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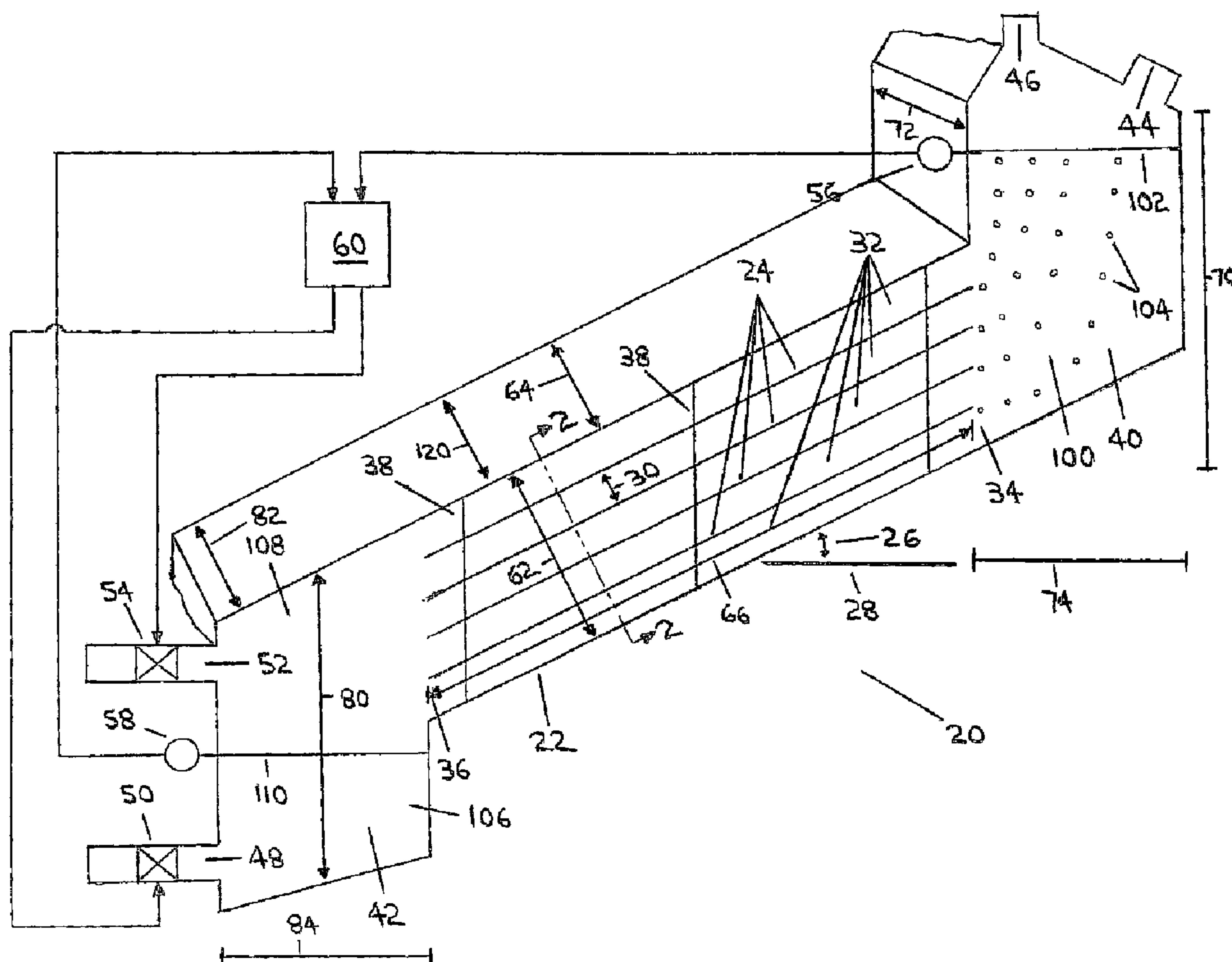
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(54) Titre : APPAREIL ET METHODE PERMETTANT LA SEPARATION DU MOUSSAGE DE FLOTTATION

(54) Title: AN APPARATUS AND A METHOD FOR SEPARATING A FLOTATION FROTH



(57) Abrégé/Abstract:

A separator and method for separating a flotation froth into a water component and a bitumen component. The separator includes a plurality of inclined plates separated by a plate separation distance, thereby providing inclined channels between the plates, a



(57) **Abrégé(suite)/Abstract(continued):**

flotation froth inlet communicating with a first end of the plates, a water component outlet communicating with a second end of the plates, and a bitumen component outlet communicating with the second end. The method includes introducing the flotation froth into the separator adjacent to the first end of the plates and separately discharging the water and bitumen components from the separator adjacent to the second end of the plates. The separator may further include an air component outlet communicating with the first end of the plates, for discharging an air component of the flotation froth from the separator and the method may further include discharging the air component from the separator adjacent to the first end of the plates.

ABSTRACT

A separator and method for separating a flotation froth into a water component and a bitumen component. The separator includes a plurality of inclined plates separated by a plate separation distance, thereby providing inclined channels between the plates, a flotation froth inlet communicating with a first end of the plates, a water component outlet communicating with a second end of the plates, and a bitumen component outlet communicating with the second end. The method includes introducing the flotation froth into the separator adjacent to the first end of the plates and separately discharging the water and bitumen components from the separator adjacent to the second end of the plates. The separator may further include an air component outlet communicating with the first end of the plates, for discharging an air component of the flotation froth from the separator and the method may further include discharging the air component from the separator adjacent to the first end of the plates.

AN APPARATUS AND A METHOD FOR SEPARATING
A FLOTATION FROTH

TECHNICAL FIELD

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An apparatus and a method for separating a flotation froth into a plurality of components.

BACKGROUND OF THE INVENTION

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Oil sand is essentially a matrix of bitumen, solid mineral matter, and water.

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The bitumen portion of oil sand consists of viscous hydrocarbons which behave much like a solid at normal in situ temperatures and which act as a binder for the other portions of the oil sand matrix.

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The solid mineral matter portion of oil sand consists of sand, rock, silt and clay. Coarse solid material is generally considered to include solid mineral matter having a particle size greater than or equal to about 44 microns, while fine solid material is generally considered to include solid mineral matter having a particle size less than about 44 microns. Sand and rock are therefore generally present in oil sand as coarse solid material, due to the relatively large size of individual particles of sand and rock. Silt and clay are generally present in oil sand as fine solid material, due to the relatively small size of individual particles of silt and clay.

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The water portion of oil sand consists essentially of a film of connate water surrounding the coarse solid material in the oil sand matrix, and may also contain particles of solid mineral matter within it.

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A typical deposit of oil sand will contain about 10 percent to about 12 percent bitumen and about 3 percent to about 6 percent water, with the remainder of the oil sand being made up of solid mineral matter. Of the total amount of solid mineral matter, good quality oil sand deposits typically contain about 14 percent to about 20 percent fine solid material and about 80

percent to about 86 percent coarse solid material. Poorer quality oil sand deposits may contain 30 percent or more fine solid material. Oil sand extracted from the Athabasca area near Fort McMurray, Alberta, Canada averages about 11 percent bitumen, about 5 percent water and about 84 percent solid mineral matter, with about 15 percent to about 20 percent of the solid mineral matter being fine solid material.

Oil sand deposits are mined for the purpose of recovering bitumen from the oil sand, which bitumen is then upgraded to synthetic crude oil. Several different approaches to recovering the bitumen from the oil sand have been developed.

A conventional approach to recovering bitumen from oil sand is the use of a “hot water process” in which aggressive thermal action, aggressive chemical action and aggressive mechanical action are used to liberate and separate bitumen from the oil sand.

The hot water process includes several steps. In a first step, oil sand is conditioned by mixing the oil sand with hot water in a conditioning vessel which vigorously agitates the resulting slurry in order to completely disintegrate the oil sand. Sodium hydroxide (caustic) may be added to the slurry during conditioning to maintain a slightly basic pH in the conditioning vessel, which enhances the disintegration of the oil sand by chemically dispersing the fine solid material contained in the oil sand.

In a second step, the slurry of disintegrated oil sand undergoes a primary separation process in a primary separation vessel. The primary separation process separates the slurry into three streams. A solids stream, containing relatively large amounts of coarse solid material and relatively small amounts of residual bitumen and fine solid material, settles out from the slurry and is withdrawn from a lower portion of the primary separation vessel. A bitumen froth stream, containing relatively large amounts of air entrained bitumen and relatively small amounts of solid mineral matter, floats to the top of the slurry and is withdrawn from an upper portion of the primary separation vessel. A middlings stream, containing a relatively small amount of residual bitumen and a relatively large amount of fine solid material, is withdrawn from an intermediate portion of the primary separation vessel.

In a third step, the middlings stream is treated or scavenged, typically by froth flotation, to recover a portion of the residual bitumen contained therein as a flotation froth. The flotation froth which is recovered from the middlings stream may be returned to the primary separation process or may be combined with the bitumen froth stream.

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In a fourth step, the bitumen froth stream is subjected to a froth treatment process in which solid mineral matter and water is separated from the bitumen froth to produce a “clean” and “dry” bitumen froth.

