feed stream
- adjusting the rate at which one or more flocculant(s) are added to a thickener underflow stream during re-flocculation
- adjusting the rate at which other additives (e.g. coagulants) are added to a tailings treatment process
- adjusting whether a tailings stream from an extraction plant (e.g. flotation tailings (FT) or froth treatment tailings (FTT) (e.g. TSRU tailings)) are fed to a tailings treatment process or are by-passed to a designated area
- adjusting the rate at which Fluid Fine Tailings (FFT) are fed to a mixbox for mixing the slurry
- adjusting the rate at which an additional tailings streams, such as coarse sand tailings (CST), are fed to a mixbox for mixing the slurry
- adjusting the operating parameters of flocculant mixing equipment during re-flocculation (e.g. dynamic mixer rotations per minute (rpm))
- adjusting operating parameters of a thickener (e.g. underflow and overflow rates, rake speed, and shear thinning loop speed) to control the residence time and bed height in the thickener.

[0083] As mentioned briefly above, for a wide range of slurry variability, integration of an operation strategy such as illustrated in Figure 5, may not only facilitate additive dosage recommendation against a changing slurry but may also infer a compositional range of the slurry, providing guidance on upstream or downstream operation, such as changing a tailing stream(s) blending ratio, recycling FFT, or changing bed residence time. The correlation between slurry composition and additive dosage may be continuous or discrete. The slurry compositional range may be compared to an acceptable operating window of a tailings treatment process to determine whether the slurry should be fed to the treatment unit or diverted to a designated area, e.g. a tailings pond.

[0084] The composition and solid mass flow rates and/or blending rate of a slurry to a thickener may be adjusted by varying the feed rates of FFT or another stream (e.g. CST) to achieve a target dosage level, thus regulating an overall feed composition range to a solid-liquid separation unit to maintain its steady and desired performance and managing additive supply.

[0085] Operation parameters of a solid-liquid separation unit, e.g. bed height of a thickener, may be adjusted to match the compositional range of the slurry to achieve a desired product specification.

[0086] The inferred compositional range variation along with feed rate and density as a function of stream time may be integrated to inform compositional range of thickener underflow, that may then be used together with additional information for further process decisions of downstream operations, for instance dilution, dosage level of flocculation, agglomeration or aggregation steps, mixing control, use of additional additives, or diversion of a stream.

[0087] The method described herein may also be used to screen additive(s) types and performances against a live feed stream by using one or multiple slip streams and comparing them against base additive(s) in use.

[0088] Compositional online analyzer(s) in the slurry(ies) or slip streams may be used for dosage control and to provide guidance to downstream or upstream operations.

[0089] Compositional online analyzer(s) in the slurry(ies) or slip streams may be integrated with flocculation monitoring system(s) in the same or separate slip streams for dosage control and to provide guidance to downstream or upstream operations.

[0090] A correlation may be developed between an optimal dosage for the slip stream(s) and an optimal dosage level for the main stream(s) and used for dosage recommendation.

[0091] A system for implementing a method described herein may include: a slurry line for carrying the slurry; at least one slip stream line for carrying a slip stream; and at least one analyzer for measuring at least a portion of the slip stream at the plurality of additive dosage levels to obtain the characteristics indicative of the degree of flocculation, agglomeration, or aggregation for each of the plurality of additive dosage levels. Consistent with Figure 8, the at least one slip stream feeds may have at least three sub slip streams arranged in parallel, and each sub slip stream may comprise at least one analyzer for measuring the sub slip stream at at least one of the plurality of additive dosage levels to obtain a characteristic indicative of a degree of flocculation, agglomeration, or aggregation for each of the plurality of additive dosage levels corresponding to each of the sub slip streams.

[0092] 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.

[0093] 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 a slurry intended as a feed stream to a solid-liquid separation process;

(b) removing a slip stream from the slurry;

(c) measuring at least a portion of the slip stream at a plurality of additive dosage levels to obtain a characteristic indicative of a degree of flocculation, agglomeration, or aggregation for each of the plurality of additive dosage levels; and

(d) adjusting an additive dosage level of the slurry;

wherein the measuring and adjusting are performed using the following logic rules, wherein the plurality of additive dosage levels are termed (n-y), (n), and (n+z), and the obtained characteristics at the plurality of additive dosage levels are termed signal (n-y), signal (n), and signal (n+z), where y and z are predetermined incremental additive dosage levels, where y and z are the same or different:

- if signal (n-y) < signal (n) < signal (n+z), then signal for additive dosage level (n+z) to the slurry and increase dosage level in next slip stream dosing;
- if signal (n-y) < signal (n) = signal (n+z), then signal for additive dosage level (n) to the slurry; and
- if signal (n-y) = signal (n) = signal (n+z), then signal for additive dosage (n-y) to the slurry and lower additive dosage level in next slip stream dosing.

2. The method of claim 1, further comprising, based on the obtained characteristics, determining a recommended additive dosage level of the slurry.

3. The method of claim 1 or 2, further comprising, based on the obtained characteristics, and correlation reference data, determining a compositional parameter of the slurry.

4. The method of claim 3, further comprising, where the determined compositional parameter falls outside of an operation window of the solid-liquid separation process, bypassing

the solids-liquid separation process and passing the slurry to a designated area as an untreated slurry.

5. The method of claim 1, wherein step d) comprises adjusting a flocculant dosage level, a coagulant dosage level, or an agglomerant dosage level of the slurry.

6. The method of claim 1, wherein step d) further comprises adjusting flocculant mixing.

7. The method of claim 1, wherein step d) further comprises adjusting the solid-liquid separation process.

8. The method of claim 1, wherein the adjusting of the additive dosage level comprises adjusting flocculant dosage level of the slurry.

