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(54) **BITUMEN SEPARATION PROCESS AND APPARATUS FOR PROBLEM ORES**

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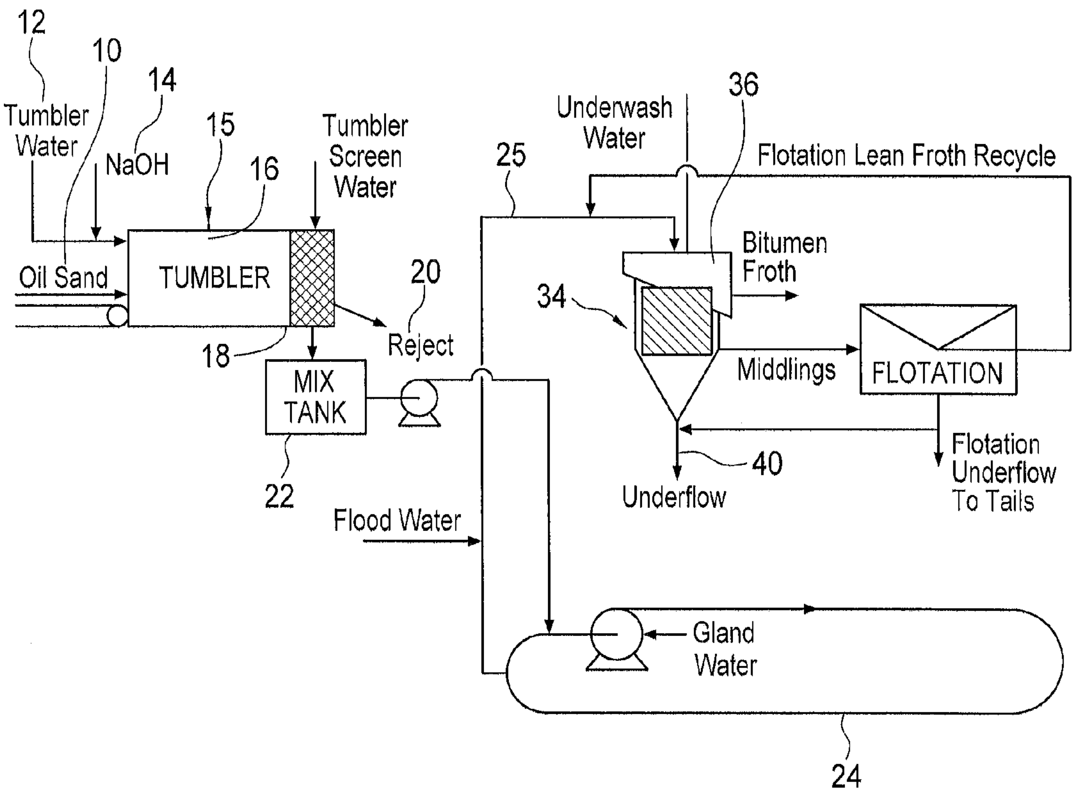
USPC **208/391**; 208/390; 196/14.52

(57) **ABSTRACT**

A process for separating from an oil sand slurry solids and bitumen is provided, comprising introducing the oil sand slurry into a separation zone comprising an upper zone and a lower zone; intercepting a settling path of the solids in the separation zone by bringing the solids into contact with at least one intercepting surface to direct the solids to the lower zone; and producing a reduced solids upper zone to allow the bitumen to rise through the upper zone with reduced hindrance from the solids.



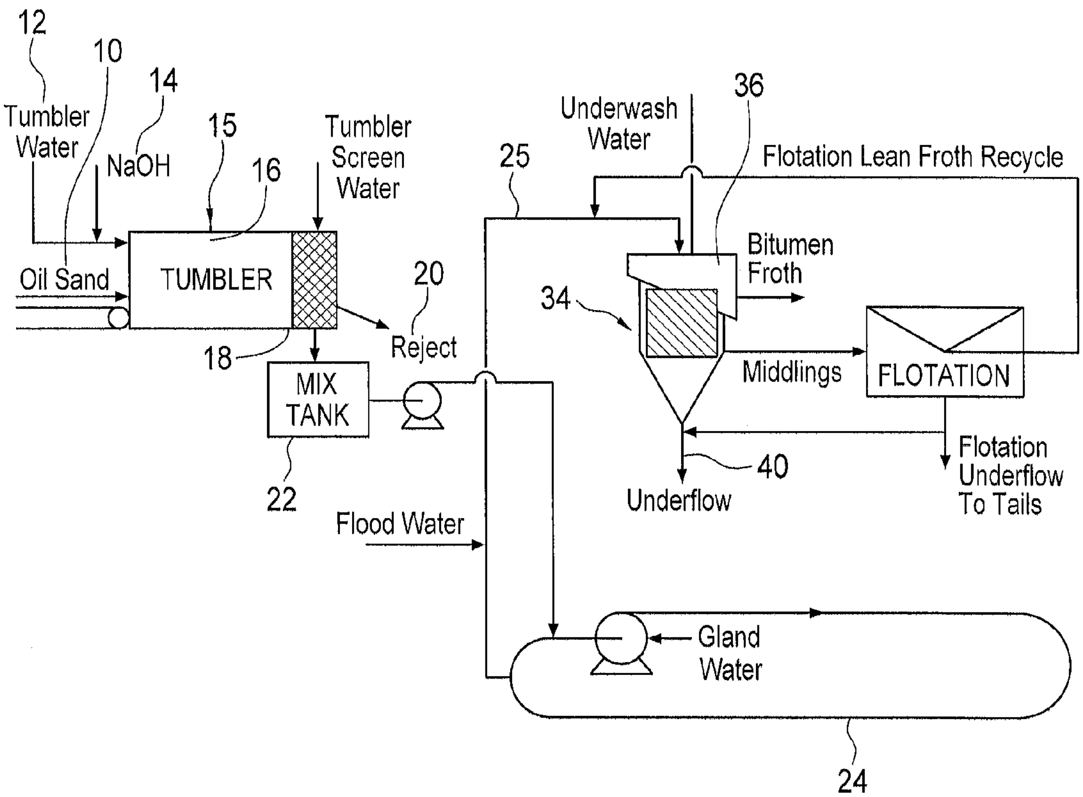

12
10
14
Tumbler Water
NaOH
15
16
Tumbler Screen Water
Oil Sand
TUMBLER
20
Reject
18
MIX TANK
22
25
Underwash Water
36
Flotation Lean Froth Recycle
Bitumen Froth
34
Middlings
FLOTATION
Flotation Underflow To Tails
40
Underflow
Flood Water
Gland Water
24