10 The solids stream which is produced in the second step is typically dewatered and/or disposed of as backfill or in berms as coarse tailings. In some circumstances, it may be feasible to recover some of the residual bitumen from the solids stream by froth flotation, as a flotation froth, before the solids stream is disposed of.

15 Another approach to recovering bitumen from oil sand is directed at “solids rejection” as a primary separation technique, in which oil sand is separated into a bitumen froth stream and a solids stream, without the production of a middlings stream.

20 One example of the solids rejection approach is described in Canadian Patent Application No. 2,030,934 (Strand), Canadian Patent Application No. 2,124,199 (Strand), Canadian Patent No. 2,123,076 (Strand et al), Canadian Patent Application No. 2,512,106 (Strand), and Canadian Patent Application No. 2,524,110 (Strand), all of which are assigned to Bitmin Resources Inc. (the “Bitmin Process”).

25 In the Bitmin Process, a countercurrent separator drum containing a spiral ribbon and mixer elements is utilized for primary separation of the oil sand. Oil sand is gently rolled from one end to the other end of the separator drum while warm water circulates in the opposite direction. The pH of the warm water in the separator drum is maintained at no greater than about 7 in order to limit the chemical dispersal of fine solid material contained in the oil sand.

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Two streams are then removed from the opposite ends of the separator drum. A solids stream containing solid mineral matter (including coarse solid material and a small amount

of fine solid material), water and a small amount of residual bitumen is removed from one end of the separator drum, and a bitumen froth stream containing bitumen, solid mineral matter (including fine solid material and a small amount of coarse solid material) and water is removed from the other end of the separator drum.

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The solids stream is filtered using a horizontal belt filter apparatus to produce dewatered coarse tailings which may be disposed of as backfill, in berms, or in some other manner. In some circumstances, it may be feasible to recover some of the residual bitumen from the solids stream by froth flotation, as a flotation froth, before the solids stream is disposed of.

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The bitumen froth stream is further processed in a froth separator to produce bitumen froth as a product stream and fine tailings containing a small amount of residual bitumen. The fine tailings are treated, typically by froth flotation, to recover some of the residual bitumen from the fine tailings as a flotation froth. The fine tailings are then dewatered in a thickener, following which all or a portion of the dewatered fine tailings may be co-filtered with the coarse tailings to produce non-segregating tailings comprising the coarse tailings and the fine tailings, or the fine tailings may be disposed of in some other manner.

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A second example of the solids rejection approach is described in Canadian Patent No. 2,332,207 (Lavender et al) and Canadian Patent No. 2,358,805 (Lavender et al), both of which are assigned to TSC Company Ltd. (the "TSC Process").

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In the TSC Process, an assembly of three hydrocyclone packs or clusters arranged countercurrently in series are utilized for primary separation of the oil sand. Two streams are removed from the hydrocyclone assembly. A solids stream containing solid mineral matter (including coarse solid material and some fine solid material), water and a small amount of residual bitumen is removed as an underflow stream from the third hydrocyclone, and a bitumen froth stream containing bitumen, solid mineral matter (including fine solid material and some coarse solid material) and water is removed as an overflow stream from the first hydrocyclone.

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The solids stream is filtered using a horizontal belt filter apparatus to produce dewatered coarse tailings which may be disposed of as backfill or in some other manner.

Conceivably, in some circumstances, it may be feasible to recover some of the residual bitumen from the solids stream by froth flotation, as a flotation froth, before the solids stream is disposed of.

5 The bitumen froth stream is further processed in a “product separator” to produce bitumen froth as a product stream and fine tailings containing a small amount of residual bitumen. The fine tailings are recycled back to the hydrocyclone assembly for further processing in the hydrocyclone assembly. Alternatively, in some circumstances it may be feasible to recover some of the residual bitumen from the solids stream by froth flotation, as a flotation froth, thereby
10 avoiding recycling of the fine tailings.

 Other approaches to recovering bitumen from oil sand may be based upon variations of the hot water process, the Bitmin Process and the TSC Process, or may be based upon other technologies.

15 Regardless of the approach which is used to recover bitumen from oil sand, it may be necessary or desirable in some circumstances to recover residual bitumen from a middlings stream or from one or more of the solids streams which are produced by the bitumen recovery process. Froth flotation techniques may often be effective for treating such middlings or solids
20 streams to recover some or all of the residual bitumen therefrom, as a flotation froth.

 A flotation froth comprising residual bitumen which is recovered from a middlings stream or from a solids stream produced by a bitumen recovery process may typically contain (approximately or about) between 4 percent and 25 percent bitumen by weight, between 65 percent
25 and 95 percent water by weight, between 1 percent and 20 percent solid mineral matter by weight, and between 30 percent and 60 percent air by volume.

 The significant amount of air which is typically contained within the flotation froth often results in difficulties being encountered in handling and processing the flotation froth.
30 Aerated flotation froth is often difficult to pump and may cause air locking problems in pump apparatus. In addition, pumping aerated flotation froth is typically relatively inefficient due to energy losses resulting from aeration compression. As a result of these difficulties, operators may

dilute the flotation froth with water before handling in order to minimize the effects of aeration on the flotation froth. Diluting the flotation froth results in a lower grade of froth, which typically requires additional processing in order to achieve a useable bitumen product.

5 For example, diluted flotation froth may need to be recycled through bitumen recovery apparatus, and recycling of product streams generally reduces the processing capacity of apparatus such as separation vessels and flotation apparatus.

10 In addition to difficulties relating to aeration of the flotation froth, flotation froth also typically contains significant amounts of solid mineral matter and water relative to the amount of bitumen contained therein. As indicated above, even without dilution the concentration of bitumen in a typical flotation froth is less than 20 percent, and the amount by weight of solid mineral matter may exceed the amount by weight of bitumen. Due to its composition, it may be difficult to increase the concentration of bitumen relative to solid mineral matter and water in a
15 flotation froth using conventional bitumen froth cleaning techniques.

 There remains a need for apparatus and methods which are useful for cleaning flotation froth to increase the concentration of bitumen therein relative to solid mineral matter and water. There also remains a need for apparatus and methods for cleaning flotation froth which
20 may also be useful for deaerating flotation froth.

SUMMARY OF THE INVENTION

 References in this document to orientations, to operating parameters, to ranges, to
25 lower limits of ranges, and to upper limits of ranges are not intended to provide strict boundaries for the scope of the invention, but should be construed to mean “approximately” or “about” or “substantially”, within the scope of the teachings of this document, unless expressly stated otherwise.

30 The present invention includes an apparatus and a method for separating a flotation froth into a water component, a bitumen component, and in preferred embodiments, an air component. The invention results in cleaning and/or deaeration of the flotation froth.

The flotation froth is comprised of between 4 percent and 25 percent bitumen by weight and between 65 percent and 95 percent water by weight.

5 The flotation froth may be further comprised of an amount of a flotation aid such as air. The amount of the flotation aid may be any amount. As a non-limiting example, the flotation froth may be comprised of between 30 percent and 60 percent air by volume. If the flotation aid is not present in large concentrations, or if for any reason it is not considered necessary or desirable to separate the air component from the flotation froth, the invention may be used to separate the
10 flotation froth only into the water component and the bitumen component.

 Due to the typical manner of production of the flotation froth, the air contained in the flotation froth may tend to be present in relatively larger bubbles or individual volumes than air which may be contained in a primary froth obtained from an oil sands primary recovery process.
15 As a result, separation of the flotation froth to separate the air component therefrom may tend to be more effective and/or efficient than a similar method for separating primary froth to remove an air component therefrom.

 The flotation froth may be further comprised of an amount of solid mineral matter.
20 The amount of the solid mineral matter may be any amount. As a non-limiting example, the flotation froth may be comprised of between 1 percent and 20 percent solid mineral matter by weight.

 The water component of the flotation froth is a component derived from the
25 flotation froth which contains a sufficient concentration of water so that it may be characterized as the water component, as distinct from the air component and the bitumen component. The water component may therefore contain amounts of air, bitumen, solid mineral matter and/or other substances.

30 The bitumen component of the flotation froth is a component derived from the flotation froth which contains a sufficient concentration of bitumen so that it may be characterized as the bitumen component, as distinct from the air component and the water component. The

bitumen component may therefore contain amounts of air, water, solid mineral matter and/or other substances.

5 The air component of the flotation froth is a component derived from the flotation froth which contains a sufficient concentration of air so that it may be characterized as the air component, as distinct from the water component and the bitumen component. The air component may therefore contain amounts of water, bitumen, solid mineral matter and/or other substances.

10 In one apparatus aspect, the invention is a separator for separating a flotation froth into a water component and a bitumen component, wherein the flotation froth is comprised of between about 65 percent and about 95 percent water by weight, and wherein the flotation froth is further comprised of between about 4 percent and about 25 percent bitumen by weight, the separator comprising:

- 15 (a) a plurality of substantially parallel plates having a first end and a second end, wherein the plates are inclined at an inclination angle relative to a horizontal reference, wherein the first end of the plates is above the second end of the plates, and wherein the plates are separated from each other by a plate separation distance, thereby providing inclined channels between the plates;
- 20 (b) a flotation froth inlet communicating with the first end of the plates, for introducing the flotation froth into the separator;
- 25 (c) a water component outlet communicating with the second end of the plates, for discharging the water component from the separator; and
- (d) a bitumen component outlet communicating with the second end of the plates, for discharging the bitumen component from the separator, wherein the bitumen component outlet is positioned above the water component outlet.