9. The method of claim 1, wherein the adjusting of the additive dosage level is performed in real-time.

10. The method of any one of claims 1 to 9, wherein the slurry is an oil sand stream.

11. The method of claim 10, wherein the oil sand stream is an oil sand tailings stream.

12. The method of claim 11, wherein the oil sand tailings stream stems from an aqueous based extraction process.

13. The method of claim 11, wherein the oil sand tailings stream stems from a solvent based extraction process.

14. The method of claim 11, wherein the oil sand tailings stream comprises coarse tailings, middlings, flotation tailings, froth separation tailings, tailings solvent recovery unit (TSRU)

tailings, fluid fine tailings (FFT), mature fine tailings (MFT), thickened tailings, thickener overflow, centrifuged tailings, hydrocycloned tailings, or a combination thereof.

15. The method of claim 11, wherein the oil sand tailings stream comprises a feed stream to a thickener, a thickener overflow, or a thickener underflow.

16. The method of claim 11, wherein the oil sand tailings stream comprises a feed stream to a centrifuge, filter, or inline mixer.

17. The method of any one of claims 1 to 9, wherein the slurry comprises a mining slurry.

18. The method of any one of claims 1 to 9, wherein the slurry comprises a thickener underflow.

19. The method of any one of claims 1 to 9, wherein the slurry comprises a drilling mud or waste stream from a drilling operation.

20. The method of any one of claims 1 to 19, wherein the characteristic comprises a measure of flocculent, agglomerate, or aggregate size.

21. The method of any one of claims 1 to 19, wherein the characteristic comprises a measure of flocculent, agglomerate, or aggregate settling rate.

22. The method of any one of claims 1 to 19, wherein the characteristic comprises a measure of supernatant turbidity.

23. The method of any one of claims 1 to 19, wherein the characteristic comprises a measure of flocculent, agglomerate, or aggregate compaction density.

24. The method of any one of claims 1 to 19, wherein the characteristic comprises a measure of flocculent, agglomerate, or aggregate filtration rate.

25. The method of any one of claims 1 to 24, wherein the measurement is performed by one or more online analyzers.

26. The method of any one of claims 1 to 25, wherein the measurement is by focused beam reflectance measurement (FBRM) or particle vision measurement (PVM).

27. The method of any one of claims 1 to 26, wherein the measurement is performed cyclically, in series, in parallel, or in a combination thereof.

28. The method of any one of claims 1 to 26, wherein the measurement is performed cyclically.

29. The method of any one of claims 1 to 26, wherein the measurement is performed in parallel.

30. The method of any one of claims 1 to 26, wherein the measurement is performed in series.

31. The method of any one of claims 1 to 30, further comprising passing the at least a portion of the slip stream through a flow meter to regulate flow.

32. The method of any one of claims 1 to 31, further comprising passing the at least a portion of the slip stream through a density meter to measure density.

33. The method of any one of claims 1 to 32, further comprising adding a dilution stream to the at least a portion of the slip stream to adjust density or solid content of the at least a portion of the slip stream prior to adding additive.

34. The method of any one of claims 1 to 33, further comprising buffering the at least a portion of the slip stream prior to adding additive.

35. The method of any one of claims 1 to 34, further comprising heating the at least a portion of the slip stream prior to the measuring.

36. The method of any one of claims 1 to 35, wherein the slurry is flowed in one or more main slurry lines each feeding a respective thickener.

37. The method of claim 36, wherein each main slurry line has a single slip stream.

38. The method of claim 36, wherein each main slurry line has multiple slip streams.

39. The method of claim 36, wherein certain main slurry lines have a single slip stream and certain main slurry lines have multiple slip streams.

40. The method of any one of claims 1 to 39, further comprising measuring at least a portion of a main slurry line to obtain a characteristic indicative of a degree of flocculation, agglomeration, or aggregation for the slurry, and combining the obtained characteristic of the slurry with the obtained characteristics of the slip stream, and accordingly adjusting the solid-liquid separation process.

41. A system for implementing the method of any one of claims 1 to 40, the system comprising:

(a) a slurry line for carrying the slurry;

(b) at least one slip stream line for carrying a slip stream;

(c) at least one analyzer for measuring at least a portion of the slip stream at the plurality of additive dosage levels to obtain the characteristics indicative of the degree of flocculation, agglomeration, or aggregation for each of the plurality of additive dosage levels;

wherein the at least one slip stream feeds at least three sub slip streams arranged in parallel, wherein each sub slip stream comprises at least one analyzer for measuring the sub slip stream at at least one of the plurality of additive dosage levels to obtain a characteristic indicative of a degree of flocculation, agglomeration, or aggregation for each of the plurality of additive dosage levels corresponding to each of the sub slip streams; and

(d) an adjustment system for adjusting an additive dosage level of the slurry;

wherein the at least one analyzer and the adjustment system are configured to perform the measuring and the adjusting using the logic rules recited in claim 1.