FIG. 1

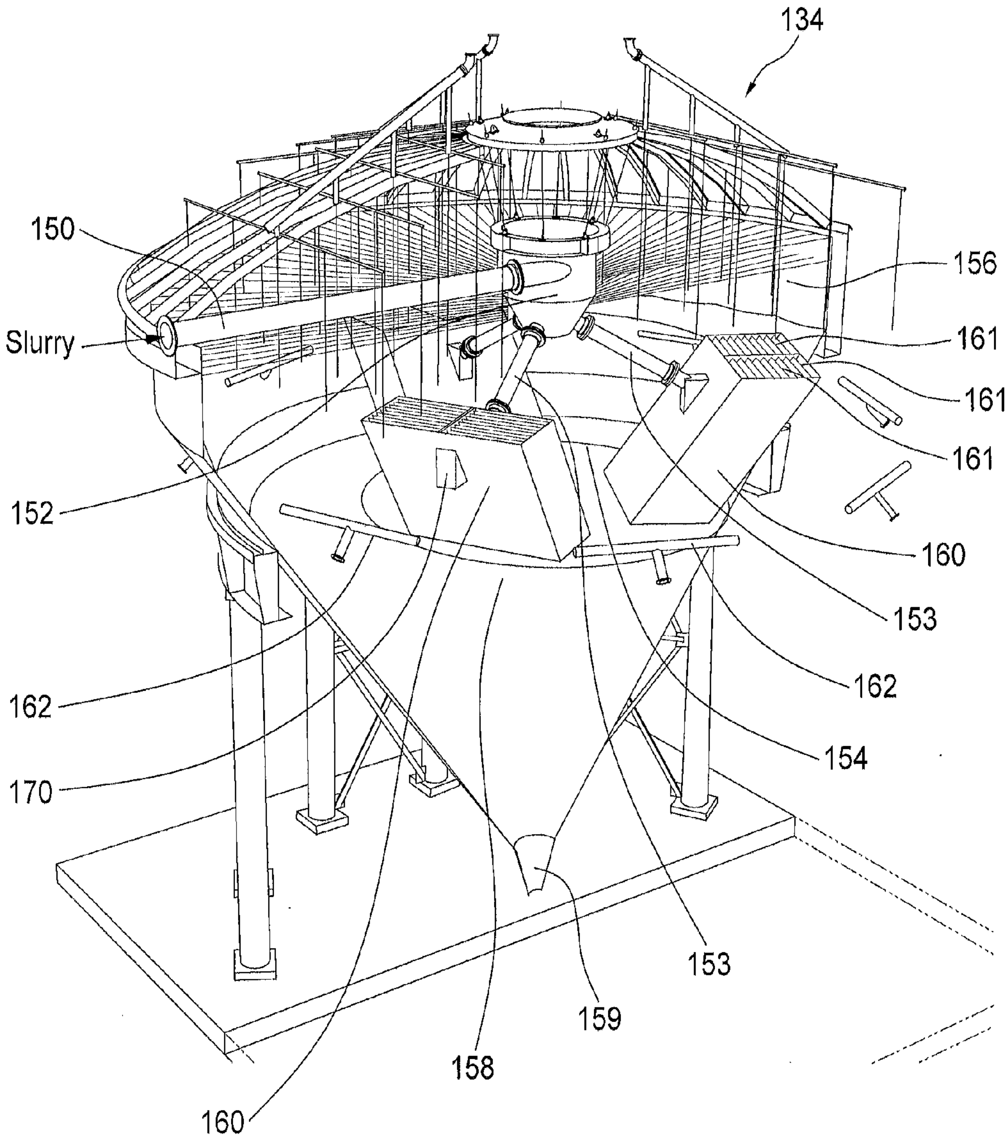

134
150
156
Slurry
161
161
161
152
160
153
162
162
154
170
153
159
158
160

FIG. 2

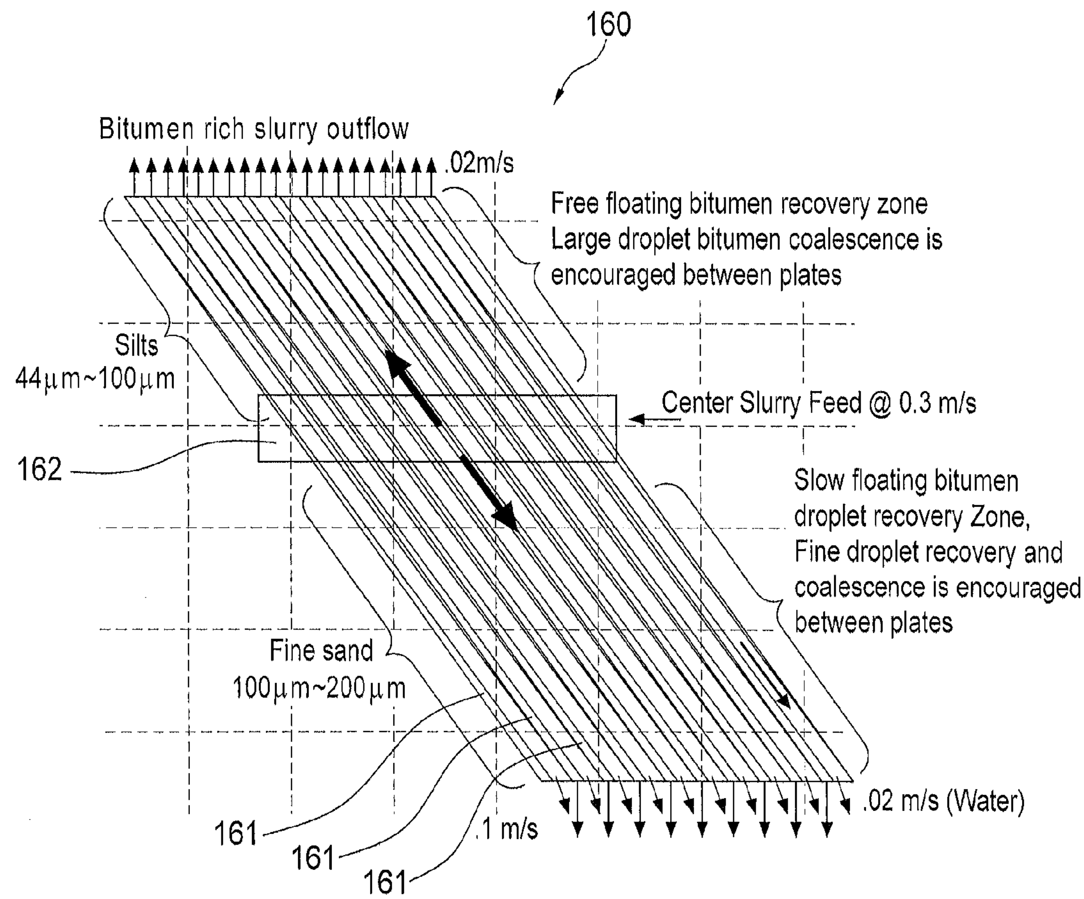

160
Bitumen rich slurry outflow
.02m/s
Free floating bitumen recovery zone
Large droplet bitumen coalescence is encouraged between plates
Silts
44μm~100μm
Center Slurry Feed @ 0.3 m/s
162
Slow floating bitumen droplet recovery Zone,
Fine droplet recovery and coalescence is encouraged between plates
Fine sand
100μm~200μm
161
161
161
.1 m/s
.02 m/s (Water)