The separator is preferably further comprised of an air component outlet communicating with the first end of the plates, for discharging an air component of the flotation froth from the separator.

5 Each of the inclined channels defines a profile in a transverse direction. The profile may be substantially planar and horizontal or may be comprised of at least one peak and at least one trough. The at least one peak and the at least one trough may be provided by the shape of the plates, by the orientation of the plates, by the configuration of the plates, or in any other suitable manner.

10 In some embodiments, each of the plates is substantially horizontal in the transverse direction and is comprised of a plurality of discontinuities so that the profile of the inclined channels is comprised of a series of alternating peaks and troughs. In some embodiments, each of the plates is substantially planar and is tilted in the transverse direction at a transverse inclination
15 angle relative to a transverse horizontal reference so that the profile of the inclined channels is comprised of a single peak and a single trough.

The plates may be substantially parallel so that the plate separation distance between two adjacent plates is substantially constant.

20 The separator may be further comprised of spacers for maintaining the plate separation distance between the plates. The plate separation distance between each pair of adjacent plates is preferably substantially the same, but in some applications, a different plate separation distance may be provided between pairs of adjacent plates.

25 In embodiments in which the profile of the inclined channels is comprised of a series of peaks and troughs, the plates may be sawtooth shaped (i.e., with pointed peaks and pointed troughs), corrugated (i.e., with flat peaks and flat troughs), undulated (i.e., with curved peaks and curved troughs), or may be any other shape in order to provide the peaks and troughs.

A purpose of the peaks and troughs may be to facilitate collecting of the bitumen component in the peaks and collecting of the water component in the troughs, thereby providing some separation of the bitumen component and the water component in the inclined channels.

5 The distance between adjacent peaks in a series of alternating peaks and troughs may be any distance which is suitable for facilitating some separation of the bitumen component and the water component in the inclined channels. In some embodiments, the plates may be configured so that the distance between adjacent peaks is between 20 centimeters and 30 centimeters. In some embodiments, the plates may be configured so that the distance between
10 adjacent peaks is 25 centimeters.

In embodiments in which the profile of the inclined channels is comprised of a single peak and a single trough, the peak may be defined by a first side of the separator in the transverse direction and the trough may be defined by a second side of the separator in the
15 transverse direction. In such embodiments the transverse inclination angle may be any angle which is suitable for facilitating some separation of the bitumen component and the water component in the inclined channels. In some embodiments, the plates may be configured so that the transverse inclination angle is between 5 degrees and 60 degrees. In some embodiments, the plates may be configured so that the transverse inclination angle is between 10 degrees and 20
20 degrees.

Each of the plates has an upper surface and a lower surface. One or both of the surfaces of the plates may be relatively smooth and/or one or both of the surfaces of the plates may be relatively rough. Providing the plates with relatively smooth surfaces may assist in minimizing
25 sticking of the flotation froth or its components to the plates. Providing the plates with relatively rough surfaces may assist in promoting separation of the flotation froth into its components. In some embodiments, both surfaces of the plates are relatively smooth.

The separator may be further comprised of a feed box adjacent to the first end of the
30 plates, for containing the flotation froth which is introduced into the separator. The feed box may extend above the first end of the plates to assist in providing that the first end of the plates is

submerged in the flotation froth. The feed box may also function as a surge tank in providing a surge volume to reduce the effects of a fluctuating supply of the flotation froth to the separator.

5 The separator may be further comprised of a feed box level sensor associated with the feed box, for sensing a level of the flotation froth in the feed box. The feed box level sensor may be comprised of any sensing device or apparatus which is capable of sensing the level of the flotation froth in the feed box. As non-limiting examples, the feed box level sensor may be comprised of an electrical sensor, a mechanical sensor, an electro-hydraulic sensor, or a hydro-mechanical sensor. In some embodiments, the feed box level sensor may be comprised of a float.
10 The feed box level sensor may also be comprised of a visual sensing device such as a sight glass.

The separator may be further comprised of a discharge box adjacent to the second end of the plates, for collecting the water component and the bitumen component before they are discharged from the separator. The discharge box may extend below the second end of the plates
15 so that the discharge box can provide for some gravity separation of the water component and the bitumen component after the flotation froth has passed through the inclined channels.

The water component outlet and the bitumen component outlet may communicate with the discharge box.
20

The separator may be further comprised of a discharge box interface sensor associated with the discharge box, for sensing an interface between the water component and the bitumen component in the discharge box. The discharge box interface sensor may be comprised of any sensing device or apparatus which is capable of sensing the interface between the water
25 component and the bitumen component in the discharge box. As non-limiting examples, the discharge box interface sensor may be comprised of an electrical sensor, a mechanical sensor, an electro-hydraulic sensor, or a hydro-mechanical sensor. In some embodiments, the discharge box interface sensor may be comprised of a capacitance probe or a segmented dielectric probe. The discharge box interface sensor may also be comprised of a visual sensing device such as a sight
30 glass.

The separator may be further comprised of a water component outlet flow regulator associated with the water component outlet, for controlling the discharging of the water component from the separator. The water component outlet flow regulator may be comprised of any device or apparatus which is capable of controlling the passing of the water component through the water component outlet. As a first non-limiting example, the water component outlet flow regulator may be comprised of a variable speed pump or a variable output pump. As a second non-limiting example, the water component outlet flow regulator may be comprised of a valve. The water component outlet flow regulator may be manually controlled, semi-automatically controlled, or automatically controlled.

The separator may be further comprised of a bitumen component outlet flow regulator associated with the bitumen component outlet, for controlling the discharging of the bitumen component from the separator. The bitumen component outlet flow regulator may be comprised of any device or apparatus which is capable of controlling the passing of the bitumen component through the bitumen component outlet. As a first non-limiting example, the bitumen component outlet flow regulator may be comprised of a variable speed pump or a variable output pump. As a second non-limiting example, the bitumen component outlet flow regulator may be comprised of a valve. The bitumen component outlet flow regulator may be manually controlled, semi-automatically controlled, or automatically controlled.

The separator may be further comprised of a flotation froth inlet flow regulator associated with the flotation froth inlet, for controlling the introducing of the flotation froth into the separator. The flotation froth inlet flow regulator may be comprised of any device or apparatus which is capable of controlling the passing of the flotation froth through the flotation froth inlet. As a first non-limiting example, the flotation froth inlet flow regulator may be comprised of a variable speed pump or a variable output pump. As a second non-limiting example, the flotation froth inlet flow regulator may be comprised of a valve. The flotation froth inlet flow regulator may be manually controlled, semi-automatically controlled, or automatically controlled.

The purpose of the water component outlet flow regulator, the bitumen component outlet flow regulator, and the flotation froth inlet flow regulator is to facilitate control of the levels in the separator of the flotation froth, the water component and the bitumen component.

In some embodiments, the separator is comprised of the water component outlet flow regulator, the bitumen component outlet flow regulator and the flotation froth inlet flow regulator, so that control of the levels in the separator of the flotation froth, the water component and the bitumen component is facilitated by controlling the introducing of the flotation froth into the separator and by controlling the discharging of the water component and the bitumen component from the separator.

In some embodiments, the separator is comprised of the water component outlet flow regulator and the bitumen component outlet flow regulator, but does not include the flotation froth inlet flow regulator. In such embodiments, control of the levels in the separator of the flotation froth, the water component and the bitumen component is facilitated by controlling the discharging of the water component and the bitumen component from the separator.

The separator may be further comprised of a controller for controlling the operation of the separator. The controller may be operatively connected with the flow regulators associated with the separator and may therefore control the operation of the flow regulators.

In some embodiments, the controller may be operatively connected with and control the operation of the flotation froth inlet flow regulator, the water component outlet flow regulator and the bitumen component outlet flow regulator.

In some embodiments in which the separator does not include the flotation froth inlet flow regulator, the controller may be operatively connected with and may control the operation of the water component outlet flow regulator and the bitumen component outlet flow regulator.

The separator may be operated manually, semi-automatically or automatically so that the interface between the water component and the bitumen component in the discharge box is maintained above the water component outlet and below the bitumen component outlet, and/or the separator may be operated manually, semi-automatically or automatically so that the level of the flotation froth in the feed box is maintained above the first end of the plates.

In some embodiments in which the separator is comprised of the controller, the controller may be configured to receive data from the feed box level sensor and the discharge box interface sensor and to use the data to control the flow regulators which are associated with the separator.

In some embodiments in which the separator is comprised of the controller, the controller may be configured to receive data from the feed box level sensor and the discharge box interface sensor and to use the data to control the water component outlet flow regulator and the bitumen component outlet flow regulator in order to maintain the interface between the water component and the bitumen component in the discharge box above the water component outlet and below the bitumen component outlet, and/or in order to maintain the level of the flotation froth in the feed box above the first end of the plates.

