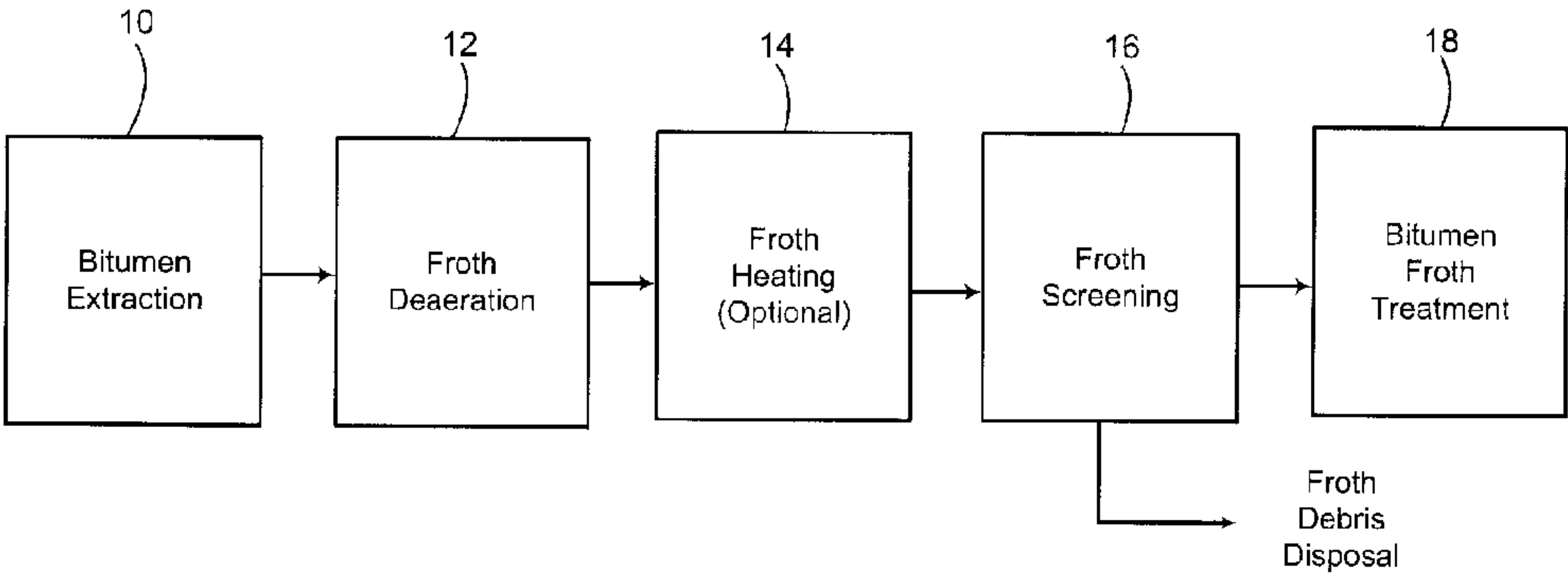




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(54) Titre : PROCÉDES ET SYSTEMES DE PRETRAITEMENT DE MOUSSE DE BITUME POUR TRAITEME T DE MOUSSE

(54) Title: PROCESSES AND SYSTEMS FOR PRE-TREATING BITUMEN FROTH FOR FROTH TREATMENT



(57) **Abrégé/Abstract:**
Pre-treatment of bitumen froth can include removal of solid debris using a moving screen onto which the froth is supplied. The moving screen can be configured and operated so that the debris is advanced toward a downstream section, and the screened froth is collected below at least an upstream section, while the moving screen can be washed, for example by using various spray configurations. The screening can include removal of debris having a non-aggregatable size so as to prevent or reduce accumulation of the debris at the water-hydrocarbon interface in a downstream separation vessel. Enhanced froth screening and downstream processing is facilitated.

ABSTRACT

Pre-treatment of bitumen froth includes removal of solid debris using a moving screen onto which the froth is supplied. The moving screen is configured and operated so that the debris is advanced toward a downstream section, and the screened froth is collected below at least an upstream section, while the moving screen is washed, for example by using various spray configurations. The screening includes removal of debris having a non-aggregatable size so as to prevent or reduce accumulation of the debris at the water-hydrocarbon interface in a downstream separation vessel. Enhanced froth screening and downstream processing is facilitated.

PROCESSES AND SYSTEMS FOR PRE-TREATING BITUMEN FROTH FOR FROTH TREATMENT

FIELD OF THE INVENTION

- 5 The present invention generally relates to the field of bitumen froth treatment operations and, more particularly, to pre-treating bitumen froth before undergoing froth treatment, such as paraffinic froth treatment.

BACKGROUND

- During oil sands processing, oil sands ore containing bitumen is mixed with
10 heated water to form a slurry of oil sand and water. This slurry is then fed into a primary separation vessel (PSV), or separation cell, where the more buoyant bitumen component floats to the surface to form a froth which is commonly referred to as bitumen froth. Due to their density and affinity to hydrocarbons, debris such as coal, petrified wood, green wood, and plastics are found in varying
15 quantities in the slurry, and are also present in the bitumen froth.

- This debris floats in the bitumen froth and often consists of large particles which can clog equipment used in froth treatment and downstream process operations. Furthermore, the debris typically has a density between that of water and diluted bitumen, which results in the debris tending to accumulate at the
20 hydrocarbon/water interface. Smaller sized particles, such as mineral fractions, with a diameter greater than 44 microns, are generally referred to in the industry as "sand". Even smaller mineral fractions with a particle diameter less than 44 microns are generally referred to as "fines".

- It is desirable to separate this debris from the bitumen froth before the froth is
25 further treated. Debris screening is used in various processes, but the properties of bitumen froth are such that application of general known techniques is fraught with difficulties and disadvantages.

- One reason for this is that bitumen froth is highly viscous, which tends to limit the direct separation of debris to relatively large particles, e.g. greater than 8 mm in
30 size. Diluents can be added to reduce the viscosity of the bitumen froth, but these can negatively affect downstream processing and may need to be removed before or during froth treatment. Handling the large debris particles that may be

coated with bitumen and/or diluent is also difficult, labour intensive, and can involve attendant safety risks resulting from the handling of hot, viscous, adherent materials as well as variable compositions and flow rates of such materials.

Smaller screens, e.g. having grates of 1 inch spacing, tend to require the use of
 5 the entire perimeter of a separation cell, and a dedicated work crew to clear the grating in order to prevent it from plugging up. While other screening techniques using rotating trommels or linear screens can advantageously reduce the clogging in certain applications, there are disadvantages related to handling periodic surges and debris exceeding the screen's capacity, which is sensitive to density
 10 and viscosity.

Attempts have been made to grind or strain large debris particles after a diluent is added, but this tends to lead to the debris interfering at the oil/water interface, which makes oil/water separation more difficult. Furthermore, handling diluent-contaminated debris is best avoided.

15 Bitumen froth can also have a high gas content. Usually the gas essentially consists of air. When bitumen froth exits the PSV, it typically includes 30-50% vol. gas. This volume of gas needs to be significantly reduced so as to prevent vapour lock and other pumping problems when the froth is pumped downstream for treatment. It is also desirable to reduce the gas content of the froth prior to
 20 paraffinic froth treatment.

Upon performing de-aeration using some of these known techniques, the gas content of the bitumen froth may be reduced to 10-15% vol., which has generally been considered sufficiently de-aerated for the purposes of froth pumping. However, flow variations or surges from separation cells can adversely influence
 25 de-aeration operations, which may interrupt the flow of de-aerated bitumen exiting the de-aerator and heading towards the pump, which can cause vapour lock in the froth pump, further causing flow problems in the operations of downstream units.

There are also other disadvantages with known de-aeration techniques. Static de-
 30 aeration only removes about 50% vol. of gas from the froth, and does not prevent re-entrainment of air or other gases into the froth, resulting in bitumen froth often having at least 9.5% vol. of gas. The process of steam de-aeration typically consists of froth cascading against rising steam and condensing on shed decks.

However, the viscosity and surface tension of the froth can result in unstable flows over the shed decks. Mechanical de-aeration can involve installation of impellers in a launder. Although certain data indicate that de-aerated froth having less than 5% vol. can be achieved by using mechanical de-aeration, the commercial viability of such a technique is not known.

SUMMARY OF THE INVENTION

The present invention provides processes and systems for pre-treating bitumen froth containing debris for a froth treatment operation, such as a paraffinic froth treatment operation.

10 In one implementation, there is provided a process for pre-treating a variable flow of bitumen froth prior to a froth treatment operation, comprising:

providing the variable flow of bitumen froth to a feed unit;

adjusting the feed unit in response to the variable flow to provide a regulated flow of the bitumen froth;

15 subjecting the regulated flow of the bitumen froth to screening to remove debris from the regulated flow of the bitumen froth to produce screened bitumen froth and separated debris; and

providing the screened bitumen froth into the froth treatment operation.

20 In one optional implementation, the feed unit comprises an upstream compartment and a downstream compartment and the feed unit is adjusted to provide the regulated flow of the bitumen froth from the upstream compartment into the downstream compartment.

25 In another optional implementation, the feed unit comprises a surge tank comprising a regulator device separating the upstream compartment and the downstream compartment.

In another optional implementation, the surge tank retains the bitumen froth for a duration ranging from about 1 minute to about 10 minutes.

In another optional implementation, the adjusting of the feed unit comprises displacement of the regulator device.

In another optional implementation, the regulator device comprises a partition defining the upstream compartment and the downstream compartment.

In another optional implementation, the partition is vertically displaceable.

In another optional implementation, the adjusting comprises:

- 5 gradually increasing the regulated flow of bitumen froth in response to a flow surge of the variable flow of bitumen froth; or
- gradually decreasing the regulated flow of bitumen froth in response to a large decrease of the variable flow of bitumen froth.

In another optional implementation, the process further comprises:

- 10 dispending the regulated flow of the bitumen froth so as to have a consistent quantity for the screening.

In another optional implementation, the process further comprises:

spraying a wash fluid onto the bitumen froth or screen unit during the screening.

- 15 In another optional implementation, the froth treatment operation is a paraffinic froth treatment operation.

In another implementation, there is provided a system for pre-treating a variable flow of bitumen froth prior to a froth treatment operation, comprising:

a feed unit comprising:

- 20 an upstream compartment comprising an inlet for receiving the variable flow of the bitumen froth;
- a downstream compartment; and
- a regulator device separating and regulating transfer of the bitumen froth from the upstream compartment to the downstream
- 25 compartment, to provide a regulated flow of the bitumen froth into the downstream compartment; and
- a screen unit in fluid communication with the downstream compartment of the feed unit for receiving the bitumen froth therefrom to remove debris

from the bitumen froth to produce screened bitumen froth and separated debris.

In one optional implementation, the feed unit comprises a surge tank.

5 In another optional implementation, the regulator device comprises a partition provided within the surge tank and separating the upstream compartment from the downstream compartment.

In another optional implementation, the wall comprises a plate arranged transversely with respect to the flow of the bitumen froth.

10 In another optional implementation, the partition has a top edge and is vertically displaceable for adjusting the flow rate of the bitumen froth flowing over the top edge into the downstream compartment.