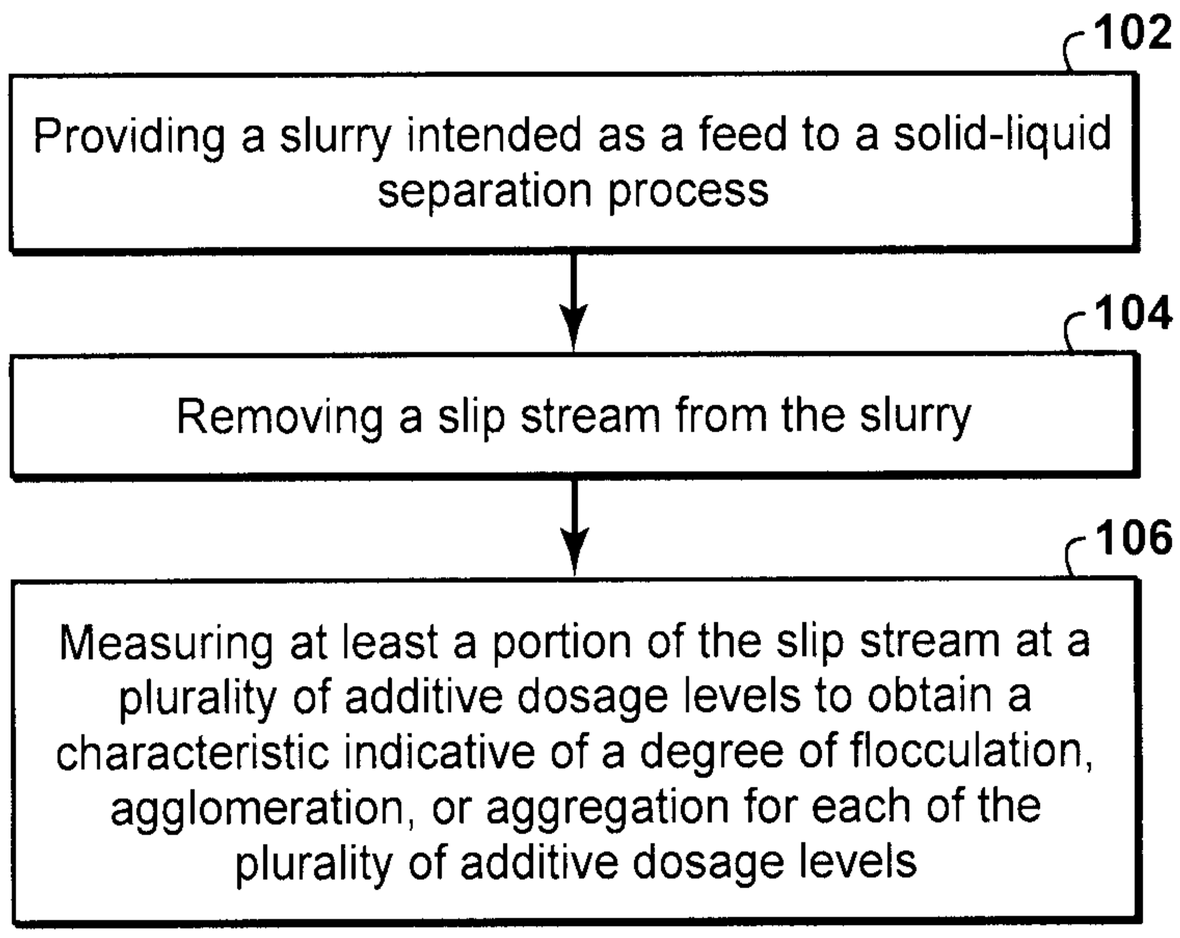

102
Providing a slurry intended as a feed to a solid-liquid separation process
104
Removing a slip stream from the slurry
106
Measuring at least a portion of the slip stream at a plurality of additive dosage levels to obtain a characteristic indicative of a degree of flocculation, agglomeration, or aggregation for each of the plurality of additive dosage levels