The controller may be comprised of any device, apparatus, or combination of devices and apparatus which is capable of performing the intended functions of the controller and which is compatible with the device and/or apparatus with which it is associated. As non-limiting examples, the controller may be comprised of one or more electric, electronic, mechanical, electro-mechanical, hydraulic, electro-hydraulic or pneumatic devices or apparatus.

The plates may be constructed of any material or combination of materials which is suitable for use in processing flotation froth. The plates may have relatively smooth surfaces or may have roughened surfaces.

The inclination angle of the plates may be any angle which will facilitate passing of the flotation froth through the inclined channels while providing a desired residence time of the flotation froth in the inclined channels or projected area of the separator. The plate separation distance may be any distance between the plates which will facilitate passing of the flotation froth through the inclined channels without significant plugging of the inclined channels by the components of the flotation froth. The plate separation distance may be minimized in order to maximize the surface area to volume ratio of the flotation froth as it passes through the inclined channels.

The minimum plate separation distance for avoiding plugging of the inclined channels may be dependent in part upon the inclination angle of the plates. For example, the plate separation distance may possibly be reduced without increasing the risk of plugging of the inclined channels, if the inclination angle is correspondingly increased, and the plate separation distance may need to be increased if the inclination angle is reduced in order to avoid increasing the risk of plugging of the inclined channels.

In some embodiments, the inclination angle of the plates may be between 15 degrees and 60 degrees. In some embodiments, the inclination angle of the plates may be between 25 degrees and 35 degrees.

As used herein, the plate separation distance is the space between opposing adjacent surfaces of two adjacent plates, measured in a direction which is normal to the plate surfaces. In some embodiments, the plate separation distance may be between 60 millimeters and 90 millimeters. In some embodiments, the plate separation distance may be between 60 and 80 millimeters. In some embodiments, the plate separation distance may be between 60 millimeters and 70 millimeters.

In some embodiments, the inclination angle of the plates may be between 15 degrees and 60 degrees and the plate separation distance may be between 60 millimeters and 90 millimeters. In some embodiments, the inclination angle of the plates may be between 25 degrees and 35 degrees and the plate separation distance may be between 60 millimeters and 80 millimeters. In some embodiments, the inclination angle of the plates may be between 25 degrees and 35 degrees and the inclination angle may be between 60 millimeters and 70 millimeters.

The separator may be sized to separate a desired volume and/or flowrate of the flotation froth, and/or to provide a desired residence time and/or separation of the flotation froth. The separator may be comprised of any number of plates which is sufficient to accommodate the desired volume and/or flowrate of the flotation froth. The plates, the feed box and the discharge box may be of any size or dimension which is sufficient to accommodate the desired volume

and/or flowrate of the flotation froth and which is sufficient to accommodate the desired residence time and/or separation of the flotation froth.

5 The separator may be further comprised of a vessel for containing and/or comprising features of the separator. The vessel may contain the plates. The feed box and/or the discharge box may be integrally formed with or connected with the vessel. The vessel may be any suitable shape. By way of non-limiting examples, the vessel may be generally cylindrical or generally rectangular.

10 In some embodiments where the vessel is generally rectangular, the vessel may have a height, a width and a length. The height and the width of the vessel may define a cross-sectional area of the vessel. In some embodiments, the cross-sectional area of the vessel is substantially square. A ratio of the length of the vessel to the cross-sectional area of the vessel may be at least about 1:1 m/m².

15 The method of the invention may be performed using a separator according to a separator embodiment of the invention or with any other suitable apparatus which is compatible with the performance of the method.

20 In one method aspect, the invention is a method of separating a flotation froth into a water component and a bitumen component, the method comprising:

- 25 (a) providing a separator comprising a plurality of substantially parallel plates having a first end and a second end, wherein the plates are inclined at an inclination angle relative to a horizontal reference, wherein the first end of the plates is above the second end of the plates, and wherein the plates are separated from each other by a plate separation distance, thereby providing inclined channels between the plates;
- 30 (b) introducing the flotation froth into the separator adjacent to the first end of the plates so that the flotation froth passes through the inclined channels from the first end of the plates toward the second end of the plates, wherein the flotation froth is comprised of between about 65 percent and about 95 percent water by weight, and

wherein the flotation froth is further comprised of between about 4 percent and about 25 percent bitumen by weight; and

- 5 (d) separately discharging the water component and the bitumen component from the separator adjacent to the second end of the plates.

The method is preferably further comprised of discharging an air component of the flotation froth from the separator adjacent to the first end of the plates.

10 The method may be performed in a continuous manner or in a batch manner.

The method generally may be performed at any temperature which facilitates passing of the flotation froth through the inclined channels and separation of the flotation froth into the air component, the water component and the bitumen component.

15 The method may be performed at a temperature between a low temperature limit and a high temperature limit. The low temperature limit for performing the method may be the lowest temperature which facilitates passing of the flotation froth through the inclined channels and separation of the flotation froth into the air component, the water component and the bitumen
20 component. The high temperature limit for performing the method may be the highest temperature at which the method may be performed without causing excessive vaporization of hydrocarbons which are contained in the flotation froth.

25 As one non-limiting example, the flotation froth which is introduced into the separator may have a temperature of between 35 degrees Celsius and 70 degrees Celsius. As a second non-limiting example, the flotation froth which is introduced into the separator may have a temperature of between 40 degrees Celsius and 60 degrees Celsius.

30 The separator may be further comprised of a feed box adjacent to the first end of the plates, the feed box may extend above the first end of the plates, and the method may be further comprised of maintaining a level of the flotation froth in the feed box above the first end of the plates.

The separator may be further comprised of a discharge box adjacent to the second end of the plates, and the method may be further comprised of collecting the water component and the bitumen component in the discharge box before discharging the water component and the bitumen component from the separator. The discharge box may extend below the second end of the plates.

The method may be further comprised of maintaining an interface between the water component and the bitumen component in the discharge box so that the interface is above the location of discharging of the water component from the separator and so that the interface is below the location of discharging the bitumen component from the separator.

The separator may be further comprised of a water component outlet communicating with the discharge box, the separator may be further comprised of a bitumen component outlet communicating with the discharge box, the bitumen component outlet may be positioned above the water component outlet, and the method may be further comprised of maintaining an interface between the water component and the bitumen component in the discharge box above the water component outlet and below the bitumen component outlet.

The separator may be further comprised of a flotation froth inlet communicating with the first end of the plates. The separator may be further comprised of an air component outlet communicating with the first end of the plates.

Maintaining the interface between the water component and the bitumen component in the discharge box and maintaining the level of the flotation froth in the feed box may be comprised of at least one of controlling the introducing of the flotation froth into the separator, controlling the discharging of the water component from the separator, and controlling the discharging of the bitumen component from the separator.

In some embodiments, the introducing of the flotation froth into the separator may not be controlled. In some embodiments, maintaining the interface between the water component and the bitumen component in the discharge box and maintaining the level of the flotation froth in

the feed box may be comprised of controlling the discharging of the water component from the separator and controlling the discharging of the bitumen component from the separator.

5 Controlling the introducing of the flotation froth into the separator, controlling the discharging of the water component from the separator, and/or controlling the discharging of the bitumen component from the separator may be performed manually, semi-automatically or automatically.

10 The separator may be further comprised of a controller for controlling the introducing of the flotation froth into the separator, controlling the discharging of the water component from the separator, and/or controlling the discharging of the bitumen component from the separator.

15 The separator may be further comprised of a feed box level sensor, associated with the feed box, for sensing the level of the flotation froth in the feed box. The separator may be further comprised of a discharge box interface sensor, associated with the discharge box, for sensing the interface between the water component and the bitumen component in the discharge box.

20 The controller may be configured to receive data from the feed box level sensor and the discharge box interface sensor and to use the data to control the operation of the separator in order to maintain the interface between the water component and the bitumen component in the discharge box and/or in order to maintain the level of the flotation froth in the feed box.

25 The method may be further comprised of disposing of at least a portion of the water component. The water component may be disposed of as tailings and/or as waste water.

30 The method may be further comprised of subjecting at least a portion of the water component to an oil sands secondary recovery process in order to recover bitumen from the water component. The oil sands secondary recovery process may be comprised of any process which is compatible with the composition of the water component. The oil sands secondary recovery process may be a process within the overall oil sands recovery process which has produced the

flotation froth, so that subjecting the water component to the oil sands secondary recovery process may be comprised of recycling the water component to an earlier step of the overall oil sands recovery process. Alternatively, the oil sands secondary recovery process may be a process which is independent of the overall oil sands recovery process which has produced the flotation froth.

5

The method may be further comprised of combining at least a portion of the bitumen component with a bitumen product obtained from an oil sands primary recovery process. The oil sands primary recovery process may be a hot water process, a solids rejection process, or some other type of process. The oil sands primary recovery process may be a process within the overall oil sands recovery process which has produced the flotation froth or may be a process which is independent of the overall oil sands recovery process which has produced the flotation froth.