FIG. 3

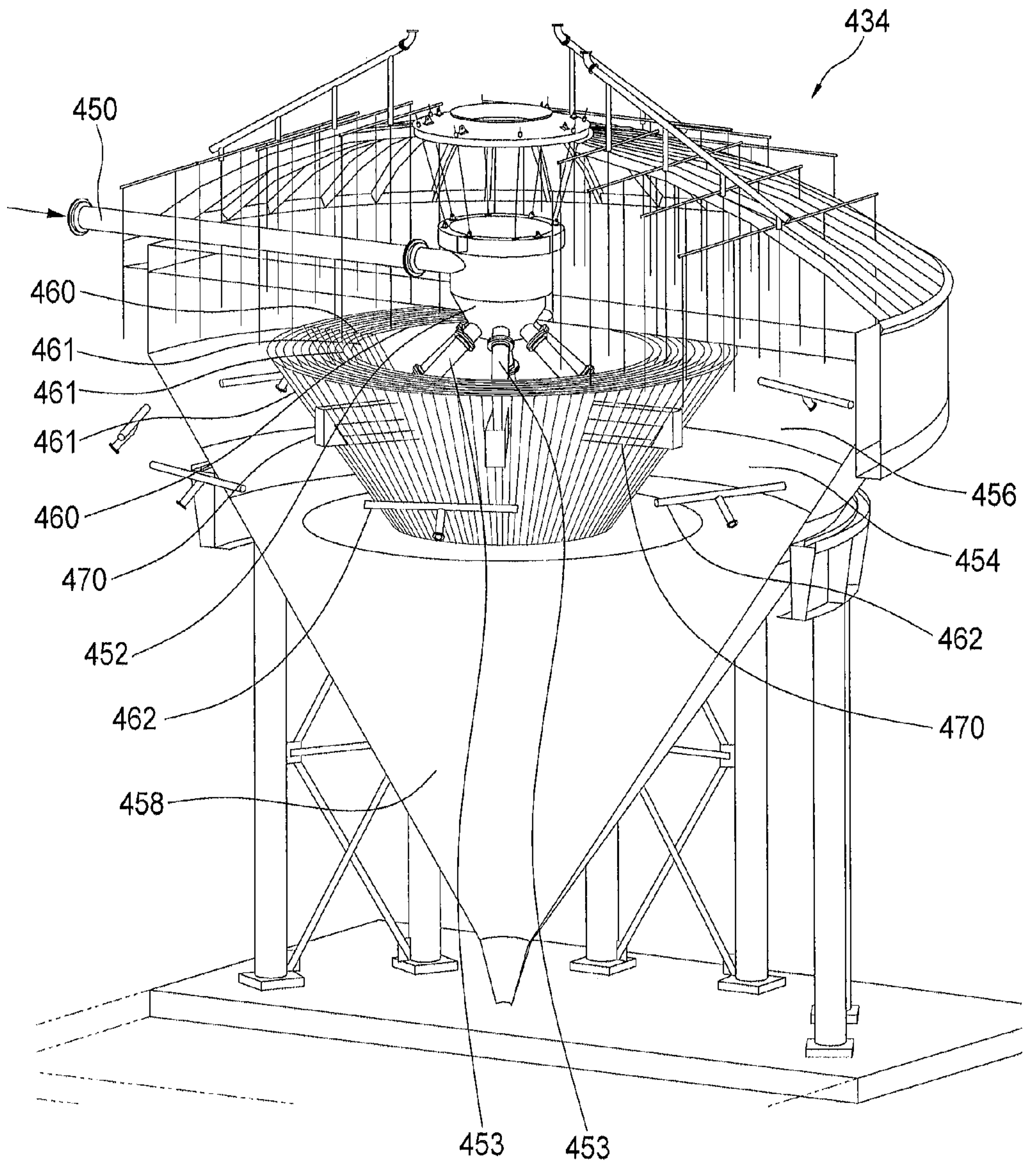

434
450
460
461
461
461
460
470
452
462
458
456
454
462
470
453
453

FIG. 4

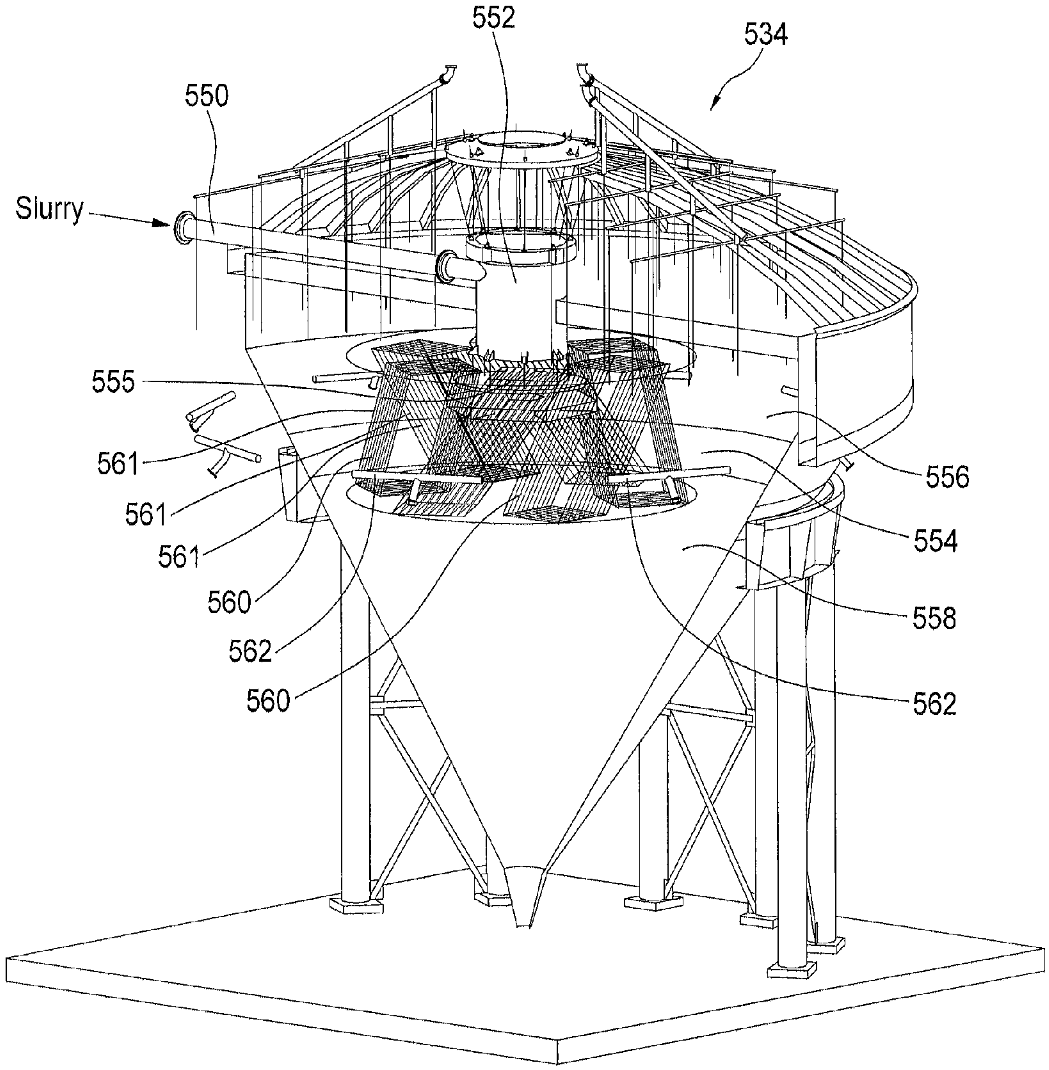


FIG. 5

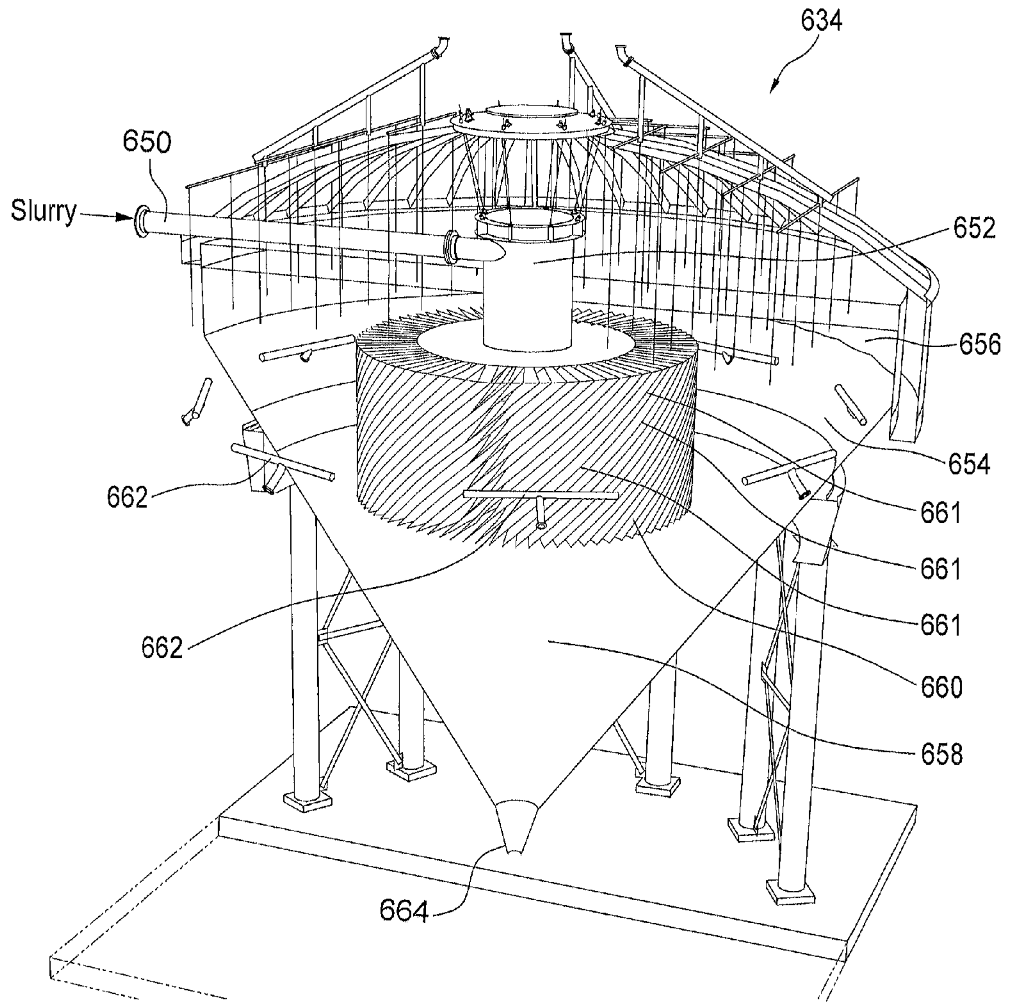


FIG. 6

BITUMEN SEPARATION PROCESS AND APPARATUS FOR PROBLEM ORES

FIELD OF THE INVENTION

[0001] The present invention relates to an apparatus and a process for improving bitumen recovery from problem oil sand ores such as those that have higher fines content and/or lower bitumen grade. More particularly, conditioned oil sand slurry prepared from problems ores is introduced into a bitumen separation vessel having at least one intercepting surface.

BACKGROUND OF THE INVENTION

[0002] Existing water-based oil sand extraction flowsheets are practically limited to processing ores that are relatively high in bitumen content and low in fines content, and, preferably, of estuarine facies. However, there exists an abundance of "problem ores" that cannot be processed in existing extraction plants unless a high proportion of high-grade good processing ores are blended into these ore feeds. "Problem ores" (also referred to as "poor ores") refers to those oil sand ores having high fines content or low bitumen content or both. Generally, poor ores will have less than 8 or 9 wt % bitumen content. An example of a "problem ore" or "poor ore" would be an ore comprising 6.1 wt % bitumen, 7.0 wt % water, 86.9 wt % solids, wherein 43.0 wt % of the solids are fines, <44 μn. Hence, it is necessary to plan well ahead prior to the opening of a new mine to ensure that sufficient amount of good ores will be available for blending.