FIG. 1

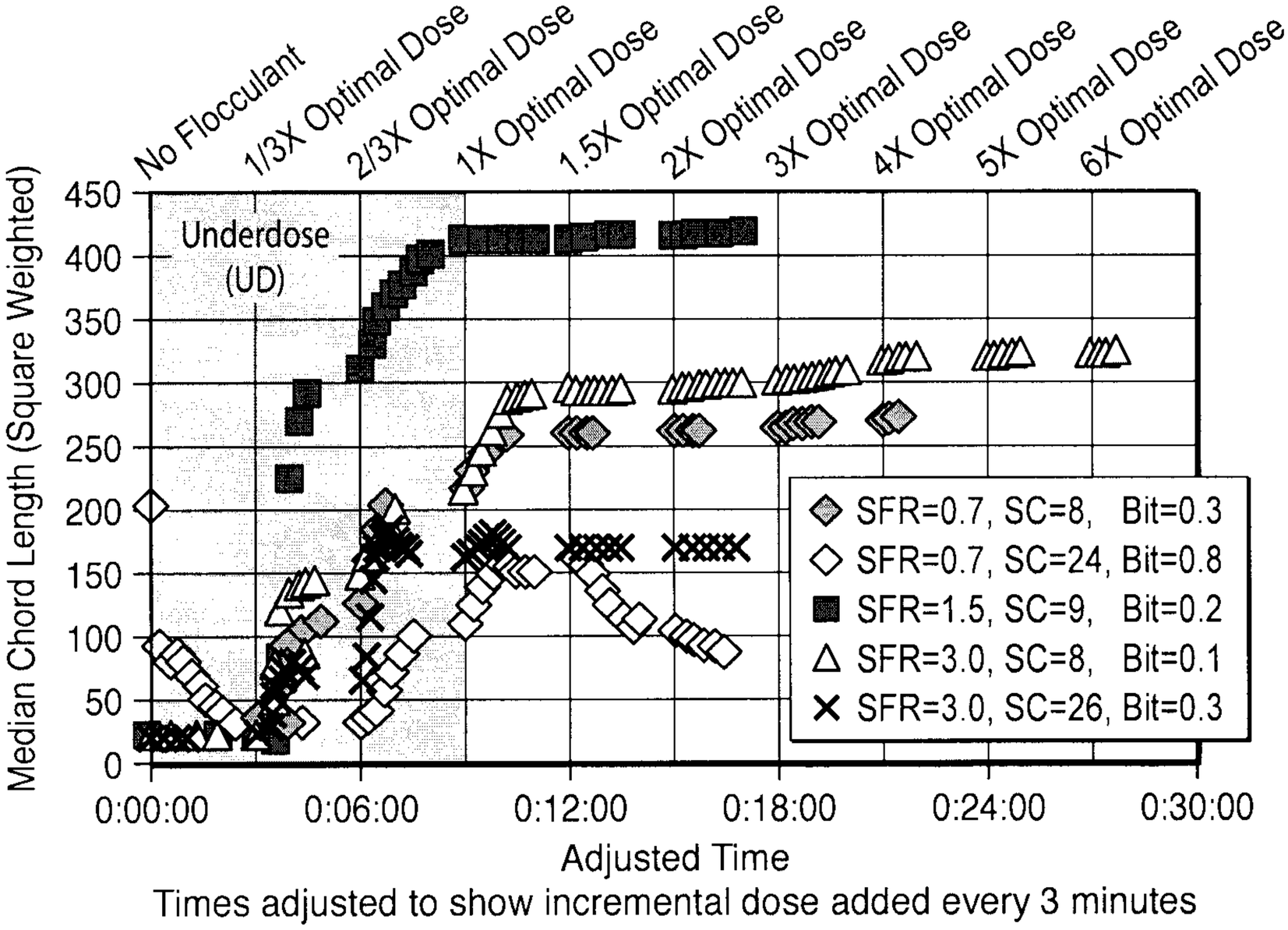

No Flocculant
1/3X Optimal Dose
2/3X Optimal Dose
1X Optimal Dose
1.5X Optimal Dose
2X Optimal Dose
3X Optimal Dose
4X Optimal Dose
5X Optimal Dose
6X Optimal Dose
Underdose (UD)
Median Chord Length (Square Weighted)
450
400
350
300
250
200
150
100
50
0
0:00:00
0:06:00
0:12:00
0:18:00
0:24:00
0:30:00
Adjusted Time
Times adjusted to show incremental dose added every 3 minutes
SFR=0.7, SC=8, Bit=0.3
SFR=0.7, SC=24, Bit=0.8
SFR=1.5, SC=9, Bit=0.2
SFR=3.0, SC=8, Bit=0.1
SFR=3.0, SC=26, Bit=0.3

FIG. 2

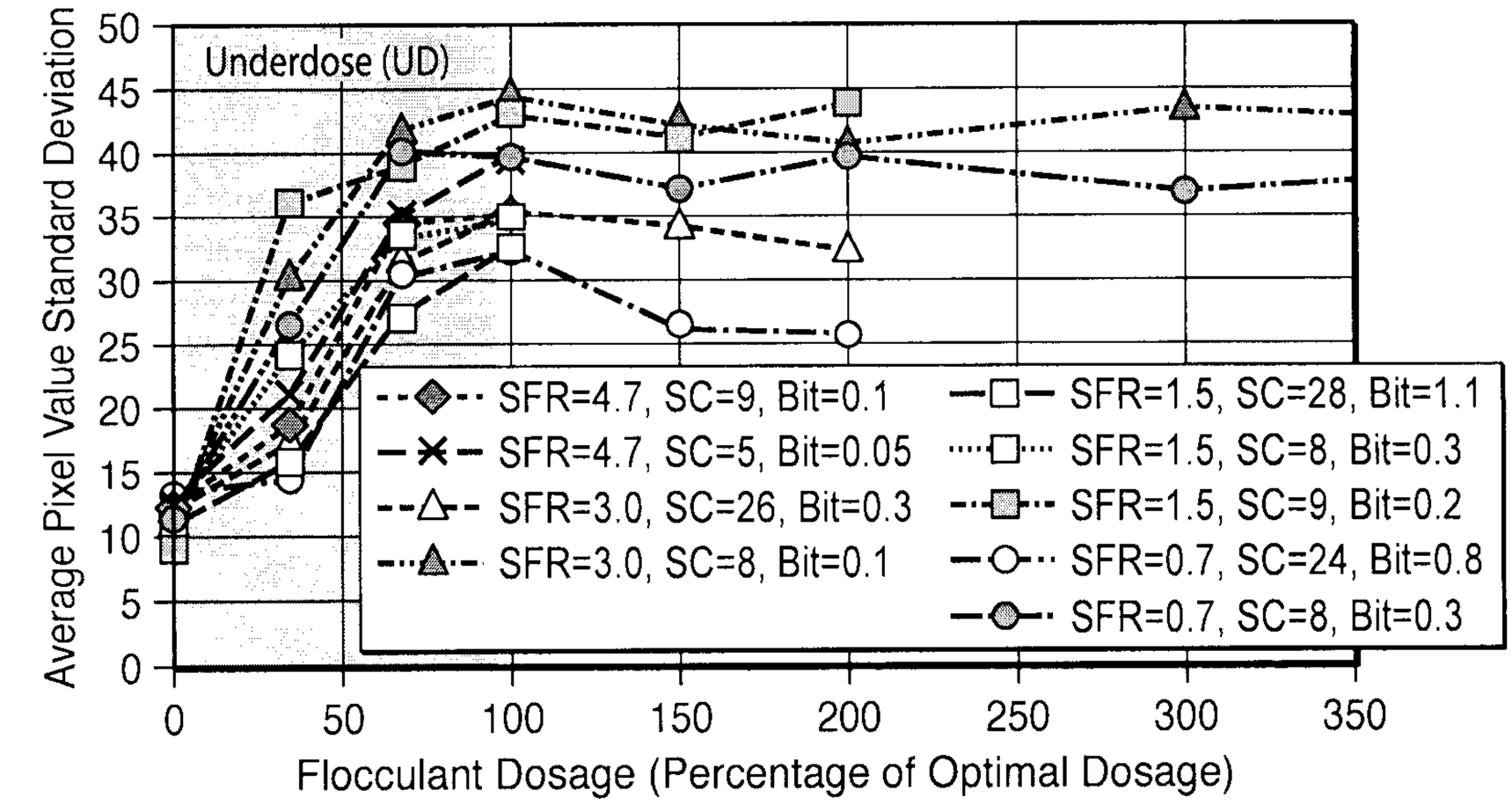

Underdose (UD)
Average Pixel Value Standard Deviation
50
45
40
35
30
25
20
15
10
5
0
0
50
100
150
200
250
300
350
Flocculant Dosage (Percentage of Optimal Dosage)
SFR=4.7, SC=9, Bit=0.1
SFR=4.7, SC=5, Bit=0.05
SFR=3.0, SC=26, Bit=0.3
SFR=3.0, SC=8, Bit=0.1
SFR=1.5, SC=28, Bit=1.1
SFR=1.5, SC=8, Bit=0.3
SFR=1.5, SC=9, Bit=0.2
SFR=0.7, SC=24, Bit=0.8
SFR=0.7, SC=8, Bit=0.3