10

The method may be further comprised of recycling at least a portion of the bitumen component to an oil sands primary recovery process. The oil sands primary recovery process may be a hot water process, a solids rejection process, or some other type of process. The oil sands primary recovery process may be a process within the overall oil sands recovery process which has produced the flotation froth or may be a process which is independent of the overall oil sands recovery process which has produced the flotation froth.

15

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BRIEF DESCRIPTION OF DRAWINGS

Embodiments of the invention will now be described with reference to the accompanying drawings, in which:

25

Figure 1 is a schematic cross-section side view and partial pictorial view of a separator according to an embodiment of the invention.

30

Figure 2 is a schematic transverse cross-section view of the vessel portion of the separator of Figure 1, taken along line 2-2 in Figure 1, in which the profile of the inclined channels is comprised of a series of alternating peaks and troughs.

Figure 3 is a schematic transverse cross-section view of an isolated portion of three inclined plates defining two inclined channels, in which the profile of the inclined channels is comprised of a series of alternating sawtooth shaped peaks and troughs (i.e., pointed peaks and pointed troughs) which are formed by discontinuities in the plates.

5

Figure 4 is a schematic transverse cross-section view of an isolated portion of three inclined plates defining two inclined channels, in which the profile of the inclined channels is comprised of a series of alternating corrugated peaks and troughs (i.e., flat peaks and flat troughs) which are formed by discontinuities in the plates.

10

Figure 5 is a schematic transverse cross-section view of an isolated portion of three inclined plates defining two inclined channels, in which the profile of the inclined channels is comprised of a series of alternating undulated peaks and troughs (i.e., curved peaks and curved troughs) which are formed by discontinuities in the plates.

15

Figure 6 is a schematic transverse cross-section view of the vessel portion of the separator of Figure 1, taken along line 2-2 in Figure 1, in which the profile of the inclined channels is comprised of a single peak and a single trough.

20

Figure 7 is a schematic transverse cross-section view of an isolated portion of three inclined plates defining two inclined channels, in which the plates are substantially planar and in which the profile of the inclined channels is comprised of a single peak and a single trough.

DETAILED DESCRIPTION

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The present invention is directed at an apparatus and a method for separating a flotation froth into a water component, a bitumen component, and in preferred embodiments, an air component.

30

In the following description of embodiments of the invention, the apparatus is comprised of a separator, and the method is comprised of a method of using the separator to

separate the flotation froth into the air component, the water component and the bitumen component.

5 The invention may be used for separating a wide range of materials in addition to flotation froth. In the following description of specific embodiments of the invention, however, the apparatus and method are particularly intended for use in separating a flotation froth which is comprised of between 65 percent and 95 percent water by weight and between 4 percent and 25 percent bitumen by weight. In other words, the specific embodiments of the invention are particularly intended for use in separating a flotation froth which contains a relatively low
10 concentration of bitumen and a relatively high concentration of water in comparison with other materials such as, for example, a primary bitumen froth obtained from an oil sands primary recovery process.

The flotation froth may also be comprised of a significant amount of a flotation aid
15 such as air. For example, the flotation froth may be comprised of between 30 percent and 60 percent air by volume.

Referring to Figures 1-7, in some embodiments of the apparatus of the invention, the apparatus is comprised of a separator (20) for separating a flotation froth (100) into an air
20 component (104), a water component (106) and a bitumen component (108). Figures 1-5 are not drawn to scale.

As depicted in Figure 1, for convenience, ease of fabrication and ease of operation, the separator (20) is comprised of a vessel (22) which contains and/or comprises features of the
25 separator (20). Although the vessel (22) may be fabricated and configured to be capable of being pressurized and/or operated as a pressure vessel, the vessel (22) is preferably fabricated and configured to be operated at pressures which are not significantly higher or lower than the ambient pressure surrounding the separator (20).

30 The vessel (22) may be fabricated to have any suitable size and cross-section shape. As depicted in Figure 2 and Figure 6, the vessel (22) has a substantially rectangular or square

cross-section shape. Alternatively, in some embodiments the cross-section shape of the vessel (22) may be substantially round or may be some other shape.

5 The separator (20) is comprised of a plurality of substantially parallel plates (24) which are inclined at an inclination angle (26) relative to a horizontal reference (28). The plates (24) are arranged in a stacked manner, but are separated from each other by a plate separation distance (30), thereby providing inclined channels (32) between the plates (24).

10 The plates (24) have a first end (34) and a second end (36). The first end (34) of the plates (24) is above the second end (36) of the plates (24).

15 As depicted in Figure 1, the plates (24) are contained within the vessel (22). The separation between the plates (24) and the position of the plates (24) within the vessel (22) is maintained by spacers (38) which interconnect the plates (24) and connect the plates (24) with the vessel (22).

20 The separator (20) is further comprised of a feed box (40), for containing the flotation froth (100) which is introduced into the separator (20). The feed box (40) may also function as a surge tank in providing a surge volume to reduce the effects of a fluctuating supply of the flotation froth (100) to the separator (20).

25 The feed box (40) is adjacent to the first end (34) of the plates (24) and extends above the first end (34) of the plates (24). As depicted in Figure 1, the feed box (40) is integrally formed with or connected with the vessel (22).

The separator is further comprised of a discharge box (42), for collecting the water component and the bitumen component before they are discharged from the separator (20).

30 The discharge box (42) is adjacent to the second end (36) of the plates (24) and extends below the second end (36) of the plates (24). As depicted in Figure 1, the discharge box (42) is integrally formed with or connected with the vessel (22).

A flotation froth inlet (44) communicates with the first end (34) of the plates (24). As depicted in Figure 1, the flotation froth inlet (44) is associated with the feed box (40) so that the flotation froth inlet (44) communicates with the first end (34) of the plates (24) via the feed box (40). Optionally, a flotation froth inlet flow regulator (not shown) may be provided, for facilitating control of the introducing of the flotation froth (100) into the separator (20). A source of flotation froth (not shown) delivers the flotation froth (100) to the separator (20) through the flotation froth inlet (44).

In the embodiments depicted in Figures 1-7, an air component outlet (46) communicates with the first end (34) of the plates (24). As depicted in Figure 1, the air component outlet (46) is associated with the feed box (40) so that the air component outlet (46) communicates with the first end (34) of the plates (24) via the feed box (40). The air component outlet (46) may be omitted if the flotation froth (100) contains relatively small amounts of a flotation aid such as air or if for any reason it is not considered necessary or desirable to separate the air component (104) from the flotation froth (100).

As depicted in Figure 1, the air component outlet (46) is comprised of a vent for venting the air component (104) to the ambient atmosphere. Alternatively, the air component outlet (46) may be connected with a line (not shown) and/or other apparatus (not shown) for collecting, treating and/or compressing the air component (104).

A water component outlet (48) communicates with the second end (36) of the plates (24). As depicted in Figure 1, the water component outlet (48) is associated with the discharge box (42) so that the water component outlet (48) communicates with the second end (36) of the plates (24) via the discharge box (42). A water component outlet flow regulator (50) facilitates control of the discharging of the water component from the separator (20). In the embodiment depicted in Figure 1, the water component outlet flow regulator (50) is comprised of a variable speed pump or a variable output pump.

A bitumen component outlet (52) communicates with the second end (36) of the plates (24). As depicted in Figure 1, the bitumen component outlet (52) is associated with the discharge box (42) so that the bitumen component outlet (52) communicates with the second end

(36) of the plates (24) via the discharge box (42). A bitumen component outlet flow regulator (54) facilitates control of the discharging of the bitumen component from the separator (20). In the embodiment depicted in Figure 1, the bitumen component outlet flow regulator (54) is comprised of a variable speed pump or a variable output pump.

5

A feed box level sensor (56) is associated with the feed box (40). The feed box level sensor (56) senses a level of the flotation froth (100) in the feed box (40), which results in the generation of data by the feed box level sensor (56). The nature of the data generated by the feed box level sensor (56) is dependent upon the nature of the feed box level sensor (56), and may, as non-limiting examples, be comprised of electric signals, mechanical signals or optical signals.

10

A discharge box interface sensor (58) is associated with the discharge box (42). The discharge box interface sensor (58) senses an interface between the water component and the bitumen component in the discharge box (42), which results in the generation of data by the discharge box interface sensor (58). The nature of the data generated by the discharge box interface sensor (58) is dependent upon the nature of the discharge box interface sensor (58), and may, as non-limiting examples, be comprised of electric signals, mechanical signals or optical signals.

15

A controller (60) is operatively connected with the feed box level sensor (56) and with the discharge box interface sensor (58) so that the controller (60) can receive the data generated by the sensors (56,58).

20

The controller (60) is also operatively connected with the water component outlet flow regulator (50) and with the bitumen component outlet flow regulator (54).

25

The controller (60) is configured to receive the data from the feed box level sensor (56) and the discharge box interface sensor (58) and to use the data to control the water component outlet flow regulator (50) and the bitumen component outlet flow regulator (54), as described in detail below.

30

The vessel (22) is supported on vessel supports (not shown). In the embodiment depicted in Figure 1, the vessel (22) is configured so that the inclination angle (26) of the plates (24) is between 25 degrees and 35 degrees. In the embodiment depicted in Figure 2, the plate separation distance (30) is about 63 millimeters.