[0003] Ore blending criteria include limiting the fines content (<44 μm) in the ore feed and the solids d_{50} to some specified maximum levels to prevent processability and pipeline sanding issues, thereby limiting the maximum proportion of problem ores in the blends. By way of example and without being limiting, it may be desirable to limit the fines content to a maximum of about 28-30% and the solid d_{50} to about 250-300 μm. Thus, the proportion of problem ores in blends may be limited to about 30% in many cases.

[0004] However, blending criteria are not always possible to meet and are simply missed at times during day-to-day operations. Furthermore, ore blending activities significantly increase operation cost, energy usage and reduce production capacity. The challenge is to widen the processability window for an extraction plant to be able to handle greater types of ore feed and, as such, reduce the need for ore blending and reduce the impact of blending upset when same occurs.

[0005] A prior patent application of the present applicant, US 2011/0127198, describes treating conditioned oil sand slurry in a de-sander circuit prior to introducing it into a bitumen separation vessel to improve bitumen recovery/froth quality for problem ores. However, there are significant costs involved in implementing and maintaining such a de-sander circuit as well as added complexity to the process flowsheet and operation. Hence, there is still a need for additional/alternative technology to remove solids from conditioned slurry to improve the processability of problem ores without added process and operation complexity and significant costs increased.

SUMMARY OF THE INVENTION

[0006] The current application is directed to a process and apparatus for separating from a conditioned oil sand slurry solids and bitumen. The present invention is particularly useful with, but not limited to, problem ores, for example, ores having high amounts of fine solids, which fine solids may interfere in bitumen separation, froth treatment, and tailings management. By enhancing the removal of solids in a separation zone, the bitumen droplets are allowed to float up more readily through the separation zone due to the reduction in physical hindrance from the solids.

[0007] More particularly, in one aspect, a process for separating from an oil sand slurry solids and bitumen is provided, comprising:

[0008] introducing the oil sand slurry into a separation zone comprising at least an upper zone and a lower zone;

[0009] intercepting a settling path of the solids in the separation zone by bringing the solids into contact with at least one intercepting surface to direct the solids to the lower zone; and

[0010] producing a reduced solids upper zone to allow the bitumen to rise through the upper zone with reduced hindrance from the solids.

[0011] In one embodiment, the separation zone is present in a bitumen separation vessel and the at least one intercepting surface is at least one inclined plate. The configuration of the at least one inclined plate can be selected from a variety of configurations, some of which are described in more detail below.