FIG. 3

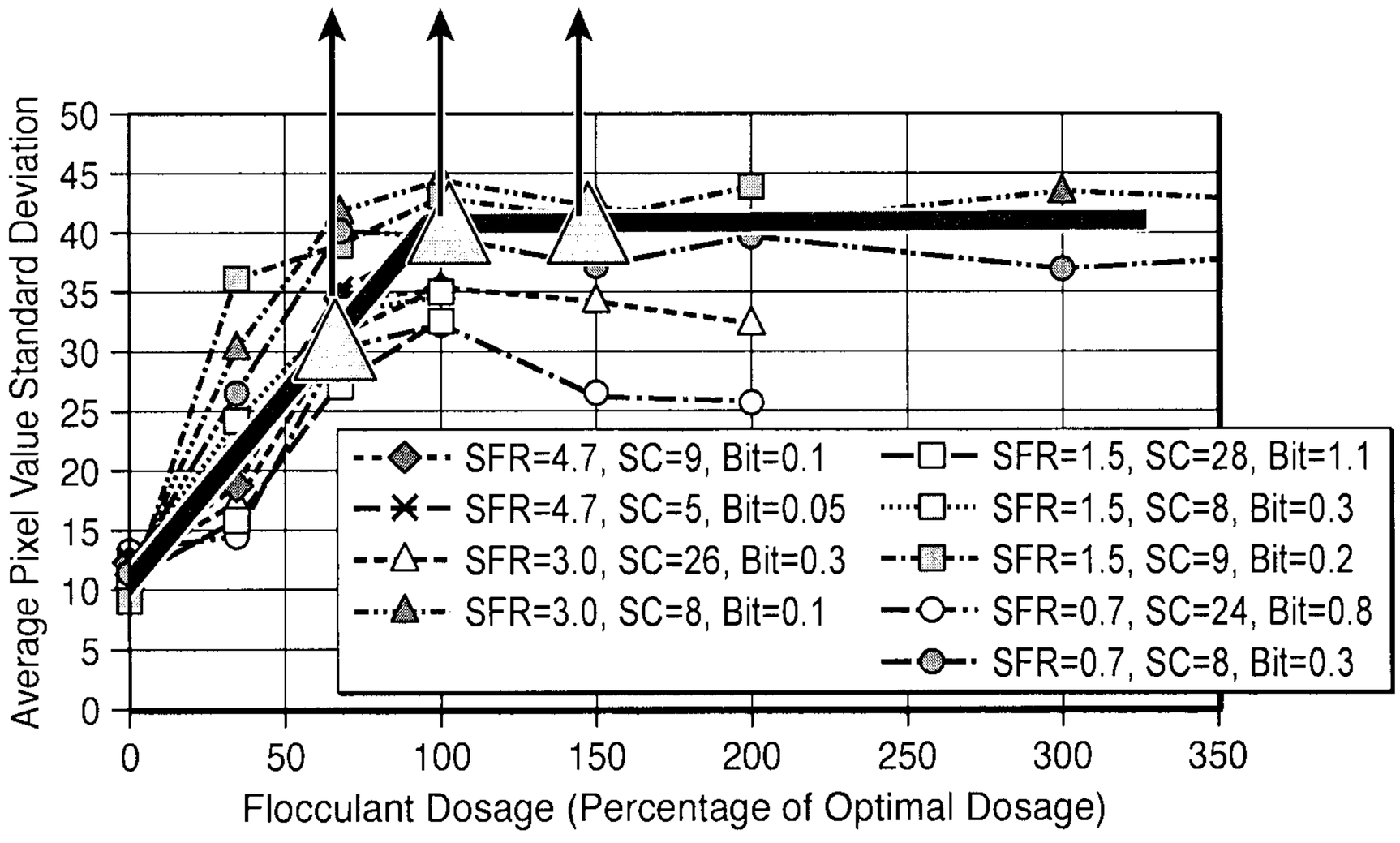

Average Pixel Value Standard Deviation
50
45
40
35
30
25
20
15
10
5
0
0
50
100
150
200
250
300
350
Flocculant Dosage (Percentage of Optimal Dosage)
SFR=4.7, SC=9, Bit=0.1
SFR=4.7, SC=5, Bit=0.05
SFR=3.0, SC=26, Bit=0.3
SFR=3.0, SC=8, Bit=0.1
SFR=1.5, SC=28, Bit=1.1
SFR=1.5, SC=8, Bit=0.3
SFR=1.5, SC=9, Bit=0.2
SFR=0.7, SC=24, Bit=0.8
SFR=0.7, SC=8, Bit=0.3