5

Referring to Figure 1, Figure 2 and Figure 6, the vessel (22) has a height (62), a width (64) and a length (66). In the embodiment depicted in Figure 1, Figure 2 and Figure 6, the height (62) of the vessel (22) is 2 meters, the width (64) of the vessel (22) is 2 meters, and the length (66) of the vessel (22) is 20 meters.

10

In the embodiment depicted in Figure 1, Figure 2 and Figure 6, the vessel (22) therefore contains about 30 plates (24).

Referring to Figure 1, the feed box (40) has a height (70), a width (72) and a length (74). In the embodiment depicted in Figure 1, the height (70) of the feed box (40) is 3 meters, the width (72) of the feed box (40) is 2 meters, and the length (74) of the feed box (40) is 2 meters.

15

Referring to Figure 1, the discharge box (42) has a height (80), a width (82) and a length (84). In the embodiment depicted in Figure 1, the height (80) of the discharge box (42) is 3 meters, the width (82) of the discharge box (42) is 2 meters, and the length (84) of the discharge box (42) is 2 meters.

20

Referring to Figures 2-7, each of the inclined channels (32) defines a profile (90) in a transverse direction (120), wherein the profile (90) is comprised of at least one peak (92) and one trough (94). Figures 2-6 depict different configurations of the plates (24) which provide different profiles (90), all of which comprise at least one peak (92) and one trough (94).

25

In the embodiments depicted in Figures 2-5, each of the plates (24) is substantially horizontal in the transverse direction (120) and is comprised of a plurality of discontinuities (122) so that the profile (90) of the inclined channels (32) is comprised of a series of alternating peaks (92) and troughs (94).

30

Referring to Figures 2 and 3, the profile (90) of the inclined channels (32) is sawtooth shaped (i.e., with alternating pointed peaks (92) and pointed troughs (94)). Referring to Figure 4, the profile (90) of the inclined channels (32) is corrugated (i.e., with alternating flat peaks (92) and flat troughs (94)). Referring to Figure 5, the profile (90) of the inclined channels (32) is undulating (i.e., with alternating curved peaks (92) and curved troughs (94)) are depicted. Figures 3-5 represent non-limiting examples of possible profiles (90) of the inclined channels (32) in embodiments of the invention in which the profile (90) of the inclined channels (32) is comprised of a series of alternating peaks (92) and troughs (94).

As depicted in Figures 2-5, the distance between adjacent peaks (92) on a particular plate is between 20 centimeters and 30 centimeters. This distance is exemplary only. The distance between adjacent peaks (92) may be any distance which facilitates some separation of the water component (106) and the bitumen component (108) in the inclined channels (32).

In the embodiment depicted in Figures 6-7, each of the plates (24) is substantially planar and is tilted in the transverse direction (120) at a transverse inclination angle (124) relative to a transverse horizontal reference (125) so that the profile (90) of the inclined channels (32) is comprised of a single peak (92) and a single trough (94). The single peak (92) is defined by a first side (126) of the vessel (22) in the transverse direction (120) and the single trough (94) is defined by a second side (128) of the vessel (22) in the transverse direction (120).

As depicted in Figures 6-7, the transverse inclination angle (124) is about 10 degrees. This angle is exemplary only. The transverse inclination angle (124) may be any distance which facilitates some separation of the water component (106) and the bitumen component (108) in the inclined channels (32). For example, in some embodiments the transverse inclination angle (124) may be between 5 degrees and 60 degrees. In other embodiments the transverse inclination angle may be between 10 degrees and 20 degrees.

Referring to Figure 2 and Figure 6, baffles (96) are provided between the uppermost plate (24) and the vessel (24) and between the lowermost plate (24) and the vessel (24), in order to direct the flotation froth (100) so that it passes through the inclined channels (32) which are provided between pairs of adjacent plates (24).

The method of the invention is now described in association with the embodiments of the apparatus of the invention which are depicted in Figures 1-7. In the description of the method that follows, the profile (90) of the inclined channels (32) may be any profile (90), including any of the profiles (90) depicted in Figures 2-7, which is comprised of at least one peak (92) and at least one trough (94) and which is capable of facilitating some separation of the water component (106) and the bitumen component (108) in the inclined channels (32).

The method of the invention separates the flotation froth (100) into the air component (104), the water component (106) and the bitumen component (108).

In the following description of the method, the method is performed on a continuous basis, with flotation froth (100) continuously being introduced into the separator (20) from a source (not shown) of the flotation froth (100). The method may also be performed on a batch basis, with flotation froth (100) intermittently being introduced into the separator (20).

Referring to Figure 1, the flotation froth (100) is introduced into the separator (20) through the flotation froth inlet (44) so that the flotation froth (100) is deposited into the feed box (40).

The flotation froth (100) has a level (102) in the feed box (40). The flotation froth (100) may undergo some limited amount of separation while it is in the feed box (40). For example, a portion of the air component (104) of the flotation froth (100) may become separated from the flotation froth (100) in the feed box (40) and may be discharged from the separator (20) via the air component outlet (46).

The feed box (40) is adjacent to the first end (34) of the plates (24). As a result, the flotation froth (100) enters the inclined channels (32) at the first end (34) of the plates (24) under the influence of gravity.

Due to the configuration of the plates (24), the flotation froth (100) and/or the components (104,106,108) of the flotation froth (100) experience both longitudinal movement and

transverse movement within the inclined channels (32). The longitudinal movement is along each of the inclined channels (32) generally between the first end (34) of the plates (24) and the second end (36) of the plates (24). The transverse movement is in the transverse direction (120) within each of the inclined channels (32) between the plates (24) which define the inclined channels (32).

5 As a result of these longitudinal and transverse movements, the flotation froth (100) undergoes some separation in the inclined channels (32) into the air component (104), the water component (106) and the bitumen component (108).

Referring to Figures 3-5 and Figure 7, the overall effect of the transverse movement is depicted. Specifically, the air component (104) and the bitumen component (108) both migrate upward within each of the inclined channels (32) to the peak (92) or peaks (92) formed in the upper plate (24) which defines the inclined channel (32). The water component (106) migrates downward within each of the inclined channels (32) to the trough (94) or troughs (94) formed in the lower plate (24) which defines the inclined channel (32).

15 Referring to Figure 1, the overall effect of the longitudinal movement is depicted. Specifically, due to its low density relative to the other components (106,108) of the flotation froth (100), the air component (104) moves along each of the inclined channels (32) toward the first end (34) of the plates (24), passes upward through the feed box (40), and is discharged from the separator (20) via the air component outlet (46). Meanwhile, the water component (106) and the bitumen component (108) move along each of the inclined channels (32) toward the second end (36) of the plates (24) and are collected in the discharge box (42).

In the embodiments of the separator (20) which are depicted in Figures 2-5, the water component (106) and the bitumen component (108) will both be collected in the discharge box (42) from a plurality of locations along the width (64) of the vessel (22), corresponding to the plurality of peaks (92) and troughs (94). In the embodiment of the separator (20) which is depicted in Figures 6-7, the bitumen component (108) will tend to be collected in the discharge box (42) from the first side (126) of the vessel (22) and the water component (106) will tend to be collected in the discharge box (42) from the second side (128) of the vessel. As a result, the profile (90) of the inclined channels (32) as depicted in Figures 6-7 may assist in maintaining a separation between the water component (106) and the bitumen component (108) in the discharge box (42).

The bitumen component (108) has a density which is slightly lower than the density of the water component (106). As a result, the water component (106) and the bitumen component (108) will tend to form two layers in the discharge box (42), with the bitumen component (108) “floating” on top of the water component (106). An interface (110) will define a boundary between the water component (106) and the bitumen component (108) in the discharge box (42).

The bitumen component (108) also has a viscosity which is slightly higher than the viscosity of the water component (106). Due to the lower density and the higher viscosity of the bitumen component (108) relative to the water component (106), the longitudinal movement of the bitumen component (108) along the inclined channels (32) will tend to be slower than the longitudinal movement of the water component (106) along the inclined channels (32), with the result that the bitumen component (108) will take longer than the water component (106) to move to the discharge box (42).

The bitumen component (108) will therefore have a relatively longer residence time within the inclined channels (32) than the water component (106), providing the bitumen component (108) with relatively longer separation time within the inclined channels (32) than the water component (106).

The water component (106) and the bitumen component (108) may undergo further separation in the discharge box (42), by which additional bitumen and/or air is separated from the water component (106) and additional water, solid mineral matter and/or air are separated from the bitumen component (108). Additional air which is separated from the water component (106) and/or the bitumen component (108) in the discharge box (42) may reenter the inclined channels (32) as the air component, move longitudinally along the inclined channels (32) toward the first end (34) of the plates (24), through the feed box (40), and be discharged from the separator (20) via the air component outlet (46).

The water component (106) is discharged from the separator (20) via the water component outlet (48). The bitumen component (108) is discharged from the separator (20) via

the bitumen component outlet (52). The water component (106) and the bitumen component (108) are therefore separately discharged from the separator (20).