[0012] In another aspect, an apparatus for separating from an oil sand slurry solids and bitumen is provided, comprising:

[0013] a vessel having a separation zone, the separation zone further comprising at least an upper zone and a lower zone;

[0014] a feed well for feeding the oil sand slurry into the separation zone; and

[0015] at least one separation element having an intercepting surface positioned in the separation zone in a vertically downward orientation;

whereby the solids are cause by gravity to settle along the at least one separation element to the lower zone and the bitumen is caused by a decrease in specific gravity due to the settling of the solids to flow upwardly to the upper zone.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Referring to the drawings wherein like reference numerals indicate similar parts throughout the several views, several aspects of the present invention are illustrated by way of example, and not by way of limitation, in detail in the figures, wherein:

[0017] FIG. **1** is a schematic of an embodiment of the present invention showing a process line useful in processing oil sand and extracting bitumen therefrom which includes a bitumen separation vessel of the present invention.

[0018] FIG. **2** is a tear away view of one embodiment of a bitumen separation vessel useful in the present invention.

[0019] FIG. **3** is a cross-sectional of one of the inclined plate assemblies of FIG. **2**.

[0020] FIG. **4** is a tear away view of another embodiment of a bitumen separation vessel useful in the present invention.

[0021] FIG. **5** is a tear away view of another embodiment of a bitumen separation vessel useful in the present invention.

[0022] FIG. **6** is a tear away view of another embodiment of a bitumen separation vessel useful in the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0023] The detailed description set forth below in connection with the appended drawing is intended as a description of various embodiments of the present invention and is not intended to represent the only embodiments contemplated by the inventor. The detailed description includes specific details for the purpose of providing a comprehensive understanding of the present invention. However, it will be apparent to those skilled in the art that the present invention may be practiced without these specific details.

[0024] FIG. **1** is a schematic of an embodiment of the process of the present invention useful in obtaining bitumen from problem oil sand ores. Oil sand **10** is mined from an oil sand rich area such as the Athabasca Region of Alberta and mixed with heated water **12** in a slurry preparation unit, which unit is shown here generally as element **15**. As shown in FIG. **1**, slurry preparation unit **15** may comprise tumbler **16**, screening device **18** and pump box **22**; however, it is understood that any slurry preparation unit known in the art can be used. In addition to the oil sand **10** and water **12**, optionally, caustic (NaOH) **14** is also added to tumbler **16** to aid in conditioning the oil sand slurry.

[0025] The oil sand slurry is then screened through screen portion **18**, where additional water may be added to clean the rejects (e.g., oversized rocks) prior to delivering the rejects to rejects pile **20**. The screened oil sand slurry is collected in a vessel such as pump box **22** where the oil sand slurry is then pumped through a hydrotransport pipeline **24**, which pipeline **24** is of a adequate length to ensure sufficient conditioning of the oil sand slurry, e.g., thorough digestion/ablation/dispersion of the larger oil sand lumps, coalescence of released bitumen flecks and aeration of the coalesced bitumen droplets.

[0026] The conditioned oil sand slurry **25** is then fed to bitumen separation vessel **34**, which bitumen separation vessel **34** operates under somewhat more quiescent conditions to allow the bitumen droplets to rise to the top of the vessel and form bitumen froth, which froth over flows to the launder **36** and is collected for further froth treatment. Tailings **40** are either discarded or further treated for additional bitumen recovery.

[0027] FIG. **2** illustrates an embodiment of a gravity separation vessel **134** useful in separating bitumen and solids from an oil sand/water slurry. Oil sand/water slurry (which has typically been conditioned by hydrotransport through pipelines) is introduced into the gravity separation vessel **134** and, under quiescent conditions; the bitumen froth separates from the water and solids. Typically, the gravity separation vessel **134** is operated as a continuous process so that diluted slurry is continuously being introduced into the gravity separation vessel **134** while end products, such as bitumen froth, a tailings stream, etc. are also being continuously removed.

[0028] The gravity separation vessel **134** has a separation chamber (also referred to herein as a separation zone) **154**. Typically, the separation chamber **154** will have a generally cylindrical upper portion (upper zone) **156** and a generally conical bottom portion (lower zone) **158**. In this illustration, the bottom of cone **158** further comprises solids outlet **159**. The upper zone **156** can have an open top and a feedwell **152** provided in the upper portion through which the diluted slurry enters the gravity separation vessel **134** via a tangential pipe **150** at the upper zone **156** of the separation chamber **154**. The separation chamber or separation zone **154** further comprises at least one inclined plate assembly **160**, which inclined plate assembly **160** can be seen in more detail in FIG. **3**. In this embodiment, a plurality of inclined plates assemblies **160** are illustrated, each inclined plate assembly **160** comprising a plurality of inclined plates **161** each of which are angled downwardly towards the center of the separation chamber **154**. The inclined plate assemblies **160** are secured to the walls of the gravity separation vessel **134** by means of fastening bars **162**.

[0029] The feedwell **152** further comprises a plurality of smaller pipes **153** and each pipe **153** has a feed distributor **170** so that the slurry feed is directed towards the center portion of the plurality of inclined plate assemblies **160** and can be substantially evenly distributed to each inclined plate **161** of each inclined plate assembly **160** for more effective use of surfaces. Thus, the inclined plate assemblies **160** are arranged so that when the diluted slurry is introduced into the separation chamber **154**, the solids in the slurry will contact the individual inclined plates **161** inside the inclined plate assemblies For this and other subsequent inclined plate assemblies where there can be significant surface settling area not being occupied by the assemblies, it may be advantageous, but not essential, to feed a portion of the diluted slurry to the gravity separation vessel **134** while the rest of the diluted slurry is fed to the inclined plate assemblies **160**. This added optional feed arrangement will make use of all available settling areas and at the same time help in reducing the flux to the inclined plate assemblies for further improvement in overall performance.