FIG. 4

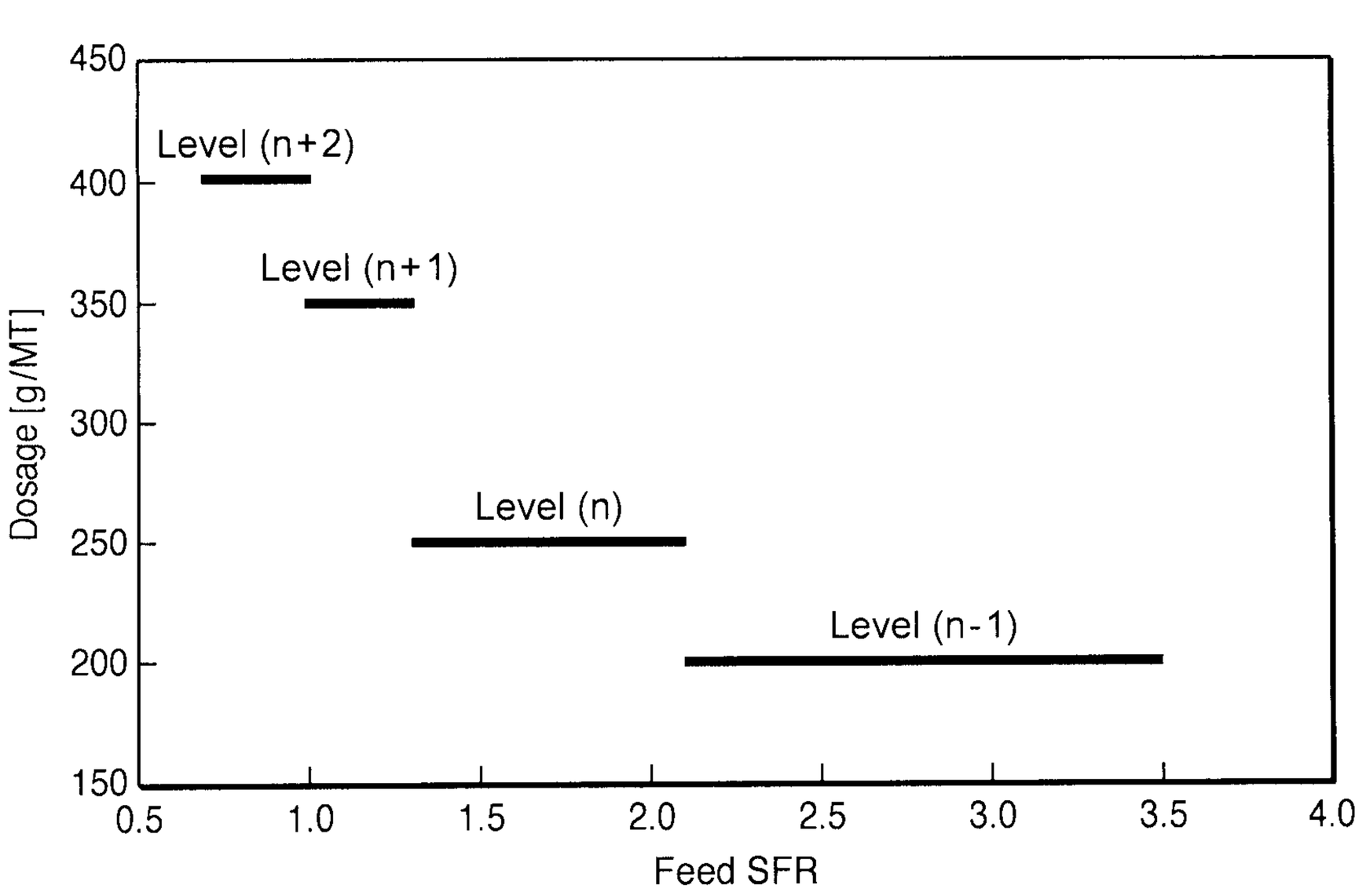

Dosage [g/MT]
450
400
350
300
250
200
150
Level (n+2)
Level (n+1)
Level (n)
Level (n-1)
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Feed SFR