In another optional implementation, the regulator device comprises a weir.

In another optional implementation, the system further comprises:

15 a spraying apparatus arranged with respect to the screen unit for spraying wash fluid over the bitumen froth and/or the screen unit.

In another optional implementation, the screen unit comprises a moving screen device.

In another optional implementation, the moving screen device includes a speed adjuster for adjusting speed of the moving screen device.

20 In another optional implementation, the moving screen device comprises a linear screen.

In another optional implementation, the froth treatment operation is a paraffinic froth treatment operation.

25 In another implementation, there is provided a system for pre-treating bitumen froth comprising solid debris prior to froth treatment, comprising:

a moving screen device comprising:

an upstream section;

a downstream section;

means to advance the bitumen froth from the upstream section toward the downstream section while a portion of the bitumen froth passes through the screen as screened bitumen froth and the solid debris is advanced toward the downstream section;

- 5 a feed inlet arranged at the upstream section of the moving screen device for feeding the bitumen froth thereto;
- a washing device for providing washing fluid to the moving screen device; and
- a froth launder below the upstream section of the moving screen device for
- 10 receiving the screened bitumen froth.

In one optional implementation, the washing device is configured in relation to the downstream section of the moving screen to enable washing the debris present on the downstream section and to produce washed debris and spent washing fluid.

- 15 In another optional implementation, the system further comprises a debris launder arranged proximate the downstream section for receiving the washed debris.

In another optional implementation, the system further comprises a wash fluid launder for receiving the spent washing fluid.

- In another optional implementation, the wash fluid launder is configured for
- 20 spanning the length below the moving screening unit.

In another optional implementation, the moving screen device comprises a linear screen or a drum screen.

- In another optional implementation, the system further comprises a feed unit comprising an upstream compartment, a downstream compartment, and a
- 25 regulator device separating and regulating transfer of the bitumen froth from the upstream compartment to the downstream compartment, the downstream compartment being in fluid communication with the feed inlet for feeding the bitumen froth to the upstream section of the moving screen device.

- In another optional implementation, the froth treatment operation is a paraffinic
- 30 froth treatment operation.

In another implementation, there is provided a process for pre-treating bitumen froth comprising solid debris prior to froth treatment, comprising:

- feeding the bitumen froth to an upstream section of a moving screen device;
- 5 screening the bitumen froth to produce screened bitumen froth and separated solid debris;
- advancing the separated solid debris toward a downstream section of the moving screen device;
- receiving the screened bitumen froth below the upstream section of the moving screen device; and
- 10 washing the moving screen device.

In one optional implementation, the washing comprises spraying the downstream section of the moving screen device to enable washing the separated solid debris present on the downstream section and to produce washed debris and spent washing fluid.

In another optional implementation, the washing comprises spraying a screen of the moving screen device to produce additional spent washing fluid.

In another optional implementation, the process further comprises receiving the spent washing fluid in a wash fluid launder.

20 In another optional implementation, the process further comprises recycling the spent washing fluid for reuse in spraying.

In another optional implementation, the process further comprises recuperating energy from the spent washing fluid.

25 In another optional implementation, the froth treatment comprises a paraffinic froth treatment operation.

In another implementation, there is provided a process for pre-treating bitumen froth prior to froth treatment, comprising:

- subjecting the bitumen froth to de-aeration in a de-aerator comprising a cross-flow plate pack to produce a de-aerated bitumen froth; and

subjecting the de-aerated bitumen froth to screening to remove solid debris therefrom and to produce screened bitumen froth and debris.

In one optional implementation, the bitumen froth is pre-heated and introduced into the cross-flow plate pack.

- 5 In another optional implementation, subjecting the bitumen froth to de-aeration comprises slowing bitumen froth flow across the de-aerator.

In another optional implementation, subjecting the bitumen froth to de-aeration further comprises minimizing the depth that gas bubbles within the bitumen froth need to rise to be released from the bitumen froth.

- 10 In another optional implementation, subjecting the bitumen froth to de-aeration further comprises increasing turbulence in the bitumen froth to augment release of gas bubbles.

In another optional implementation, the froth treatment comprises a paraffinic froth treatment operation.

- 15 In another implementation, there is provided a system for pre-treating bitumen froth prior to froth treatment, comprising:

a de-aerator unit having a cross-flow plate pack for producing a de-aerated bitumen froth; and

- 20 a screening unit for receiving de-aerated bitumen froth from the de-aerator unit so as to remove solid debris therefrom to produce screened bitumen froth and rejected debris

In one optional implementation, a heater is provided upstream of the cross-flow plate pack for supplying a pre-heated bitumen froth to the cross-flow plate pack.

- 25 In another optional implementation, the cross-flow plate pack comprises an inlet defining an expanding nozzle so as to slow bitumen froth flow across the de-aerator unit.

In another optional implementation, the inlet defines a substantially frusto-conical shape.

In another optional implementation, the de-aerator unit further comprises a de-aeration chamber having opposed side walls, a bottom wall and a top wall, the de-aeration chamber promoting cross-flow of the bitumen froth.

5 In another optional implementation, the cross-flow plate pack further comprises multiple plates arranged in spaced-apart relationship, thereby defining flow channels through which the bitumen froth is conveyed.

In another optional implementation, the length of each plate is about ten times the width of the same plate.

10 In another optional implementation, the cross-flow plate pack further comprises a weir for stabilising bitumen froth flow.

In another optional implementation, the de-aerator unit further comprises water sprayers positioned above the bitumen froth for spraying gases released from the bitumen froth so as to remove mists of bitumen collecting above the bitumen froth.

15 In another optional implementation, the froth treatment comprises a paraffinic froth treatment operation.

In another implementation, there is provided a treatment process comprising:

subjecting the bitumen froth to pre-treatment to produce a pre-treated froth, wherein the bitumen froth comprises bitumen, water, air and solids, the solids comprising fines and debris;

20 adding a paraffinic solvent to the pre-treated froth to form a diluted froth comprising precipitated water-solid-asphaltene aggregates;

separating the diluted froth into an upper hydrocarbon rich fraction and a lower tailings fraction containing the water-solid-asphaltene aggregates, wherein a water-hydrocarbon interface forms between the upper fraction and the lower fraction;

25

wherein the pre-treatment comprises:

removing from the bitumen froth at least a portion of the debris having a non-aggregatable size so as to prevent or reduce accumulation of the debris at the water-hydrocarbon interface.

In one optional implementation, the step of removing the portion of the debris comprises subjecting the bitumen froth to screening.

In another optional implementation, the process further comprises:

5 monitoring the water-hydrocarbon interface to determine the accumulation of debris therein; and

 adjusting the pre-treatment of the bitumen froth in response to the accumulation of the debris in the water-hydrocarbon interface.

In another optional implementation, the monitoring comprises measuring a thickness of accumulated debris in the water-hydrocarbon interface.

10 In another optional implementation, the adjusting of the pre-treatment comprises:

 adjusting the screening; and/or

 adjusting a temperature of the bitumen froth;

In another optional implementation, the adjusting of screening comprises:

 adjusting a speed of a moving screen device; and/or

15 modifying a pore size of a screen.

In another optional implementation, the moving screen device comprises a linear screen.

20 In another optional implementation, in response to an increase in the accumulation of debris in the water-hydrocarbon interface, the speed of the moving screen device is increased.

In another optional implementation, in response to an increase in the accumulation of debris in the water-hydrocarbon interface, the pore size of the moving screen device is decreased.

25 In another optional implementation, the screening is performed through pores having a size of about 1 to about 4 orders of magnitude greater than the size of aggregatable solids in the bitumen froth.

In another optional implementation, the screening is performed through pores having a size of about 2 to about 3 orders of magnitude greater than the size of aggregatable solids in the bitumen froth.

In another implementation, there is provided a process for pre-treating bitumen froth prior to a froth treatment operation, comprising feeding the bitumen froth onto a screen having pores with different sizes, the pores being positioned with respect to an area of the screen and a supply of the bitumen froth in order to promote even distribution of the bitumen froth over the screen.

In one optional implementation, the pores comprise a first set of pores each defining a small opening and a second set of pores each defining a larger opening, the first set of pores being arranged to receive a main feed flow of the bitumen froth and the second set of pores being arranged to receive an outward spreading flow of the bitumen froth.

In another optional implementation, the screen comprises a moving screen device.

In another optional implementation, the process further comprises adjusting the speed of the moving screen device.

In another optional implementation, the froth treatment operation is a paraffinic froth treatment operation.

In another implementation, there is provided a system for pre-treating bitumen froth prior to a froth treatment operation, comprising:

a screen unit having a plurality of pores that are disposed with respect to the screen to promote even distribution of the bitumen froth over the screen and to produce a screened bitumen froth;

a feed inlet in fluid communication with the screen unit for feeding the bitumen froth to the screen unit; and

a froth launder positioned below the screen unit for receiving the screened bitumen froth.

In one optional implementation, the pores comprise a first set of pores each defining a small opening and a second set of pores each defining a larger opening, the first set of pores being arranged to receive a main feed flow of the bitumen froth and the second set of pores being arranged to receive an outward spreading flow of the bitumen froth.

In another optional implementation, the first set of pores are disposed about along a middle line of the screen and the second set of pores are disposed near the extremities of the screen.

5 In another optional implementation, the screen unit comprises a moving screen device.

In another optional implementation, the moving screen device includes a speed adjuster for adjusting speed of the moving screen device.

In another optional implementation, the moving screen device comprises a linear screen.

10 In another optional implementation, the froth treatment comprises a paraffinic froth treatment operation.

In another implementation, there is provided a process for pre-treating bitumen froth prior to a froth treatment operation, the bitumen froth comprising bitumen, fines, water, air and debris, the process comprising:

15 subjecting the bitumen froth to heating and de-aeration to produce a heated de-aerated bitumen froth;

 subjecting the heated de-aerated bitumen froth to screening to remove the debris therefrom and produce screened bitumen froth and separated debris; and

20 regulating the heating, the de-aeration and the screening such that the screened bitumen froth comprises a consistent air content prior to being introduced into the paraffinic froth treatment operation.

In one optional implementation, the de-aeration and the heating of the bitumen froth is performed concurrently.

25 In another optional implementation, the heating is performed before the de-aeration in a separate heater.

In another optional implementation, the heating is performed after the de-aeration in a separate heater.

30 In another optional implementation, the bitumen froth is heated to a temperature greater than about 65 °C.

In another optional implementation, the heating is performed by a direct steam injector.

In another optional implementation, the screening is performed by a moving screen device.

- 5 In another optional implementation, the regulating includes adjusting speed of the moving screen device.

In another optional implementation, the screening further comprises spraying wash fluid over the heated de-aerated bitumen froth and the regulating includes adjusting flow rate, direction or composition of the wash fluid or a combination
10 thereof.

In another optional implementation, the process further comprises subjecting the separated debris to washing with washing liquid to produce a washed debris and spent washing liquid.

- 15 In another optional implementation, the washing of the debris is at least partly performed during the screening.

In another optional implementation, the froth treatment operation is a paraffinic froth treatment operation.