[0030] FIG. **3** shows the inclined plate assembly **160** of FIG. **2** having a plurality of individual inclined plates **161**, each plate **161** being at an angle of about 55° and substantially, but not necessarily, parallel to one another. Slurry is continuously fed at about 0.3 m/sec towards the center **162** of the inclined plate assembly **160**. The fine sand present in the slurry having a particle size of about 100 μm to about 200 μm (together with the larger sand particles) will be directed downwardly by the interfering surfaces of the inclined plates **161**, thereby allowing the fine sand to more rapidly move to the lower zone **158** of the separation zone **154**. In turn, due to the rapid reduction in solids (including the fine sand) in this area, this gives the more slow floating bitumen droplets more of an opportunity to move upward, to coalesce and float to the upper zone **156**. Furthermore, the silts, generally having an average particle size of about 44 μm to about 100 μm and which have a certain tendency to move upwardly, will instead contact the interfering surfaces of the inclined plates **161** and thereby may also be directed downwardly towards the lower zone **158**. Thus, the bitumen droplets will be encouraged to coalesce between the plates **161** in a relatively free floating bitumen recovery zone. Another key advantage of the inclined plate assembly is that the assembly can be design to significantly reduce the Reynolds numbers (in some cases, from turbulent to laminar regime) which further enhance the bitumen—solids separation.

[0031] Hence, a froth layer results which contains a more significant portion of bitumen and lesser portions of water and solids, even when poor ore is used. The tailings layer which collects at the bottom of the gravity separation vessel will now contain a majority of sand and silt. The bitumen froth layer in the gravity separation vessel **134** can be recovered and routed for further treatment, such as de-aeration, addition of a diluent (such as naphtha or paraffin) to form diluted bitumen, etc., so that the recovered bitumen can be further upgraded to a petroleum product. The tailings layer containing sand and other solids that have settled out of the liquid in the gravity separation vessel can be removed as a tailings stream, such as through bottom outlet **159**. The tailings stream can either be discarded or further treated to remove additional bitumen that may still be present in the tailings stream.

[0032] FIG. **4** shows another embodiment of a gravity separation vessel **434** of the present invention. In this embodiment, separation vessel **434** has a separation chamber (separation zone) **454**, having a generally cylindrical upper portion (upper zone) **456** and a generally conical bottom portion (lower zone) **458**. The upper zone **456** can have an open top and a feedwell **452** provided in the upper portion through which the diluted slurry enters the gravity separation vessel **434** via a tangential pipe **450** at the upper zone **456** of the separation chamber **454**.

[0033] The separation chamber or separation zone **454** further comprises at least one inclined plate assembly **460**, which inclined plate assembly **460** is arranged in a cone configuration. In this embodiment, a plurality of cone-shaped inclined plates **461** are illustrated, each plate being larger than the next plate to give a "nested cone" overall configuration to the inclined plate assembly **160**. Once again, each assembly **460** comprising a plurality of inclined plates **461**, each of which is angled downwardly towards the center of the separation chamber. The inclined plate assembly **460** is secured to the walls of the gravity separation vessel **434** by means of fastening bars **462**.

[0034] In the "nested cone" embodiment, the feedwell **452** further comprises a plurality of smaller pipes **453** and each pipe **453** has a feed distributor **470** so that the slurry feed is directed towards the center portion of the plurality of inclined plates **461** of inclined plate assembly **460**. Thus, the inclined plate assembly **460** is arranged so that when the diluted slurry is introduced into the separation chamber **454**, the solids in the slurry will contact the individual inclined plates **461** which make up the inclined plate assembly.

[0035] FIG. **5** shows another embodiment of a gravity separation vessel **534** of the present invention. In this embodiment, separation vessel **534** has a separation chamber (separation zone) **554**, having a generally cylindrical upper portion (upper zone) **556** and a generally conical bottom portion (lower zone) **558**. The upper zone **556** can have an open top and a feedwell **552** provided in the upper portion through which the diluted slurry enters the gravity separation vessel **534** via a tangential pipe **550** at the upper zone **556** of the separation chamber **554**.

[0036] The separation chamber or separation zone **554** further comprises at least one inclined plate assembly **560**, which inclined plate assembly **560** comprising a plurality of inclined plates **561**, each of which is angled downwardly towards the center of the separation chamber. The inclined plate assemblies **560** are secured to the walls of the gravity separation vessel **534** by means of fastening bars **562**.

[0037] In this embodiment, the feedwell **552** further comprises a deflector plate **555** so that the slurry feed is deflected towards the center portion of the plurality of inclined plate assemblies **560**. Thus, the inclined plate assemblies **560** are arranged so that when the diluted slurry is introduced into the separation chamber **554**, the solids in the slurry will contact the individual inclined plates inside the inclined plate assemblies. FIG. **5** incorporates more inclined plate assemblies inside the separation chamber than that shown in FIG. **2**.

[0038] FIG. **6** shows another embodiment of a gravity separation vessel **634** of the present invention. In this embodiment, separation vessel **634** has a separation chamber (separation zone) **654**, having a generally cylindrical upper portion (upper zone) **656** and a generally conical bottom portion (lower zone) **658**. In this illustration, the bottom of cone **658** has a tailings outlet **660**. The upper zone **656** can have an open top and a feedwell **652** provided in the upper portion through which the diluted slurry enters the gravity separation vessel **634** via a tangential pipe **650** at the upper zone **656** of the separation chamber **654**.

[0039] The separation chamber or separation zone **654** further comprises at least one inclined plate assembly **660**, which inclined plate assembly **660** is in a circular configuration. In this embodiment, inclined plates assembly **660** comprises a plurality of inclined plates **661**, each of which is angled downwardly and to one side so as to form an essentially circular inclined plate assembly **660**. The inclined plate assembly **660** is secured to the walls of the gravity separation vessel **634** by means of fastening bars **662**.

[0040] In this embodiment, the bottom portion of feedwell **652**, while concealed may be similar to the feedwell as shown in FIG. **5** so that the slurry feed is directed towards the center portion of the inclined plate assembly **660**. Thus, the inclined plate assembly **660** is arranged so that when the diluted slurry is introduced into the separation chamber **654**, the solids in the slurry will contact the individual inclined plates **661** inside the inclined plate assemblies.