FIG. 5

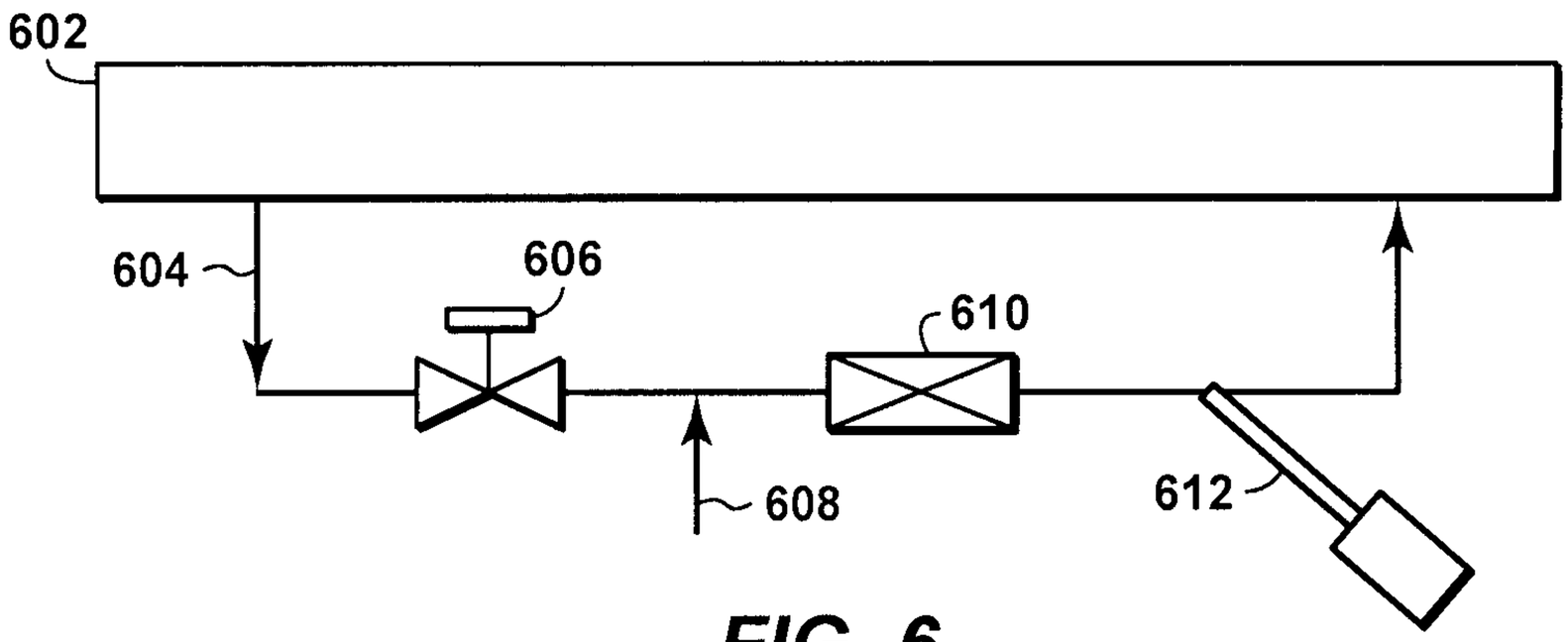


FIG. 6

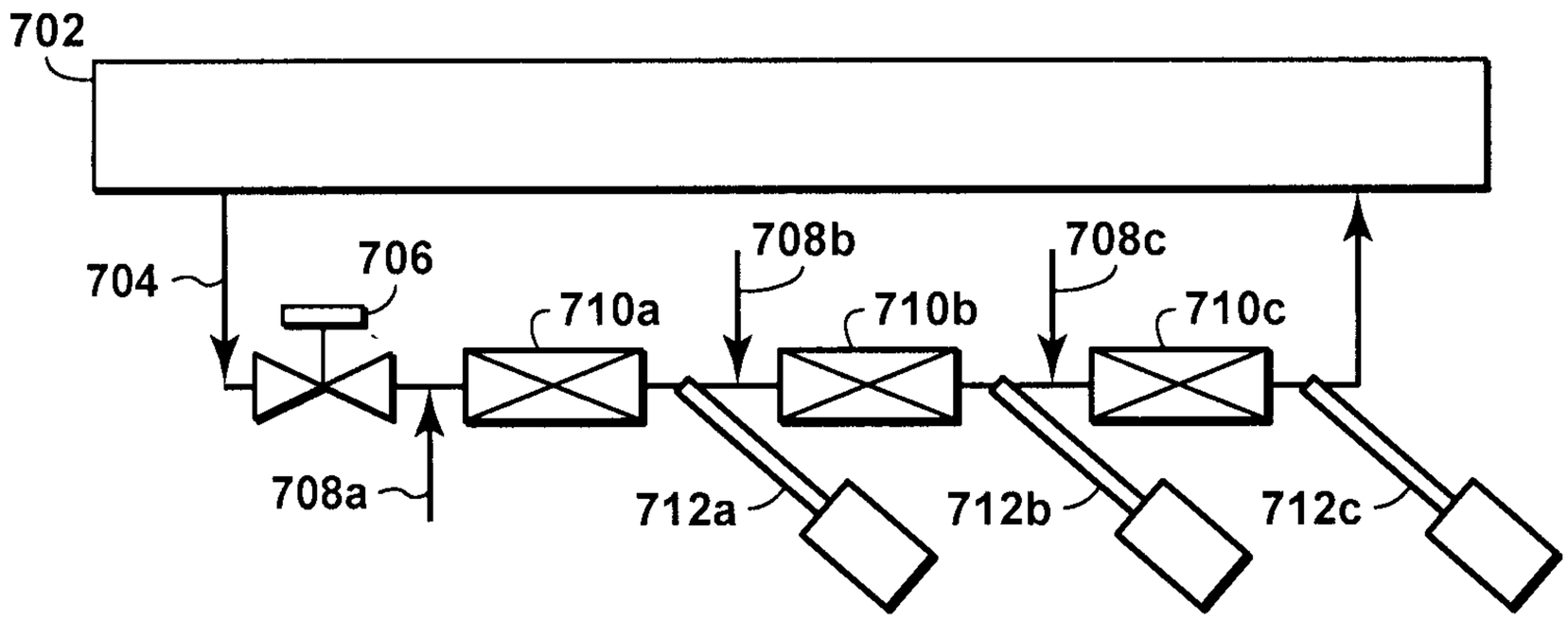


FIG. 7