5 The level (102) of the flotation froth (100) in the feed box (40) is maintained so that it is above the first end (34) of the plates (24), thereby ensuring that the flotation froth (100) contained in the feed box (40) is in communication with the first end (34) of the plates (24). The level (102) of the flotation froth (100) is sensed by the feed box level sensor (56), which results in the generation of data by the feed box level sensor (56).

10 The interface (110) between the water component (106) and the bitumen component (108) in the discharge box (42) is maintained so that it is above the water component outlet (48) and below the bitumen component outlet (52), thereby preserving the separation of the water component (106) and the bitumen component (108) when they are discharged from the separator (20). The interface (110) is sensed by the discharge box interface sensor (58), which
15 results in the generation of data by the discharge box interface sensor (58).

The controller (60) receives the data from the feed box level sensor (56) and the discharge box interface sensor (58) and uses the data to control the water component outlet flow regulator (50) and the bitumen component outlet flow regulator (54). In particular embodiments of
20 the invention, the controller (60) may receive electrical or electronic data from the sensors (56,58) and may control the flow regulators (50,54) mechanically, hydraulically, pneumatically, electrically, or in some other suitable manner.

By controlling the water component outlet flow regulator (50) and the bitumen
25 component outlet flow regulator (54), the level (102) of the flotation froth (100) in the feed box (40) can be maintained above the first end (34) of the plates (24) and the interface (110) between the water component (106) and the bitumen component (108) in the discharge box (42) can be maintained so that it is above the water component outlet (48) and below the bitumen component outlet (52).

30 The level (102) of the flotation froth (100) in the feed box (40) may be maintained by controlling the water component outlet flow regulator (50). By increasing the rate of discharge

of the water component (106) from the separator (20), the level (102) of the flotation froth (100) in the feed box (40) can be lowered. By decreasing the rate of discharge of the water component (106) from the separator (20), the level (102) of the flotation froth (100) in the feed box (40) can be raised.

5

The interface (110) between the water component (106) and the bitumen component (108) in the discharge box (42) may be maintained by controlling the bitumen component outlet flow regulator (54). By increasing the rate of discharge of the bitumen component (108) from the separator (20), the interface (110) in the discharge box (42) can be raised. By decreasing the rate of discharge of the bitumen component (108) from the separator (20), the interface (110) in the discharge box (42) can be lowered.

10

The water component (106) which is discharged from the separator (20) may be disposed of in some manner, such as being disposed of as tailings or waste water. If the water component (106) contains significant amounts of bitumen, the water component (106) may be subjected to an oil sands secondary recovery process in order to recover bitumen therefrom.

15

The bitumen component (108) which is discharged from the separator (20) may have a quality which is sufficiently high so that the bitumen component (108) is suitable as a bitumen product, in which case the bitumen component (108) may be combined with one or more bitumen products obtained from other oil sands recovery processes, such as an oil sands primary recovery process. Alternatively, if the bitumen component (108) has a quality which is not sufficiently high so that the bitumen component (108) is suitable as a bitumen product, the bitumen component (108) may be recycled for further processing to another oil sands recovery process, such as an oil sands primary recovery process.

20

25

Based upon numerical modelling of the invention, it is believed that the water component (106) which is produced by the method of the invention may be expected to be comprised of between 1 percent and 3 percent bitumen by weight, between 5 percent and 20 percent solid mineral matter by weight, and between 65 percent and 90 percent water by weight.

30

Similarly, based upon numerical modelling of the invention as described in the Examples which follow, it is believed that the bitumen component (108) may be expected to be comprised of between 25 percent and 50 percent bitumen by weight, between 8 percent and 25 percent solid mineral matter by weight, between 25 percent and 65 percent water by weight, and less than 20 percent or perhaps even less than 10 percent air by volume.

Examples

Two Examples of the performance of the method of the invention, based upon numerical modelling, are provided.

In both Examples, the separator (20) is comprised of a vessel, a feed box (40) and a discharge box (42). The vessel (22) has a height (62) of 2 meters, a width (64) of 2 meters and a length (66) of 20 meters. The feed box (40) has a height (70) of 3 meters, a width (72) of 2 meters and a length (74) of 2 meters. The discharge box (42) has a height (80) of 3 meters, a width (82) of 2 meters and a length (84) of 2 meters.

In both Examples, the plates (24) are contained within the vessel (22). The thickness of the plates (24) is about 3 millimeters and the plate separation distance (30) is 63 millimeters. The distance between centerlines of adjacent plates (24) is therefore about 66 millimeters so that the separator (20) includes about 30 plates (24). The inclined channels (32) have a corrugated profile (90) similar to the profile (90) depicted in Figure 4, with alternating flat peaks (92) and flat troughs (94). The distance between adjacent peaks (92) on a particular plate (24) is 30 centimeters. The inclination angle (26) of the plates is 25 degrees.

In Example 1, the flotation froth (100) is a "high grade" flotation froth (100) obtained from a middlings stream produced by a hot water oil sands recovery process. The high grade flotation froth (100) is comprised of 20 percent bitumen by weight, 10 percent solid mineral matter by weight, and 70 percent water by weight.

In Example 1, the separator (20) is operated to provide a mean residence time of the flotation froth (100) in the separator (20) of 12.8 minutes.

In Example 2, the flotation froth (100) is a “low grade” flotation froth (100) obtained from a middlings stream produced by a hot water oil sands recovery process. The low grade flotation froth (100) is comprised of 10 percent bitumen by weight, 12 percent solid mineral matter by weight, and 78 percent water by weight.

In Example 2, the separator (20) is operated to provide a mean residence time of the flotation froth (100) in the separator (20) of 6.5 minutes.

Model material balances for Example 1 and Example 2 are provided at the end of this Description.

The apparatus and the method of the invention therefore provide for the separation of the flotation froth (100) into the water component (106), the bitumen component (108), and optionally the air component (104). The bitumen component (108) contains a significantly higher concentration of bitumen and may contain a significantly lower amount of air than the flotation froth (100). The increased concentration of bitumen in the bitumen component (108) may increase the potential value of the bitumen component (108) relative to the flotation froth (100), and the reduced amount of air in the bitumen component (108) may reduce potential handling and/or transport difficulties relative to the flotation froth (100).

In this document, the word “comprising” is used in its non-limiting sense to mean that items following the word are included, but items not specifically mentioned are not excluded. A reference to an element by the indefinite article “a” does not exclude the possibility that more than one of the elements is present, unless the context clearly requires that there be one and only one of the elements.

TABLE 1

HIGH GRADE FLOTATION FROTH						
MATERIAL STREAM	MIDDLEINGS	FLOTATION FROTH (100)	FLOTATION TAILINGS	WATER COMPONENT (106)	BITUMEN COMPONENT (108)	
BITUMEN (tph)	90.0	72.0	18.0	7.2	64.8	
WATER (tph)	2370.0	252.0	2118.0	197.6	54.4	
SOLID MINERAL MATTER (tph)	540.0	36.0	504.0	25.6	10.4	
TOTAL MASS (tph)	3000.0	360.0	2640.0	230.4	129.6	
RELATIVE DENSITY	1.125	1.067	1.133	1.074	1.056	
VOLUMETRIC FLOW (m ³ /h)	2667	337	2330	215	123	
VOLUMETRIC FLOW (U.S. gpm)	11752	1486	10266	945	541	
BITUMEN (%wt.)	3.00	20.00	0.68	3.13	50.00	
WATER (%wt.)	79.00	70.00	80.23	85.75	42.00	
SOLID MINERAL MATTER (%wt.)	18.00	10.00	19.09	11.13	8.00	
Air Content (%volume)		>10%		<1%	<5%	

TABLE 2

LOW GRADE FLOTATION FROTH					
MATERIAL STREAM	MIDDLEINGS	FLOTATION FROTH (100)	FLOTATION TAILINGS	WATER COMPONENT (106)	BITUMEN COMPONENT (108)
BITUMEN (tph)	90.0	72.0	18.0	7.2	64.8
WATER (tph)	2370.0	561.6	1808.4	480.6	81.0
SOLID MINERAL MATTER (tph)	540.0	86.4	453.6	70.2	16.2
TOTAL MASS (tph)	3000.0	720.0	2280.0	558.0	162.0
RELATIVE DENSITY	1.125	1.081	1.140	1.084	1.069
VOLUMETRIC FLOW (m ³ /h)	2667	666	2001	515	152
VOLUMETRIC FLOW (U.S. gpm)	11752	2936	8816	2268	668
BITUMEN (%wt.)	3.00	10.00	0.79	1.29	40.00
WATER (%wt.)	79.00	78.00	79.32	86.13	50.00
SOLID MINERAL MATTER (%wt.)	18.00	12.00	19.89	12.58	10.00
Air Content (%volume)		>10%		<1%	<5%

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A separator for separating a flotation froth into a water component and a bitumen
5 component, wherein the flotation froth is comprised of between about 65 percent and about 95 percent water by weight, and wherein the flotation froth is further comprised of between about 4 percent and about 25 percent bitumen by weight, the separator comprising:
 - (a) a plurality of substantially parallel plates having a first end and a second end,
10 wherein the plates are inclined at an inclination angle relative to a horizontal reference, wherein the first end of the plates is above the second end of the plates, and wherein the plates are separated from each other by a plate separation distance, thereby providing inclined channels between the plates;
 - 15 (b) a flotation froth inlet communicating with the first end of the plates, for introducing the flotation froth into the separator;
 - (c) a water component outlet communicating with the second end of the plates, for discharging the water component from the separator; and
20
 - (d) a bitumen component outlet communicating with the second end of the plates, for discharging the bitumen component from the separator, wherein the bitumen component outlet is positioned above the water component outlet.
- 25 2. The separator as claimed in claim 1 wherein each of the inclined channels defines a profile in a transverse direction, wherein the profile is comprised of at least one peak and at least one trough.
3. The separator as claimed in claim 2, further comprising an air component outlet
30 communicating with the first end of the plates, for discharging an air component of the flotation froth from the separator.