- In another implementation, there is provided a system for pre-treating bitumen froth prior to a froth treatment operation, the bitumen froth comprising bitumen,
20 fines, water, air and debris, the system comprising:

a de-aeration unit for de-aerating the bitumen froth and a heater for heating the bitumen froth, in order to produce a heated de-aerated bitumen froth;

- 25 a screening unit for removing the debris from the heated de-aerated bitumen froth to produce screened bitumen froth and separated debris;
and

the de-aeration unit and the screening unit are coupled and regulated such that the screened bitumen froth comprises a consistent air content prior to being introduced into the paraffinic froth treatment operation.

- 30 In one optional implementation, a heater is provided upstream of the de-aeration unit for supplying a pre-heated bitumen froth to thereto.

In another optional implementation, a heater is provided downstream of the de-aeration unit for heating bitumen froth after de-aeration in the de-aeration unit.

In another optional implementation, the bitumen froth is heated to a temperature greater than about 65 °C.

- 5 In another optional implementation, the heater is a direct steam injector.

In another optional implementation, the de-aeration unit comprises a de-aeration chamber having opposed side walls, a bottom wall and a top wall, the de-aeration chamber promoting flow of the bitumen froth.

- 10 In another optional implementation, the de-aeration unit further comprises water sprayers positioned above the bitumen froth for spraying gases released from the bitumen froth so as to remove mists of bitumen collecting above the bitumen froth.

In another optional implementation, the screening unit comprises a moving screen device.

- 15 In another optional implementation, the moving screen device includes a speed adjuster for adjusting speed of the moving screen device.

In another optional implementation, the moving screen device comprises a linear screen.

In another optional implementation, the screening unit comprises washing sprays for spraying wash fluid over the heated de-aerated bitumen froth.

- 20 In another optional implementation, the system further comprises a washing unit for washing the separated debris with a washing liquid to produce a washed debris and spent washing liquid.

In another optional implementation, the froth treatment comprises a paraffinic froth treatment operation.

25 **BRIEF DESCRIPTION OF THE DRAWINGS**

Fig 1 is a process flow diagram illustrating production and treatment of bitumen froth.

Fig 2 is a process flow diagram of a bitumen froth pre-treatment operation.

- 30 Fig 3 is another process flow diagram of a bitumen froth pre-treatment operation with a pre-heating unit.

Figs 4A and 4B are additional process flow diagrams of a bitumen froth pre-treatment operation.

Fig 5 is another process flow diagram of a bitumen froth pre-treatment operation with a de-aeration apparatus.

5 Fig 6 is a top view schematic of a screen.

DETAILED DESCRIPTION

Referring to Fig 1, a general process overview is illustrated. Mined bitumen ore is broken down, mixed with water and processed to form a slurry which is fed to a bitumen extraction step 10. Bitumen extraction generates bitumen froth which is
 10 fed to a froth de-aeration step 12. The resulting de-aerated froth is then subjected to an optional froth heating step 14 followed by a froth screening step 16 to remove debris. Once the debris is removed from the bitumen froth, the screened froth is provided to a bitumen froth treatment step 18, e.g., a paraffinic froth treatment (PFT) operation.

15 Processes and systems are described for pre-treating the bitumen froth in preparation for the PFT operation. In some implementations, the pre-treatment system for pre-treating bitumen froth containing debris is able to regulate and smooth-out the flow of froth upstream of a screen so as to optimise debris separation at the screen, and is also able to stabilize the flow of froth to
 20 downstream froth-treatment units, such as PFT separation vessels. The process and system by which this is achieved permits adaptability in response to froth or debris flow surges, while removing debris particles of various sizes in an efficient manner.

Referring to Figs 2-5, implementations of the froth pre-treatment system 20 are
 25 illustrated. The pre-treatment system 20 may comprise various units for pre-treating the bitumen froth containing debris in order to reduce the gas content and debris content of bitumen froth 22.

Still referring to Figs 2-5, the bitumen froth may be received from what is commonly called a primary separation vessel (PSV) 24 as illustrated. It should
 30 nevertheless be understood that the pre-treatment system 20 may receive bitumen froth from a number of units and sources depending on the source and upstream processing of the froth. For instance, in some implementations, the

bitumen froth is derived from an oil sands mining and extraction operation where the bitumen containing ore is processed to produce the bitumen froth 22. In other implementations, the bitumen froth may be derived from an in situ recovery process in which bitumen and/or heavy oil are recovered using underground wells. The bitumen froth 22 may also be a combination of froth derived from an oil sands mining and extraction operation and an in situ recovery operation. The bitumen froth may also be fed to the pre-treatment system 20 from a holding tank or a unit other than the PSV 24 depending on the infrastructural design integrating the extraction step with the pre-treatment step.

10 In some implementations as illustrated in Fig 2, in standard operating mode the pre-treatment system 20 receives bitumen froth 22 from a PSV 24, which separates oil sand ore slurry 26 into an underflow tailings stream, a middlings stream, and an overflow of the bitumen froth 22. The oil sand ore slurry 26 has a composition dependant on the slurry preparation operation, as well as on the geological body from which the ore was obtained. Thus, the oil sand ore slurry 26 and, in turn, the bitumen froth 22, may vary in composition and flow rate. These variations may occur gradually or as a step change, often reflecting the nature of the oil sand ore body. The variations may also derive from upsets in upstream unit operations in oil sand mining and extraction operations. As noted above, the bitumen froth 22 provided to the pre-treatment system 20, rather than coming from an oil sands mining and extraction operation, may be derived from an in situ heavy hydrocarbon operation. In situ operations involve subterranean wells located in bitumen containing reservoirs and use heat, steam, hot water, solvent or various combinations thereof to mobilize the bitumen so that it can be withdrawn through a production well. In situ bitumen containing streams may be subjected to bitumen froth treatment, such as paraffinic froth treatment (PFT), to improve bitumen quality by reducing asphaltene content.

After being treated in the PSV 24, the bitumen froth 22 is typically highly aerated with gas contents in the range of 30-50% vol. In addition, as a result of the density of various types of debris and the debris' affinity to hydrocarbons, particles such as coal, petrified wood, green wood, and plastics are found in varying quantities in the bitumen froth 22. Furthermore, the gas content of the froth 22 is often

unstable, with large froth vapour bubbles breaking as the froth 22 is transported through the system 20.

In order to improve the pumping of bitumen froth 22 through the system 20 using conventional pumps 28, the gas content of the froth 22 is reduced.

- 5 Referring to Figs 2-4B, after being treated in the PSV 24, the froth 22 is sent to a de-aerator 30 so as to reduce its gas content to a level that will prevent vapour locking in downstream equipment. The de-aerator 30 produces a de-aerated froth 32 in which the gas content can be reduced below 15% vol., for instance in a range of 10-15% vol. The gas content of the de-aerated froth 32 may be
10 sufficiently low such that there is reduced or no vapour locking when the de-aerated froth 32 is pumped by downstream pumps 28.

Bitumen froth de-aeration and heating

- The general operation of some implementations of the de-aerator 30 is now described, with reference to Figs 2-4B. The steam de-aerator 30 receives the
15 bitumen froth 22 at an upper portion and produces the de-aerated froth stream 32 from a lower portion. The bitumen froth 22 which arrives from the PSV 24 may be de-aerated by condensing on structures, which may be called shed decks 34, and cascading down a series of these shed decks arranged in vertical columns. Each shed deck 34 can be configured in the form of an inverted "V" or a "W". The
20 bitumen froth 22 increases its liquid content by condensing in the center of the "W"-shaped shed deck 34. The outer arms of the "W" act as weirs that allow the fluid to pool inside the "W" until there is enough that it spills over these outer arm weirs as a thin curtain to the next shed deck 34 below. In order to consolidate the bitumen froth 22 by reducing its gas content, steam is typically injected below the
25 shed decks 34. The steam rises counter-currently up the columns of shed decks 34. As the froth 22 is heated by the steam, its gas is released.

- Conventional steam de-aerators may lead to the viscosity and surface tension of the bitumen froth 22 causing unstable flows over weirs and localised streams, which can reduce pumping efficiency after de-aeration. Steam de-aerators may
30 also heat the bitumen froth 22 to temperatures that are too low to optimise the release of gas bubbles from the froth 22.

Referring to Fig 5, in some implementations, the pre-treatment system 20 includes pre-heating the bitumen froth 22 before undergoing de-aeration. This pre-heating step may be performed with a pre-heater 36 using direct steam injection (DSI), sufficient to heat the froth 22 above 75°C. The DSI pre-heater unit 5 36 may heat the froth 22 to between 70-95°C, and further optionally around 90°C. This heating step can provide certain advantages. The vapour pressure of water in the froth 22 can increase the size, i.e. volume, of the bubbles contained in the froth 22, which allows for these large bubbles to be burst more easily and the gas contained in the bubbles to be more easily released during downstream de- 10 aeration. In addition, the pre-heating reduces the viscosity of the froth 22, thus allowing a more even and continuous flow over the shed decks or other structures in the downstream de-aeration step, which reduces vapour locking in the downstream pump and, in turn, the resulting downstream flow upsets. Heating the froth 22 at this stage can also minimize the use of additional heating in 15 downstream processes for PFT. The froth 22 thus emerges from the de-aerator as a heated and de-aerated bitumen froth. The pre-heater 36 may be a DSI unit using steam 38 to heat the bitumen froth. The pre-heater 36 may also use other DSI methods or other direct or indirect heating methods. The pre-heater 36 produces a heated froth 40 which may be provided to downstream processing 20 units for de-aeration and screening. More regarding the de-aeration shown in Fig 5 will be discussed below.

Referring to Fig 3, the pre-treatment system 20 may include a heating step after de-aeration using a de-aerated froth heater 38. This heater 38 may be a DSI heater receiving steam 42 from common steam source 44 as the de-aerator 25 steam 46 provided to the upstream de-aerator 30. The common steam source 44 may be regulated and split into the DSI heater steam 42 and the de-aerator steam 46 to advantageously adjust the heating programme of the bitumen froth without requiring additional steam generating infrastructure.

Referring back to Fig 5, the pre-treatment system 20 may include a cross-flow de- 30 aeration apparatus 48 configured in between the pre-heater 36 and a downstream screening unit, which will be discussed in further detail below. It should also be noted that the cross-flow de-aeration apparatus 48 as illustrated in Fig 5 and described herein may be used upstream of a heater or without a separate heater

if desired. The pre-heated froth 40 may be introduced at the normal liquid level into the cross-flow de-aeration apparatus 48. The pre-heated froth 40 may enter the cross-flow de-aeration apparatus 48 via an entrance comprising an expanding nozzle or inlet 50 so as to slow the froth feed velocity sufficiently to substantially conform to the froth flow velocity across the cross-flow de-aeration apparatus 48. This allows for an initial gas content to disengage from the heated froth 40 without creating slug flow, which is an unstable flow resulting from the separation of gas and liquids in piping networks which can lead to process upsets and/or equipment failures by vibration. The de-aerator inlet 50 may be constructed to have a generally frusto-conical shape tapering outwardly toward de-aeration apparatus 48. The de-aerator inlet 50 may alternatively be box-shaped with generally flat side, bottom and top walls. The de-aerator inlet 50 may be positioned and configured relative to certain internals of the cross-flow de-aeration apparatus 48, such that the flow of froth distributes over the height and/or width of the internals to enhance de-aeration.