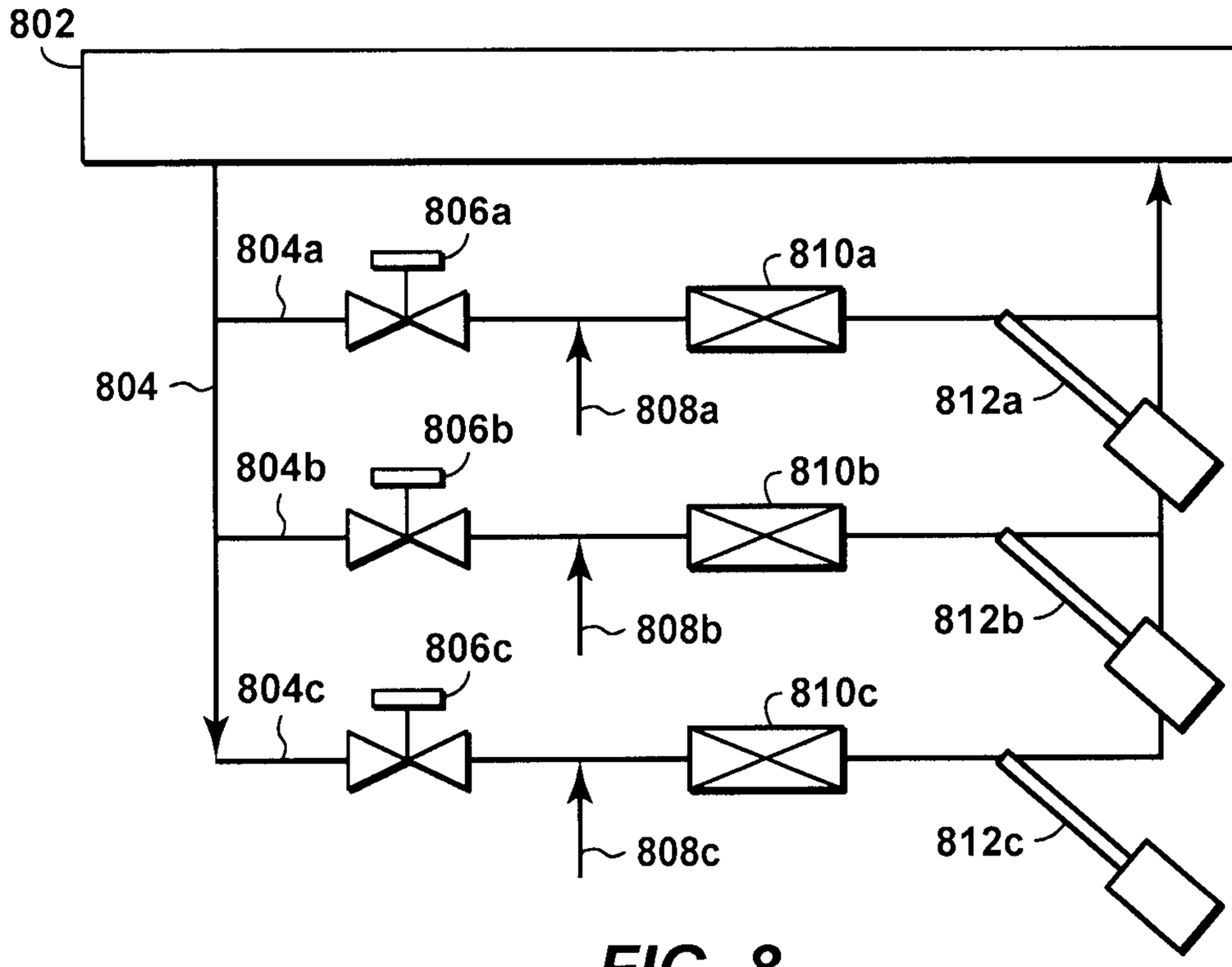
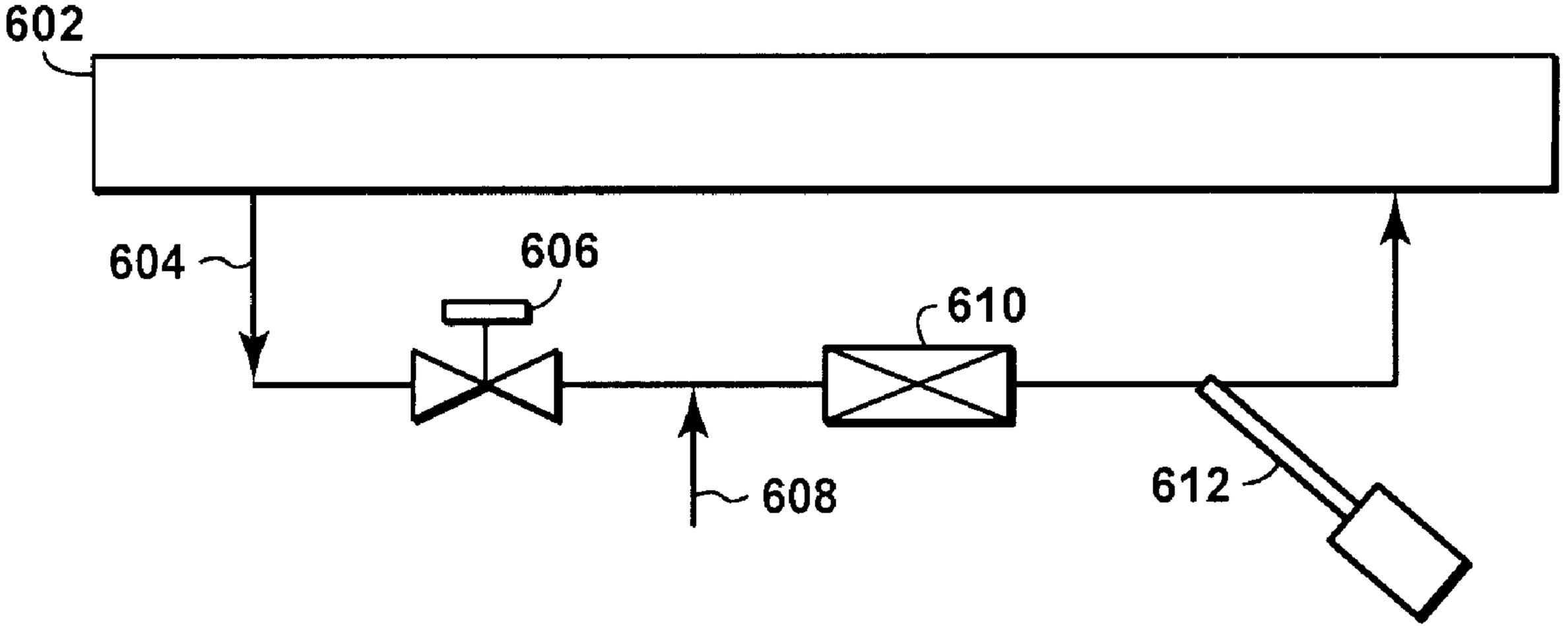


FIG. 8


602
604
606
610
608
612