4. The separator as claimed in claim 3 wherein each of the plates is substantially horizontal in the transverse direction and is comprised of a plurality of discontinuities so that the profile of the inclined channels is comprised of a series of alternating peaks and troughs.

5. The separator as claimed in claim 3 wherein each of the plates is substantially planar and is tilted in the transverse direction at a transverse inclination angle relative to a transverse horizontal reference so that the profile of the inclined channels is comprised of a single peak and a single trough.

6. The separator as claimed in claim 3, further comprising a feed box adjacent to the first end of the plates, for containing the flotation froth which is introduced into the separator.

7. The separator as claimed in claim 6 wherein the feed box extends above the first end of the plates.

8. The separator as claimed in claim 7, further comprising a feed box level sensor associated with the feed box, for sensing a level of the flotation froth in the feed box.

9. The separator as claimed in claim 7, further comprising a discharge box adjacent to the second end of the plates, for collecting the water component and the bitumen component before they are discharged from the separator, wherein the water component outlet communicates with the discharge box, and wherein the bitumen component outlet communicates with the discharge box.

10. The separator as claimed in claim 9, further comprising a discharge box interface sensor associated with the discharge box, for sensing an interface between the water component and the bitumen component in the discharge box.

11. The separator as claimed in claim 9 wherein the discharge box extends below the second end of the plates.

12. The separator as claimed in claim 9, further comprising a water component outlet flow regulator associated with the water component outlet, for controlling the discharging of the water component from the separator.

5 13. The separator as claimed in claim 12, further comprising a bitumen component outlet flow regulator associated with the bitumen component outlet, for controlling the discharging of the bitumen component from the separator.

10 14. The separator as claimed in claim 13, further comprising a discharge box interface sensor associated with the discharge box, for sensing an interface between the water component and the bitumen component in the discharge box.

15 15. The separator as claimed in claim 13, further comprising a controller operatively connected with the water component outlet flow regulator and the bitumen component outlet flow regulator.

16. The separator as claimed in claim 15, further comprising a feed box level sensor associated with the feed box, for sensing a level of the flotation froth in the feed box.

20 17. The separator as claimed in claim 16, further comprising a discharge box interface sensor associated with the discharge box, for sensing an interface between the water component and the bitumen component in the discharge box.

25 18. The separator as claimed in claim 17 wherein the controller is configured to receive data from the feed box level sensor and the discharge box interface sensor and to use the data to control the water component outlet flow regulator and the bitumen component outlet flow regulator in order to maintain the interface between the water component and the bitumen component in the discharge box above the water component outlet and below the bitumen component outlet.

30 19. The separator as claimed in claim 17 wherein the controller is configured to receive data from the feed box level sensor and the discharge box interface sensor and to use the data to

control the water component outlet flow regulator and the bitumen component outlet flow regulator in order to maintain the level of the flotation froth in the feed box above the first end of the plates.

5 20. The separator as claimed in claim 19 wherein the controller is further configured to use the data to control the water component outlet flow regulator and the bitumen component outlet flow regulator in order to maintain the interface between the water component and the bitumen component in the discharge box above the water component outlet and below the bitumen component outlet.

10 21. The separator as claimed in claim 3 wherein the inclination angle of the plates is between about 15 degrees and about 60 degrees.

15 22. The separator as claimed in claim 21 wherein the plate separation distance is between about 60 millimeters and about 90 millimeters.

23. The separator as claimed in claim 21 wherein the inclination angle of the plates is between about 25 degrees and about 35 degrees.

20 24. The separator as claimed in claim 23 wherein the plate separation distance is between about 60 millimeters and about 80 millimeters.

25 25. The separator as claimed in claim 24 wherein the plate separation distance is between about 60 millimeters and about 70 millimeters.

26. The separator as claimed in claim 4 wherein the plates are configured so that a distance between adjacent peaks is between about 20 centimeters and about 30 centimeters.

30 27. The separator as claimed in claim 5 wherein the transverse inclination angle is between about 5 degrees and about 60 degrees.

28. The separator as claimed in claim 27 wherein the transverse inclination angle is between about 10 degrees and about 20 degrees.

29. A method of separating a flotation froth into a water component and a bitumen component, the method comprising:

(a) providing a separator comprising a plurality of substantially parallel plates having a first end and a second end, wherein the plates are inclined at an inclination angle relative to a horizontal reference, wherein the first end of the plates is above the second end of the plates, and wherein the plates are separated from each other by a plate separation distance, thereby providing inclined channels between the plates;

(b) introducing the flotation froth into the separator adjacent to the first end of the plates so that the flotation froth passes through the inclined channels from the first end of the plates toward the second end of the plates, wherein the flotation froth is comprised of between about 65 percent and about 95 percent water by weight, and wherein the flotation froth is further comprised of between about 4 percent and about 25 percent bitumen by weight; and

(d) separately discharging the water component and the bitumen component from the separator adjacent to the second end of the plates.

30. The method as claimed in claim 29 wherein each of the inclined channels defines a profile in a transverse direction, wherein the profile is comprised of at least one peak and at least one trough.

31. The method as claimed in claim 30, further comprising discharging an air component of the flotation froth from the separator adjacent to the first end of the plates.

32. The method as claimed in claim 31 wherein each of the plates is substantially horizontal in the transverse direction and is comprised of a plurality of discontinuities so that the profile of the inclined channels is comprised of a series of alternating peaks and troughs.

33. The method as claimed in claim 31 wherein each of the plates is substantially planar and is tilted in the transverse direction at a transverse inclination angle relative to a transverse horizontal reference so that the profile of the inclined channels is comprised of a single peak and a single trough.

34. The method as claimed in claim 31 wherein the separator is further comprised of a feed box adjacent to the first end of the plates, wherein the feed box extends above the first end of the plates, further comprising maintaining a level of the flotation froth in the feed box above the first end of the plates.

35. The method as claimed in claim 31 wherein the separator is further comprised of a discharge box adjacent to the second end of the plates, further comprising collecting the water component and the bitumen component in the discharge box before discharging the water component and the bitumen component from the separator.

36. The method as claimed in claim 35 wherein the separator is further comprised of a water component outlet communicating with the discharge box, wherein the separator is further comprised of a bitumen component outlet communicating with the discharge box, and wherein the bitumen component outlet is positioned above the water component outlet, further comprising maintaining an interface between the water component and the bitumen component in the discharge box above the water component outlet and below the bitumen component outlet.

37. The method as claimed in claim 36 wherein the separator is further comprised of a feed box adjacent to the first end of the plates, wherein the feed box extends above the first end of the plates, further comprising maintaining a level of the flotation froth in the feed box above the first end of the plates.

38. The method as claimed in claim 37 wherein maintaining the interface in the discharge box and maintaining the level of the flotation froth in the feed box is comprised of controlling the discharging of the water component from the separator and controlling the discharging of the bitumen component from the separator.

39. The method as claimed in claim 38 wherein the discharge box extends below the second end of the plates.

5 40. The method as claimed in claim 31, further comprising disposing of at least a portion of the water component.

41. The method as claimed in claim 31, further comprising subjecting at least a portion of the water component to an oil sands secondary recovery process in order to recover bitumen
10 from the water component.

42. The method as claimed in claim 31, further comprising combining at least a portion of the bitumen component with a bitumen product obtained from an oil sands primary recovery process.
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43. The method as claimed in claim 31, further comprising recycling at least a portion of the bitumen component to an oil sands primary recovery process.

44. The method as claimed in claim 31 wherein the inclination angle of the plates is
20 between about 15 degrees and about 60 degrees.

45. The method as claimed in claim 44 wherein the plate separation distance is between about 60 millimeters and about 90 millimeters.

25 46. The method as claimed in claim 44 wherein the inclination angle of the plates is between about 25 degrees and about 35 degrees.

47. The method as claimed in claim 46 wherein the plate separation distance is between about 60 millimeters and about 80 millimeters.
30

48. The method as claimed in claim 47 wherein the plate separation distance is between about 60 millimeters and about 70 millimeters.

49. The method as claimed in claim 31 wherein the plates are configured so that a distance between adjacent peaks is between about 20 centimeters and about 30 centimeters.

5 50. The method as claimed in claim 33 wherein the transverse inclination angle is between about 5 degrees and about 60 degrees.

51. The method as claimed in claim 50 wherein the transverse inclination angle is between about 10 degrees and about 20 degrees.

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