In another possible implementation, as shown in Fig 5, the pre-treatment system 20 includes the cross-flow de-aeration apparatus 48, having a construction and configuration offering advantageous functionality for preparing bitumen froth. In one optional implementation, the cross-flow de-aeration apparatus 48 can act as a separate surge buffer. The cross-flow de-aeration apparatus 48 can include vessel side walls 52, a bottom 54 and a top 56 together defining a de-aeration chamber 58. The de-aeration chamber 58 may have an internal structure promoting cross-flow of the bitumen froth or minimizing the depth the gas bubbles need to rise in order to be released from the froth. In one optional implementation, the de-aeration chamber 58 has a cross-flow plate pack 60 which promotes cross-flow and minimises the depth the gas bubbles need to rise in order to be released from the froth. The cross-flow plate pack 60 includes a plurality of plates 62 which can be arranged in generally vertical or horizontal and spaced-apart relationship. When arranged in the generally vertical spaced-apart relationship, the plates 62 can form an angle of between about 30 to about 60 degrees above the horizontal. The plates 62 are arranged to define flow channels 64 therebetween and are oriented such that the flow channels provide fluid flow from the inlet 50 toward an outlet 66 at an opposed side of the de-aeration chamber 58. The spacing of the

plates 62 in the pack 58 may be provided so as optimise or increase turbulence in the chamber to thereby augment gas separation from the froth.

5 The de-aerator inlet 50 may be positioned and configured relative to the cross-flow plate pack 60, such that the flow of froth from the inlet is directed toward the channels 64 and is distributed over the entire height of the cross-flow plate pack 60, thereby dividing the froth into separate flow components through respective channels 64, to enhance de-aeration. The de-aerator inlet 50 may be provided outside of the side wall 52, as illustrated; the expanding part of the inlet 50 may alternatively be located partially or fully inside the de-aeration chamber 58.

10 Still referring to Fig 5, the cross-flow de-aeration apparatus 48 may also include an underflow weir 68 and an overflow weir 70 for stabilising froth fluid flows. The overflow weir 70 may be positioned at the discharge outlet 66 of the de-aeration apparatus 48, arranged just upstream of a screening step, and limits sudden flow surges from the pump or the DSI unit 36 from affecting the efficient operation of the screening step. To prevent or reduce the froth from bypassing the cross-flow
15 de-aeration apparatus 48 and heading over the overflow weir 70 to the screening unit 76, the froth may be required to flow below the underflow weir 68 prior to flowing over the overflow weir 70. This underflow weir 68 may be positioned upstream of the flow crest of the overflow weir 70. In one implementation, the underflow weir 68 comprises a rectangular weir having sufficient width and having
20 a surface oriented in a generally perpendicular relation to the cross-flow plate pack 60. The surface of such a rectangular weir can also be oriented in a general normal relation to the froth flow through the channels 64, thus allowing for dampening of froth feed surges.

25 In another implementation, the underflow weir 68 and the cross-flow plate pack 60 may be sized and configured such that underflow weir 68 spans at least the entire height of the cross-flow plate pack 60 and thus ensures dampening of froth flow through all of the channels 64. In another implementation, the overflow weir may be located so as to be at or above the height of the top plate in the cross-flow
30 plate pack 60. In yet another optional implementation, the cross-flow plate pack 60 is inclined which provides for an increased separating area where gas can be released from the froth. The spacing of the plates 62 depends, among other things, on the maximum debris particle size that can pass through the oil sand ore

preparation and which floats in the bitumen froth after processing in the PSV 24, which is typically about 100 mm to about 150 mm. The length of plates 62 can be in the order of ten times plate spacing, with the top of the plate 62 optionally placed just below the feed nozzle 50. In a further implementation, the overflow weir 70 or the underflow weir 68 or both are adjustable to vary the froth flow characteristics. The overflow weir 70 may, for example, be vertically adjustable to vary the flow rate of froth released from the de-aeration apparatus 48.

In some implementations, water sprayers (not illustrated) may be used in the cross-flow de-aeration apparatus 48. These water sprayers may be positioned in the top section of the de-aeration chamber 58, above the released gas that collects above the froth liquid. The water sprayers may advantageously be configured, positioned and operated to remove potential entrained mists of bitumen in the vapour stream, further adding to the recovery of bitumen. One technique for controlling bitumen mist is to maintain a low mist velocity above the froth liquid. The water sprayers can mitigate sudden gas/steam upsets. In addition, the water sprayers may also enable cooling of the released gas, and the recovered water/bitumen mixture may be directed to a wash water pump box 106, such as the one described below, for recycle/reuse in extraction. Some entrained water and mineral solids from the froth may settle in the de-aeration chamber 58. In order to prevent the accumulation of solids building up to a level that blocks the de-aerator 48, these may be collected in a hopper and periodically flushed by the injection of flush water to the wash water pump box 106. By recycling the bitumen in this manner, a portion of froth can be recovered.

The cross-flow de-aeration apparatus 48 de-aerates the froth so that it can be efficiently pumped, while also achieving stable froth flows at desired temperatures by maintaining a consistent gas content, the combined effect of which can mitigate upsets or surges from the PSV 24 before the froth flow reaches downstream processing such as a screening step.

Bitumen froth debris removal and surge buffering

Referring to Figs 2-4B, after de-aeration the de-aerated bitumen froth 32 may be transported or conveyed via the pump 28 to a debris separator 72. Note that there

may be one debris separator 72 as illustrated in Figs 2-4A, or two or more debris separators 72a, 72b as illustrated in Fig 4B.

Referring to Fig 2 in particular, the debris separator 72 may include a surge tank 74 followed by a screening unit 76.

5 Referring to Fig 5, in some implementations the de-aeration apparatus 48 may be directly upstream of the debris separator 72 and configured and located such that the de-aerated froth 32 is conveyed or transported by gravity alone. It should also be noted that the de-aeration apparatus 48 having enhanced surge buffering capacity may be configured directly upstream of the screening unit 76 with no
10 intermediate separate surge tank 74.

Referring back to Fig 2, before being fed to the screening unit 76, the de-aerated froth 32 may be first conveyed to a surge tank 74, which may also be referred to as a "screen feed tank" or "screen feed surge tank". The surge tank 74 may have an upstream compartment 78, which receives a variable flow of the de-aerated
15 froth 32, and a downstream compartment 80 that is separated from the upstream compartment 78 by a regulating device 82. The regulating device 82 is constructed and configured to regulate the flow of froth from the upstream compartment 78 to the downstream compartment 80. Alternatively, the regulating device 82 may have other forms and structures to aid in flow regulation of the
20 froth.

The flow regulating device 82 include a partition within the cavity of the surge tank 74, spanning across the entire width of the cavity and extending from the bottom toward the top of the cavity terminating in an upper edge 84 in spaced-apart relation with the top of the cavity of the surge tank 74. The upper edge 84 and the
25 top of the cavity thus define a froth flow opening 86 through which the froth is allowed to flow from the upstream compartment 78 to the downstream compartment 80. The partition of the flow regulating device 82 may take the form of a plate-shaped member arranged transversely with respect to the flow of the bitumen froth. The partition may be vertically displaceable for adjusting the height
30 of its upper edge 84 and thus the size of the froth flow opening 86 which, in turn, enables adjustment of the flow rate of the bitumen froth flowing over the upper edge 84 into the downstream compartment 80. The partition could also be laterally or otherwise displaceable to adjust froth flow. In one optional

implementation, the flow regulating device 82 operates as an adjustable weir, which may be controlled manually or automatically. Hereafter, the flow regulating device 82 is referred to generally as a surge tank weir 82.

5 The surge tank weir 82 allows for control of the transfer of de-aerated froth 32 from the upstream compartment 78 to the downstream compartment 80 so as to provide a regulated flow of de-aerated froth 32 to subsequent processing equipment, such as the screening unit 76. The surge tank weir 82 is displaceable so as to regulate the flow of de-aerated froth 32 in response to periodic surges. In some implementations, the surge tank 74 may include multiple surge tanks, each
10 one feeding the de-aerated froth 32 in a regulated fashion to a corresponding screening unit, or multiple surge tanks in series or parallel all feeding a screening step.

Different known surge tank weirs 82 can be used in the surge tank 74 such as rectangular weirs, V-notch weirs, or a combination of differently-shaped weirs, all
15 of which can assist in dampening de-aerated froth flow by permitting level changes in the surge tank 74. In normal operation, the surge tank weir 82 maintains a normal de-aerated froth level in the surge tank 74. When the de-aerated froth flow is interrupted, such as when the froth pump 28 vapour locks, the surge tank weir 82 permits both the de-aerated froth level in the surge tank 74
20 and de-aerated froth flow to the screening unit 76 to decline. Conversely, when the de-aerated froth flow surges, the surge tank weir 82 permits the de-aerated froth level in the tank 74 and the de-aerated froth flow to the screening unit 76 to increase. The change in flow through or over the surge tank weir 82 is stable and may be controlled and regulated in a predictable fashion, and reduces the
25 likelihood of sudden flow surges adversely impacting froth screening and other downstream processing steps.

The de-aerated froth feed surges are suppressed and regulated by the surge capacity of the surge tank 74 coupled with the surge tank weir 82.

30 The discharge of de-aerated froth 32 into the surge tank 74 may be configured either below the normal liquid level of the surge tank 74, or by drop pipe, so as to prevent the de-aerated froth 32 plunging directly into a pool of fluid in the upstream compartment 78. It is desirable to avoid having froth flows plunge into the pool so as to minimize re-entrainment of gas into the de-aerated froth 32. The

surge tank 74 provides a working retention time of froth flow and acts as a buffer against periodic surges of froth flow to the screening unit 76. The surge tank 74 retains a volume of de-aerated froth 32 and can accommodate periodic surges in froth flow by permitting the froth levels within the surge tank 74 to vary. This
 5 allows the surge tank 74 to accommodate additional volumes while still regulating the amount of de-aerated froth 32 transmitted to the screening unit 76.

The term "retention time" as used in the context of the surge tank signifies a response time to surges that may emanate from the froth pump. This retention time can range from 1 minute, where froth pumps have vapour locking sensors to
 10 cycle the froth pump for clearing the vapour lock, to up to 10 minutes for manual vapour lock control systems. An optional range of retention time is between about 2 and about 5 minutes, and further optionally about 3 minutes.

It is also noted that the upstream compartment 78 functions as a froth feed surge box and the downstream compartment 80 functions as a froth screen feed box.
 15 Referring still to Fig 2, after exiting the surge tank 74, the de-aerated and flow-regulated froth is then fed to the screening unit 76. The screening unit 76 may have a variety of constructions and configurations. In some implementations, the screening unit is a moving screen, for example a moveable linear or trommel screen which may have adjustable screen speeds or adjustable apertures or a
 20 combination thereof.

The de-aerated and flow-regulated froth is fed from the froth screen feed box 80 to the screening unit 76 in order to remove debris contained in the froth. The screening unit 76 may include a screen 86 which may be a linear screen which is connected to a conveyor system 88 for moving the screen 86 with respect to the
 25 discharge of the froth screen feed box 80. The debris in the froth is removed by passing the froth through the screen 86 and retaining the debris on the surface of the screen 86. The area of the screen 86, i.e. essentially the total surface area through which a designated froth flow rate will be maintained during screening, can vary depending in part on the size of the screen apertures or pores and the
 30 flow rate and nature of froth to the treatment. It is understood that for smaller pores, i.e. around 2 mm, a greater screen area is required to screen the same volume of froth than with pores of about 8 mm. Therefore, by adjusting the pore

size, the system operator can determine the screen area available to screen a given volume of bitumen froth.

In some implementations, an example of which is shown in Figure 6, the size of the pores 75 in the screen 86 can vary from the center of the screen 86 to its
 5 extremities. In one example of such a configuration, the pores 75a of the screen 86 in its middle are smaller than the pores 75b,75c near the screen's 86 sides. This configuration and pore size distribution reduces the open area at the center of the screen 86, thereby forcing the froth 32 outward toward the pores at the sides and thus enhancing froth distribution over the surface of the screen 86.

10 Referring to Figs 2-4B, the de-aerated and flow-regulated froth passes through the screen 86 such that debris remains on the surface of the screen 86 while screened froth 90 passes through after being collected by a screened froth
 15 launder 92. Optionally, the screened froth 90 is collected by a sloped under-pan type launder. The screened froth launder 92 may be positioned just below the lower surface of the screen 86 and may span a given section of the screen 86 under which a substantial portion of the screened froth passes. The screen 86 may have a downstream section 94 which is not covered by the screened froth
 20 launder 92. The screened froth launder 92 collects the screened froth 90 and conveys it to a screened froth pump box 96, which may further treat the screened froth 90 before conveying it, via a screened froth pump 98, to additional downstream treatment such as PFT. The screened froth pump box 96 may include a perforated distribution pipe 100 or like equipment to avoid re-
 25 entrainment of gas into the screened and de-aerated froth 90. The screened froth 90 may thus be transferred to the screened froth pump box 96 either through an inlet below the froth liquid level, or via a perforated stand pipe 100 to avoid re-entrainment of gas into the screened froth 90.

Referring to Figs 2-5, the screening unit 72 may also include a froth screen spray 102. The froth screen spray 102 sprays wash fluid, which can be warm or hot, to wash the screen. Spent wash fluid 103 may be collected by a wash fluid launder
 30 104 and sent for processing. The spent wash fluid 103 may be transported to a wash water pump box 106 for treatment so as to recycle the spent wash fluid 103 for reuse in the screen spray 102 or other unit operations, for example in oil sands

extraction, and/or to recover the bitumen contained therein. The spent wash fluid 103 is pumped using wash pump 108 to downstream units.

Each of the Figs illustrates a different froth screen spray configuration. The screen 86 as illustrated is a linear conveyor type screen which is displaceable in a linear rotational manner by a conveyor system 88 including several conveyor rollers. Depending on the setup, there may be two or four or more conveyor rollers associated with the conveyor system 88. The screen 86 is translated around by the conveyor rollers and at any given point there is at least an upper screen section and a lower screen section. There may also be an upstream side screen section and a downstream side screen section. The froth screen spray 102 may be arranged to spray and clean different sections of the screen, which will be further described below.

Referring to Fig 2, froth screen spray 102 may be provided to spray the lower section of the screen 86. In this configuration, the screen spray 102 is able to effectively "back flush" the screen 86 since the direction of spray is opposite to the direction the froth passes through the upper section of the screen 86. Backwashing can provide several advantages such as dislodging debris that may have become wedged in the pores of the screen 86. A screen wash launder 104 may be provided below the lower section of the screen 86 to collect the wash water that passes through the screen 86. The screen wash launder 104 may span the entire length of the screen setup as illustrated. The screen spray 102 may be static or displaceable and may be manually or automatically operated to spray and cleanse the entire area of the screen 86 as it passes below. This screen spraying technique is particularly useful for removing smaller debris from the screen 86 by back washing, optionally with hot wash fluid. This can aid in removing accumulated smaller debris and also in eliminating the build-up of bitumen on the screen 86 itself.

Referring to Fig 3, the froth screen spray 102 may be provided with its outlet in between the upper and lower sections of the screen 86 and it may be operated to spray onto the lower and/or side sections of the screen 86.

Referring to Fig 4A, the froth screen spray 102 may be split into multiple spray streams for spraying onto different parts of the screen 86. A first stream may be a debris wash 110 that is provided above the downstream section 94 of the screen

86 where the debris is exposed prior to collection of the debris. A second stream may be a screen wash 112 similar or identical to the example shown in Fig 2. The wash launder 104 in this scenario can be arranged to collect the spent wash fluid from both of the spray streams which enable debris washing and screen washing.

5 Collection of the combined wash fluid enables further recuperation of bitumen that coated the debris and the screen. The combined wash stream (identified by character 103 in Fig 4A) may be advantageously processed for residual bitumen recovery or recycled to unit operations in oil sands extraction to help recuperate the bitumen in the wash stream while making use of its heat in extraction units.

10 The length of the screen 86 may be provided or increased compared to other implementations to allow for the screen to be sprayed with two or more hot wash fluids.

Referring to Fig 4B, the froth screen spray 102 may be split into multiple spray streams for spraying two different screens 86a, 86b. In this illustrated scenario, a first stream 102a is used similarly to the configuration of Fig 2, while a second stream 102b is used for spraying in the second screening unit 76b in a different manner. The second stream 102b is sprayed to wash the first stage debris that is fed to the second stage screed 86b. The second screen enables additional washing of screened debris to advantageously recover more bitumen and also

15 provide contingency for mitigating the effects of surges that may affect the first screen. Hot water or another liquid, which may be aqueous or solvent based, can be sprayed over the debris to reduce bitumen adherence to the debris, and the run-off water is collected as bitumen contaminated water, which may be used for hot water and bitumen recovery in extraction. Work crews are thus no longer

20 needed to remove bitumen from debris because the debris is rinsed with hot water.

Referring to Fig 5, the froth screen spray 102 may be provided for spraying in a generally parallel orientation relative to the surface of the screen 86. In this illustrated scenario, the froth screen spray 102 sprays downwardly against the side section of the screen 86 as it too moves in a downward direction. Fig 5 also

30 shows a debris wash line 114 feeding a debris wash distribution box 116 which provides wash fluid to the debris.

For revolving trommel type screening units (not illustrated), in which the screen takes the form of a rotating perforated drum, the debris outlet may have wash water assisting debris transport. For a linear screen 86, as illustrated in the Figs, bitumen froth passes through a substantially horizontally moving screen 86 which transports removed debris to a discharge point prior to returning to the initial froth feed zone. The de-aerated froth that is transported by the screen 86 along with the debris can be collected by a pan collection system between multiple screens.

Bitumen froth debris treatment and collection

Referring to Figs 2-5, the debris separated from the screen 86 is collected by a debris launder 118 and then fed to a froth debris pump box 120. There, the debris can be rinsed with debris flush liquid 122 so as to recover bitumen still on the debris by producing washed debris and spent flush liquid. The temperature of the debris flush liquid 122 is at least 45°C and optionally about 80°C. The debris flush liquid 122 may be recycled water, and this washing action can be performed continuously with the screening of the froth. In the case of a trommel or rotatable drum screen, the debris can be conveyed by helical screws in the trommel towards an outlet, and then via a launder to the debris pump box 120. When either sensors or closed-circuit-television (CCTV) identifies the debris pump box 120 as full, a froth debris pump 125 hydraulically transfers the debris to an extraction tailings disposal. Alternatively, the debris can be collected in trash box for disposal, and the spent washing liquid can be recycled. This recycling back into a bitumen extraction process permits the reuse of energy and the recovery of bitumen. The minimal amount of spillage also promotes a cleaner oil sands plant.

Still referring to Figs 2-5, the debris pump box 120 may allow transport of the washed debris for further treatment, or may direct the washed debris directly to disposal in tailings ponds. Optionally, the launders 92, 118 handling screened froth 90 and/or debris are configured to minimize re-entrainment of gases into the screened froth 90.

Referring to Figs 2-5, the debris pump box 120 may also have a return line 123 which returns at least a portion of the debris stream back into the debris pump box 120.

Enhanced screening operational aspects

- The screening implementations described and illustrated herein may also involve enhanced operational aspects. In one optional implementation, the screening involves specifying or designating a portion of the screen surface likely to be plugged by debris during operation of the screen. During the design process it is possible to determine that amount of the screen that is likely to become plugged during operation. This amount of plugging can be accommodated by adding extra area to the screen. In anticipation of these blockages and so as to accommodate them, the designated screen area can be increased by about 25% to about 100% to reflect the variable flow of debris for a given screen speed (linear or rotational).
- Referring to Figs 2-4B, in another optional implementation the screening involves varying the screen speed to maintain a desired or determined froth level/volume on the screen at a reference location. A sensor 124, such as a non-contact sensor like an ultrasonic level detector, may be provided to measure the level/volume of de-aerated froth dispensed onto the screen 86. The sensor 124 may be configured to signal the screening unit to vary the screen speed, for example by signalling a motor to vary the screen speed, in response to changes in the level/volume. Similarly, CCTV may be used to aid operators monitoring the screen 86 to override the sensor 124, if necessary, or to adjust screen speeds themselves. The froth level may be indicative of the amount or type of debris plugging the screen 86. Thus, it can be appreciated that varying the screen speed permits adjusting the screen area so as to optimise de-aerated froth flow therethrough, even with small screen apertures, thus minimizing upsets discharging from the screening unit 76 and affecting downstream processes.
- For both trommel and linear screens, the depth of the de-aerated froth on the screen surface is reduced as the de-aerated froth flows through the screen until effectively all the de-aerated froth passes through the screen further down its length, or as the de-aerated froth is distributed to the sides and ends of the screen, as explained above. This length depends on the screen speed, and the time required for the de-aerated froth to pass through the screen. In some implementations, allowance is made to permit residual bitumen to drip from the screen and into the screened froth launder.

Enhanced coupling of pre-treatment heating and screening to PFT operations

The process and system of pre-treating bitumen froth can be coupled to a PFT operation. In a typical PFT operation, bitumen froth which has undergone a de-aeration treatment is combined with paraffinic solvent and fed into a separation apparatus which may include multiple counter-current gravity settlers. One reason
5 froth treatment is performed is to remove or substantially reduce the aqueous and solids components that are still present in the bitumen froth. One implementation of PFT involves adding paraffinic solvent to the bitumen froth in an amount sufficient to cause precipitation of asphaltenes present in the froth and this precipitation forms aggregates or "flocs" comprising water, solids and
10 asphaltenes. These water-solid-asphaltene aggregates settle to the lower fractions in the counter-current gravity settlers and become part of the tailings stream, whereas the bitumen rich upper fraction is withdrawn as overflow.

In various implementations, the pre-treatment system and process are coupled to PFT so as to enhance the efficiency of the operation. Prior to pre-treatment, the
15 bitumen froth includes bitumen, fines, water, air and debris. As noted above, the paraffinic froth treatment operation includes adding a paraffinic solvent to the bitumen froth to precipitate asphaltenes in the form of water-solid-asphaltene aggregates, and then separating the bitumen froth into an upper hydrocarbon rich fraction and a lower tailings fraction containing the water-solid-asphaltene
20 aggregates. In the PFT separation step, there is a water-hydrocarbon interface that forms between the upper fraction and the lower fraction during separation. The pre-treatment system and process may include promoting the removal of debris having a non-aggregatable size—that is, the larger debris having a size too large for entrapment within the water-solid-asphaltene aggregates to be formed in
25 the PFT operation—so as to reduce accumulation of debris at the water-hydrocarbon interface. The removal of this debris can be accomplished using screening units that are configured and operated for promoting non-aggregatable debris removal.

In some implementations, removal of non-aggregatable debris is performed by a
30 screening unit having pores with a maximum size that promotes substantial removal of the non-aggregatable debris for a given PFT operation. The size of the aggregatable solids present in the bitumen froth may be determined by various techniques including empirical testing, measurements, estimations and modelling

techniques. For example, in some PFT operations, aggregatable solids have a size between about 1 μm and about 10 μm , and thus the screen is configured, sized and operated to promote removal of larger solid debris. It should be noted that the maximum pore size of the screen may have a size that is greater than the maximum size of the aggregatable solids. In some scenarios, the screening unit can have pores sized to be about 1 to 4 orders of magnitude larger than the aggregatable solids, or 2 to 3 orders of magnitude larger than the aggregatable solids. For example, the screening unit can have pores of about 10 mm, which amounts to about 3 to 4 orders of magnitude larger than the aggregatable solids of 1 μm to 10 μm . PFT operations may vary depending on the operating temperatures and pressures in the settler vessels, the type of paraffinic solvent used (for example pentane, hexane, heptane, octane, mixtures thereof and/or isomers thereof), the solvent-to-bitumen ratio (S/B) that is employed in different stages of the PFT process, as well as process configuration and other operational parameters. In another implementation, the bitumen froth is sufficiently pre-heated prior to screening so as to reduce the viscosity of the bitumen component in the froth to enable the froth to pass through the screen pores while the solid debris within the froth, which does not undergo viscosity reduction by heating, is screened out. The froth may be heated to a relatively high temperature, for instance between about 70°C and about 95°C. In this regard, elevated froth temperatures have additional advantages in PFT operations. For instance, froth temperature entering the PFT has a number of effects on froth-paraffin mixing, separation stability and separation performance. Bitumen froth is a viscous material having a high viscosity and heating the froth prior to screening can reduce its viscosity and facilitate its processing.

In some optional implementations, the bitumen froth undergoes direct steam injection (DSI) pre-heating before being subjected to a screening step. The pre-heating reduces the viscosity of the bitumen froth and facilitates passage of the froth through the screen and removal of the debris. The heated screened froth is then fed to PFT operation which is enhanced both by the pre-heating and the pre-screening of the input froth.

More regarding certain bitumen froth heating strategies for PFT may be found in Canadian patent application No. 2,740,935 many of which may be combined with the implementations and implementations described herein.

In one implementation, the temperature of the bitumen froth is provided as high as possible without exceeding the flash temperature of the solvent and the flash temperature of water which is in the froth. The froth may be pre-heated to a temperature of at least 65°C. The froth may be pre-heated to a temperature between about 70°C and about 95°C. The froth may be pre-heated to a temperature of about 90°C.

Referring to Fig 3, in some implementations of the pre-treatment system and process, the DSI pre-heating unit 38 is provided to maintain a consistent de-aerated froth feed temperature to the downstream debris separator 72. The de-aerated froth 32 is transported via the froth pump 28 through the DSI pre-heater 38 and is heated with the steam 42 to produce a de-aerated pre-heated bitumen froth stream 126, which can be provided to the surge tank 74 and then the screening unit 76. The DSI pre-heater 38 may heat the froth such that the de-aerated pre-heated bitumen froth stream 126 has a temperature of about 65°C or more. The DSI pre-heater 38 may also be controlled in accordance with a froth heating control device 128 so achieve a consistent froth stream 126 temperature. With a consistent froth temperature, the range of froth viscosity variation is minimized, which allows for more consistent debris screening and higher temperatures also enable enhanced screening treatments.

Still referring to Fig 3, the froth 32 may be heated using the pre-heater 38 as described above to a temperature at which the vapour pressure of the water in the heated froth 126 increases, thus forming larger bubbles, which, in combination with the reduced froth viscosity from the added heat, aids in further de-aeration of the froth. The froth may be heated before being processed by the de-aerator 30. After heating, the gas content of the froth may be reduced and maintained at a consistent level. This reduction in gas content may be achieved with a de-aerator vessel 30 as described above.

Finally, it should be noted that features of various implementations may be combined with implementations and features of other implementations described herein.

CLAIMS

1. A treatment process comprising:
 - 5 subjecting the bitumen froth to pre-treatment to produce a pre-treated froth, wherein the bitumen froth comprises bitumen, water, air and solids, the solids comprising fines and debris;
 - adding a paraffinic solvent to the pre-treated froth to for a diluted froth comprising precipitated water-solid-asphaltene aggregates;
 - 10 separating the diluted froth into an upper hydrocarbon rich fraction and a lower tailings fraction containing the water-solid-asphaltene aggregates, wherein a water-hydrocarbon interface forms between the upper fraction and the lower fraction;
 - wherein the pre-treatment comprises:
 - 15 removing from the bitumen froth at least a portion of the debris having a non-aggregatable size so as to prevent or reduce accumulation of the debris at the water-hydrocarbon interface.
2. The process of claim 1, wherein the step of removing the portion of the debris comprises subjecting the bitumen froth to screening.
- 20 3. The process of claim 2, further comprising:
 - monitoring the water-hydrocarbon interface to determine the accumulation of debris therein; and
 - adjusting the pre-treatment of the bitumen froth in response to the accumulation of the debris in the water-hydrocarbon interface.
- 25 4. The process of claim 3, wherein the monitoring comprises measuring a thickness of accumulated debris in the water-hydrocarbon interface.
5. The process of claim 3 or 4, wherein the adjusting of the pre-treatment comprises:
 - adjusting the screening; and/or
 - 30 adjusting a temperature of the bitumen froth;

6. The process of claim 5, wherein the adjusting of screening comprises:
adjusting a speed of a moving screen device; and/or
modifying a pore size of a screen.
- 5 7. The process of claim 6, wherein the moving screen device comprises a linear screen.
8. The process of claim 5 or 6, wherein, in response to an increase in the accumulation of debris in the water-hydrocarbon interface, the speed of the moving screen device is increased.
- 10 9. The process of any one of claims 5 to 8, wherein, in response to an increase in the accumulation of debris in the water-hydrocarbon interface, the pore size of the moving screen device is decreased.
- 15 10. The process of any one of claims 2 to 9, wherein the screening is performed through pores having a size of about 1 to about 4 orders of magnitude greater than the size of aggregatable solids in the bitumen froth.
11. The process of any one of claims 2 to 7, wherein the screening is performed through pores having a size of about 2 to about 3 orders of magnitude greater than the size of aggregatable solids in the bitumen froth.

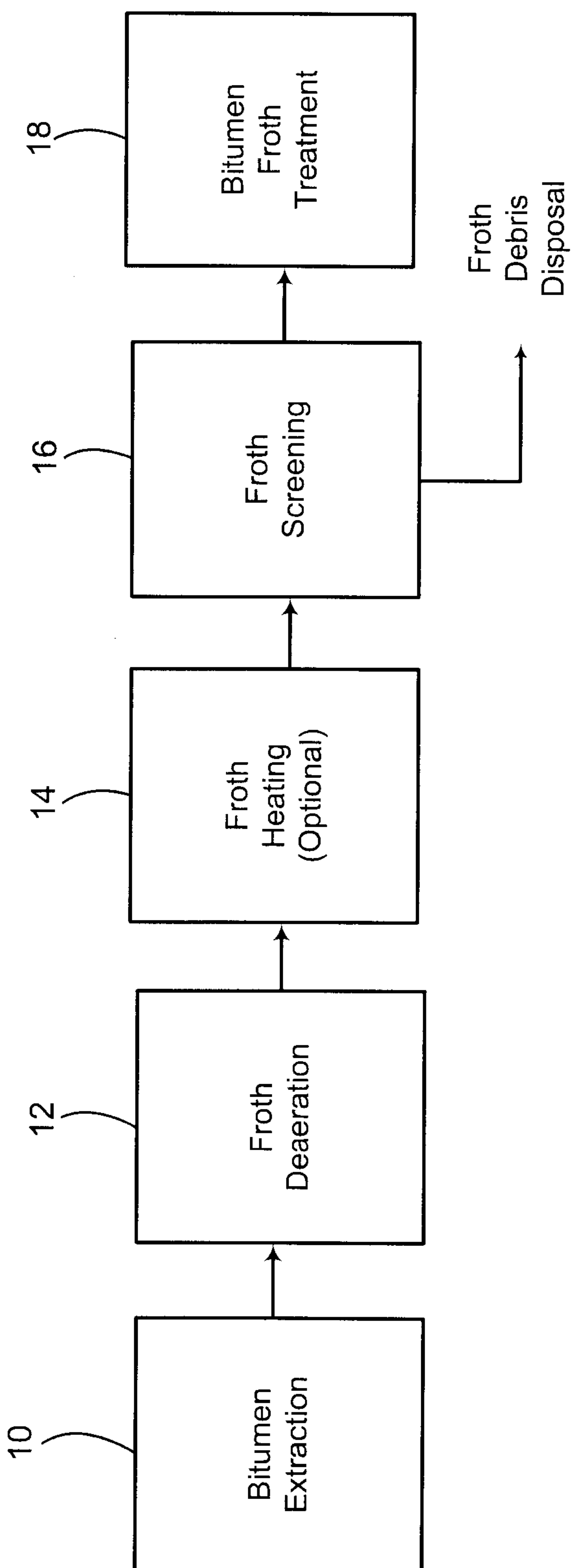


Fig. 1

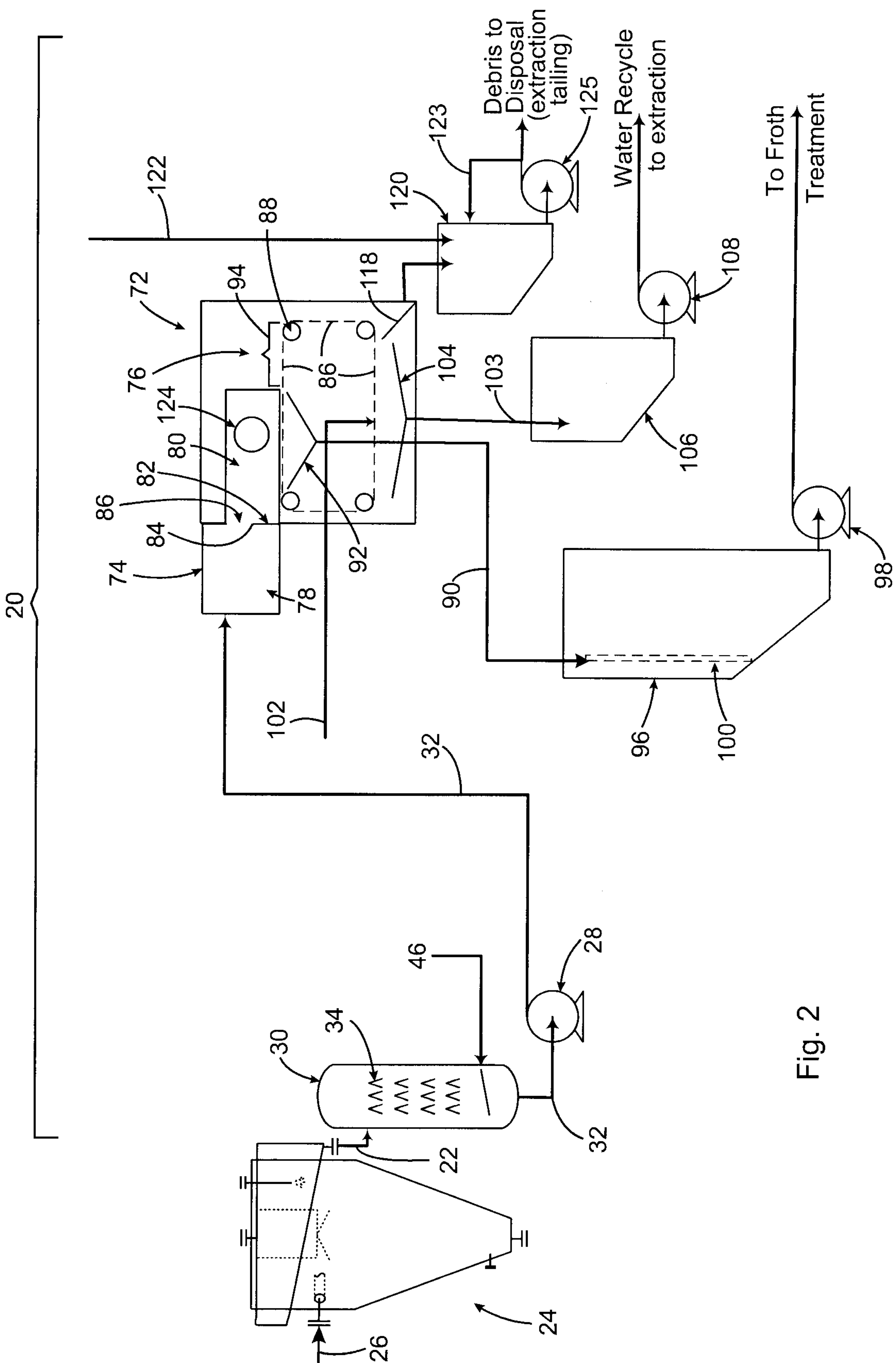
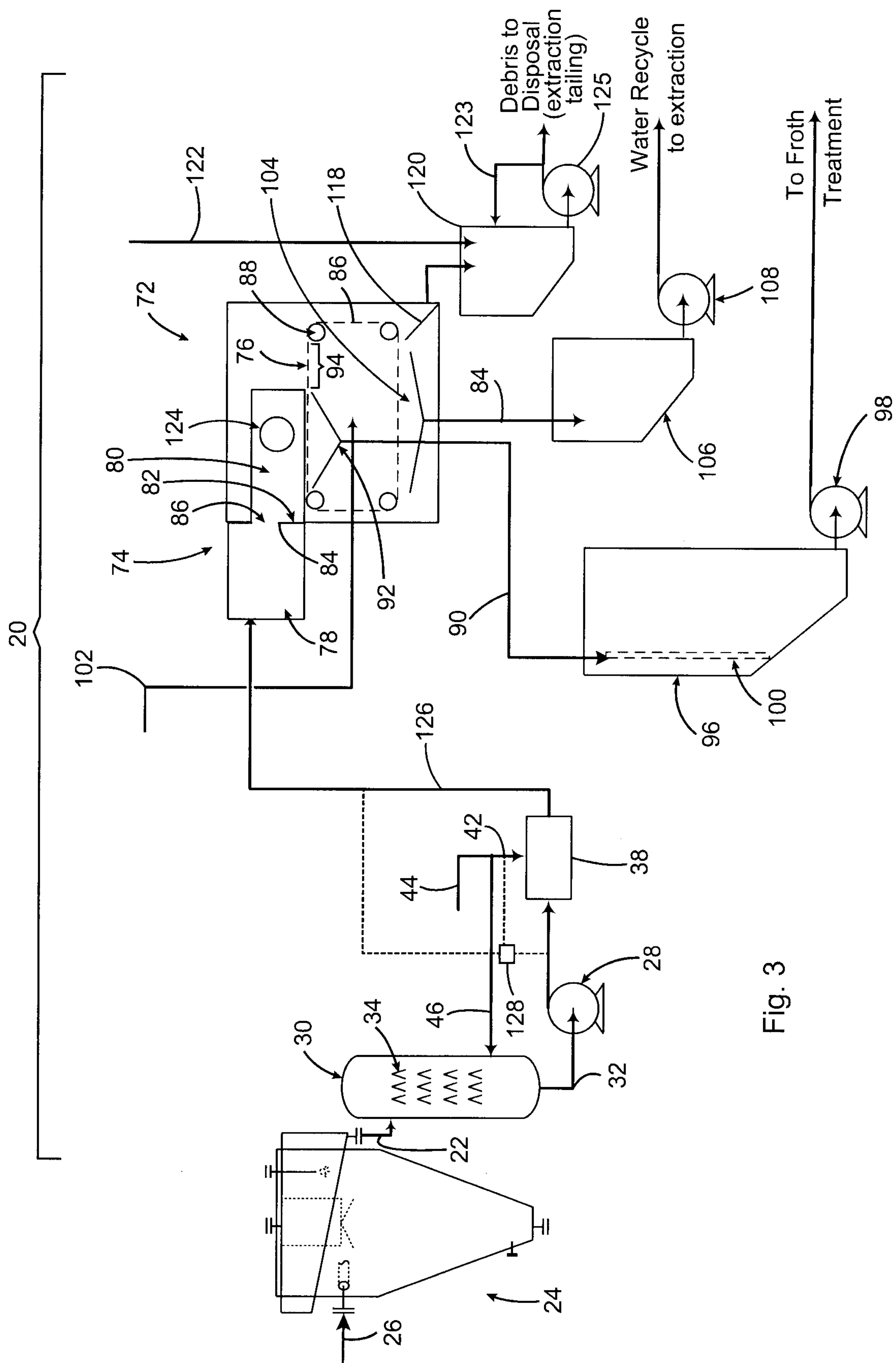
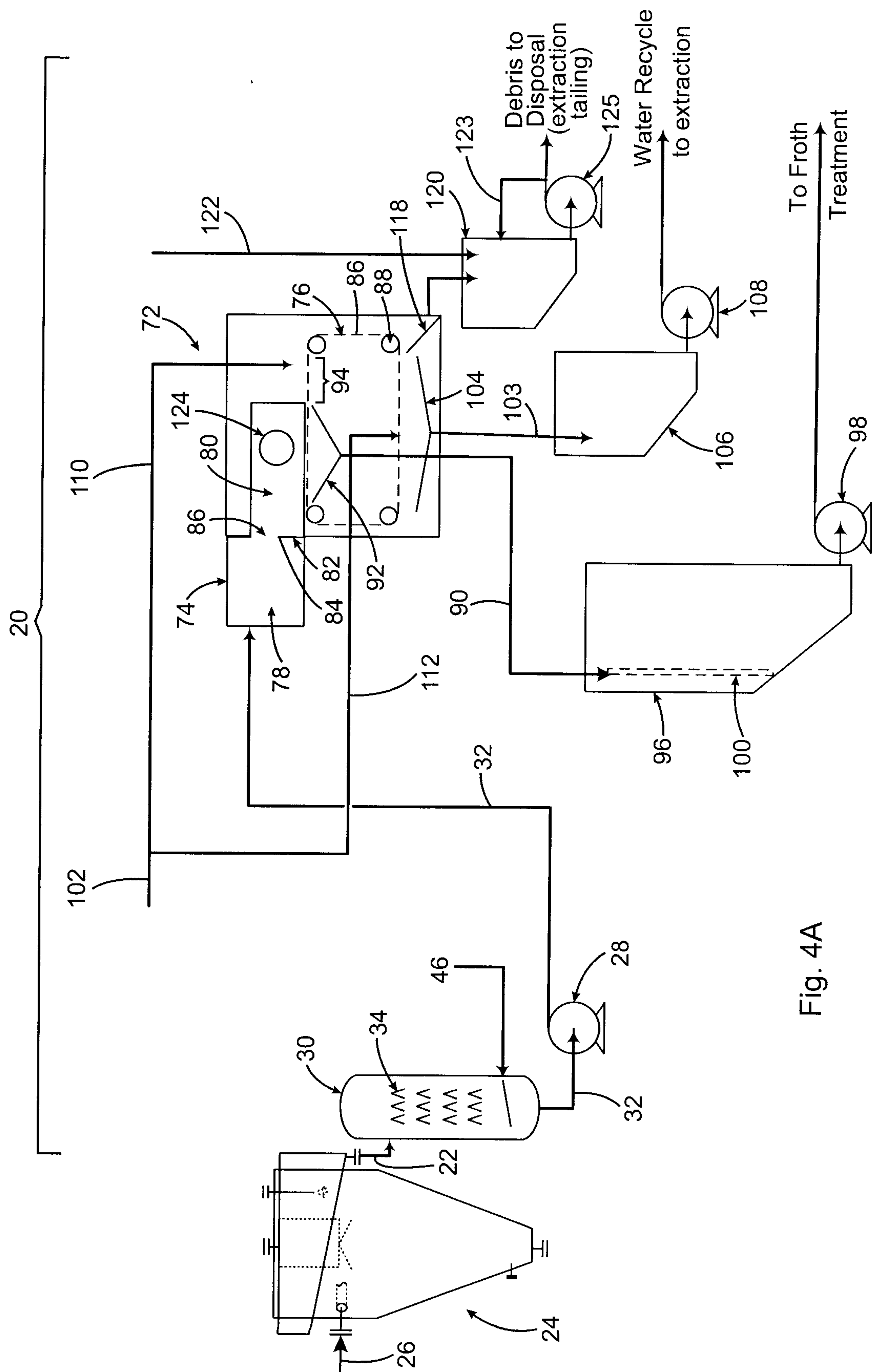
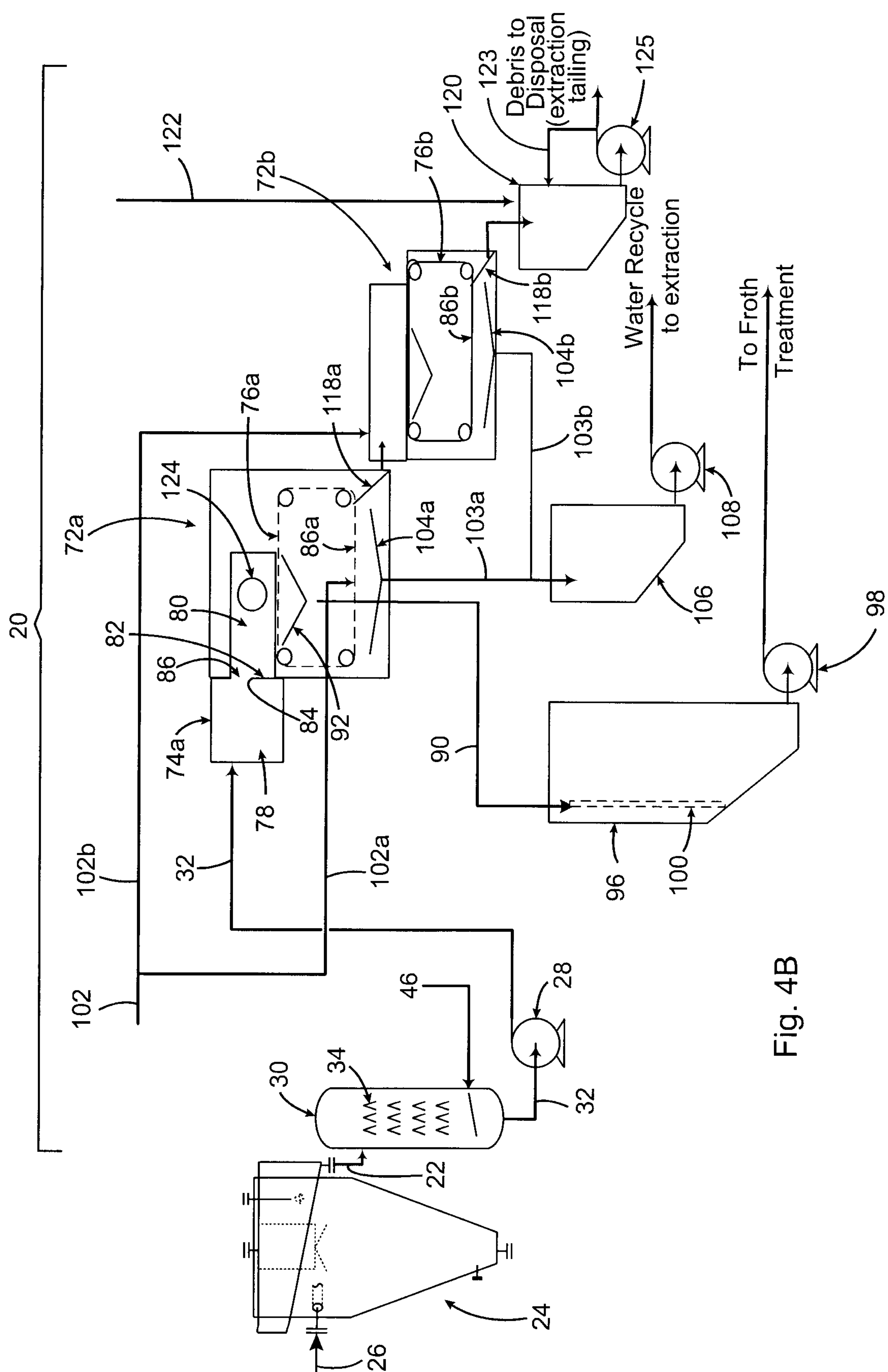
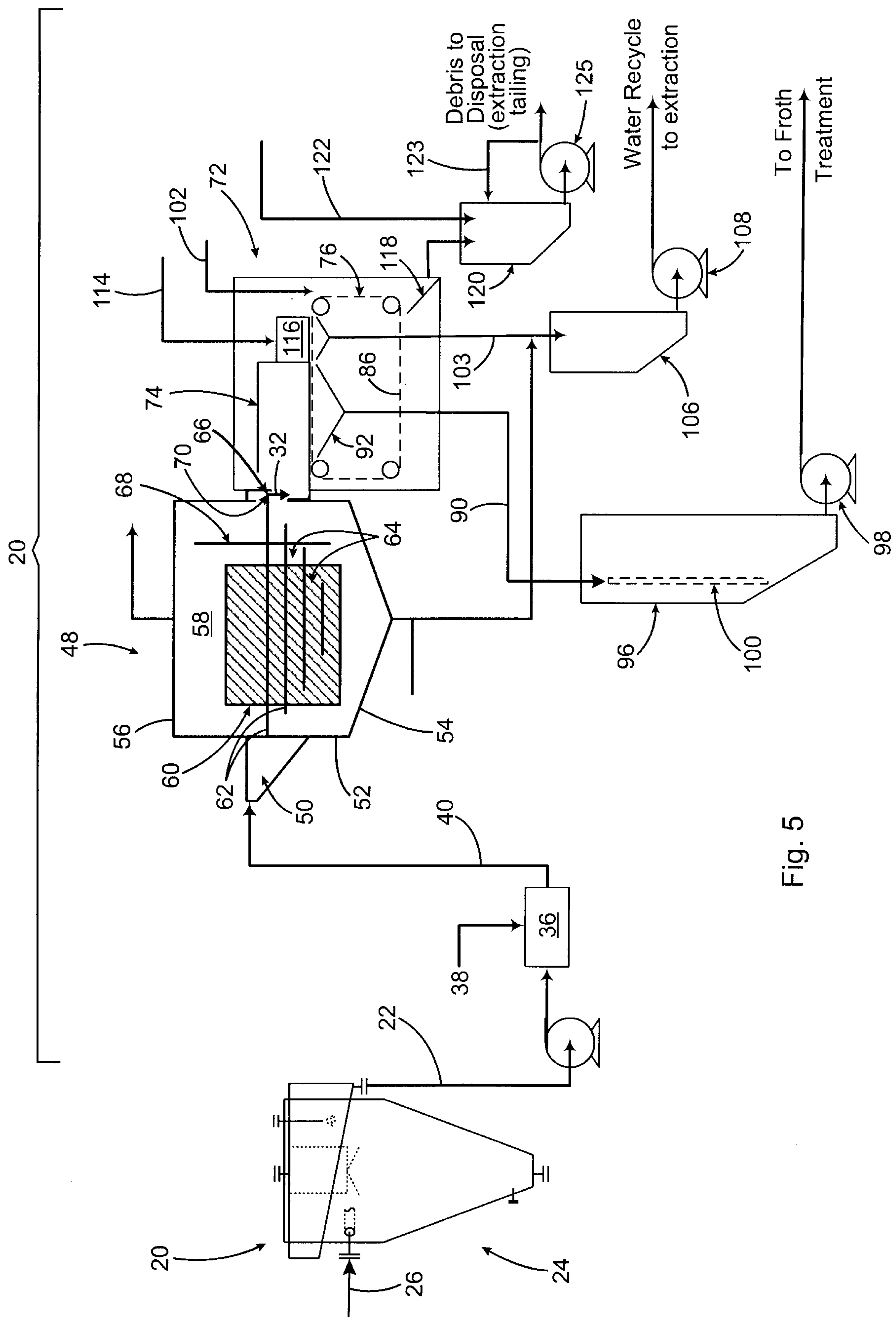


Fig. 2









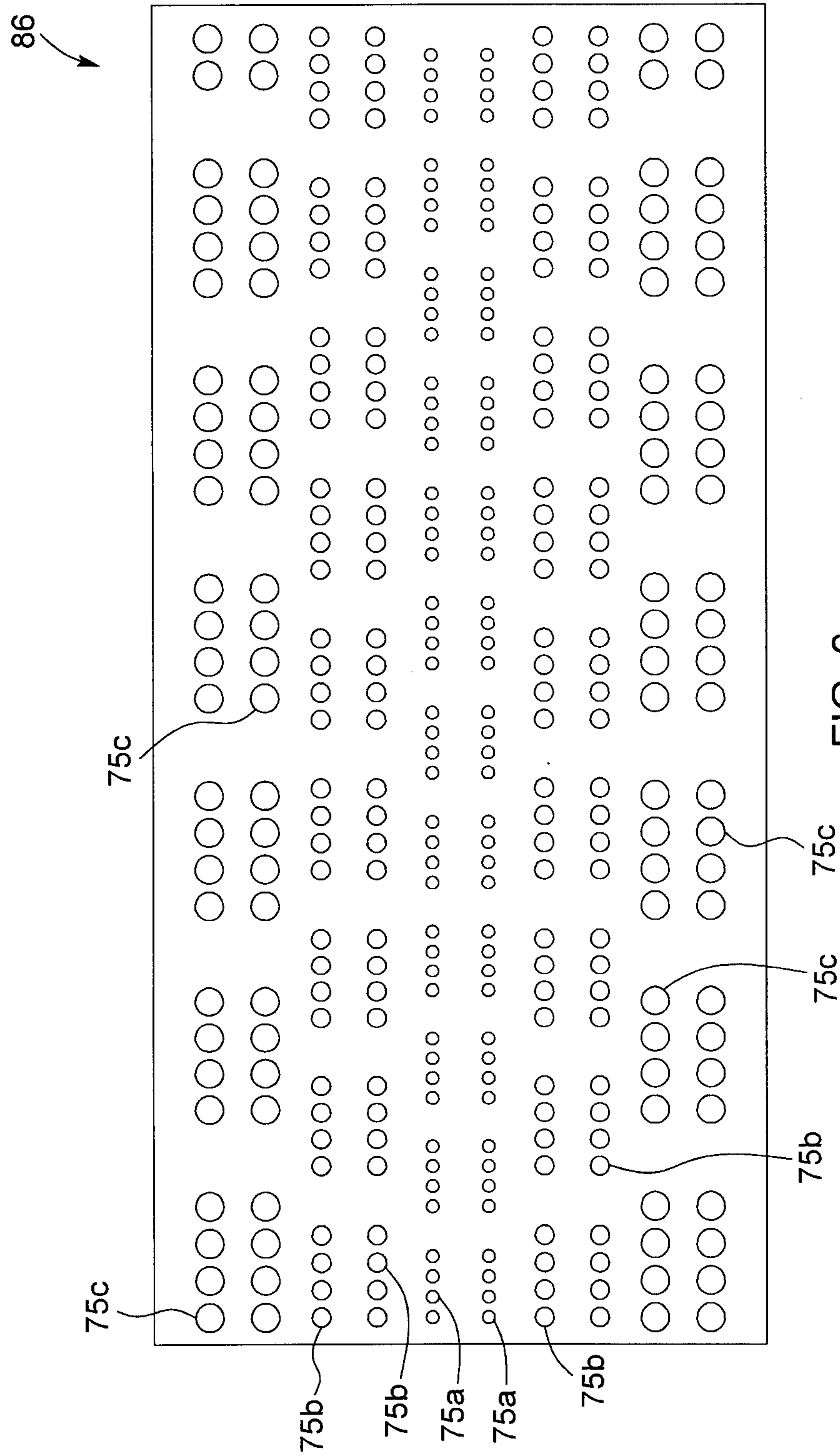


FIG. 6