EXAMPLE 1

[0041] A set of tests were conducted using an oil sand ore comprising 8.7 wt % bitumen and 28 wt % in fines solids with three different types of inclined plate assemblies (Types A, B & C) in a separation vessel to test each assemblies effect on overall extraction performance. Their test performances are compared to that of the base case performances, where the separation vessel was operated without any inclined plate assembly. The oil sand ore used is generally considered to be a "poor" ore sample, due to the relatively low amount of bitumen and relatively high amount of fines (<44 μn). The test results are summarized in Table 1 below.

TABLE 1

Inclined Plate Assembly	None	A	B	None	A	C
Oil Sand Grade, % Bitumen	8.7	8.7	8.7	8.7	8.7	8.7
Oil Sand Fines, >44 um	~28	~28	~28	~28	~28	~28
NaOH to Oil Sand, wt %	0.010	0.010	0.010	0.010	0.010	0.010
Target Flooded Slurry Density, g/cc	1.45	1.45	1.45	1.45	1.45	1.45
Rejects Free Overall Recover, %	13.3	38.9	83.1	37.0	55.5	70.1
PSV Froth % Bitumen	56.1	60.4	36.7	42.5	42.7	44.2
PSV Froth % Solids	17.1	17.9	18.6	22.4	21.7	20.4

The results in Table 1 clearly show a significant improvement in overall extraction recoveries when inclined plate assemblies (Types A, B or C) were introduced inside the separation vessel, as compared to the two base cases that were operated without any assembly at both 0.010 wt % and 0.033 wt % of NaOH additions. Without being bound to theory, it is believed that the use of inclined plate assemblies increased the solids settling area, reduced travel distance for bitumen and solids particles for better separation, and reduced turbulence, some or all of which may improve the separation performance of the separation vessel.

[0042] It is expected that even greater performance improvement may be achievable for a commercial scale primary separation vessel (PSV), as there will likely be more room and length available to design a more effective assembly of plates inside the PSV. In one embodiment, the commercial vessel may also incorporate a flow split control that optimizes overflow relative to underflow to maximize bitumen to solids separation. By way of example, and not intending to be limited, one may reduce the underflow discharge area relative to the overflow flow area. Furthermore, the one or more inclined plate assemblies can be arranged to ensure minimum turbulence flow inside the inclined plate assemblies.

[0043] From the foregoing description, one skilled in the art can easily ascertain the essential characteristics of this invention, and without departing from the spirit and scope thereof, can make various changes and modifications of the invention to adapt it to various usages and conditions. Thus, the present invention is not intended to be limited to the embodiments shown herein, but is to be accorded the full scope consistent with the claims, wherein reference to an element in the singular, such as by use of the article "a" or "an" is not intended to mean "one and only one" unless specifically so stated, but rather "one or more". All structural and functional equivalents to the elements of the various embodiments described throughout the disclosure that are known or later come to be known to those of ordinary skill in the art are intended to be encompassed by the elements of the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims.

We claim:

1. A process for separating solids and bitumen present in an oil sand slurry, comprising:
- (a) introducing the oil sand slurry into a separation zone comprising an upper zone and a lower zone;
- (b) intercepting a settling path of the solids in the separation zone by bringing the solids into contact with at least one intercepting surface to direct the solids to the lower zone; and
- (c) producing a reduced solids upper zone to allow the bitumen to rise through the upper zone with reduced hindrance from the solids.

2. The process as claimed in claim **1**, whereby the separation zone is present in a bitumen separation vessel and the at least one intercepting surface is at least one inclined plate.

3. The process as claimed in claim **2**, further comprising at least two inclined plates which form an inclined plate assembly.

4. The process as claimed in claim **1**, wherein the oil sand slurry is introduced into the separation zone so that the solids contact the at least one intercepting surface at or near the center of the at least one intercepting surface.

5. The process as claimed in claim **3**, wherein the at least two inclined plates are substantially parallel to each other.

6. The process as claimed in claim **3**, wherein the at least two inclined plates are angled downwardly and to one side.

7. The process as claimed in claim **3**, wherein the at least two inclined plates are angled downwardly and towards the center of the separation zone.

8. An apparatus for separating from an oil sand slurry solids and bitumen, comprising:
- (a) a vessel having a separation zone, the separation zone further comprising an upper zone and a lower zone;
- (b) a feed well for feeding the oil sand slurry into the separation zone; and
- (c) at least one separation element having an intercepting surface positioned in the separation zone in a vertically downward orientation;

whereby the solids present in the oil sand slurry are caused by gravity to settle along the at least one separation element to the lower zone and the bitumen is caused by a decrease in specific gravity due to the settling of the solids to flow upwardly to the upper zone.

9. The apparatus as claimed in claim **8**, wherein the at least one separation element is at least one inclined plate.

10. The apparatus as claimed in claim **9**, further comprising at least two inclined plates which form an inclined plate assembly.

11. The apparatus as claimed in claim **10**, wherein the at least two inclined plates are substantially parallel to one another.

12. The process as claimed in claim **10**, wherein the at least two inclined plates are angled downwardly and to one side.

13. The process as claimed in claim **10**, wherein the at least two inclined plates are angled downwardly and towards the center of the separation zone.

14. A process for extracting bitumen from problem oil sand ores having low bitumen content and/or high fines content, comprising:
- (a) mixing the problem oil sand ore with heated water to produce an oil sand slurry;
- (b) conditioning the oil sand slurry for a period of time sufficient to substantially disperse oil sand lumps and promote the release and coalescence of bitumen flecks from the sand grains;
- (c) introducing the conditioned oil sand slurry into a separation zone comprising an upper zone and a lower zone;
- (d) intercepting a settling path of the solids in the separation zone by bringing the solids into contact with at least one intercepting surface to direct the solids to the lower zone; and
- (e) producing a reduced solids upper zone to allow the bitumen to rise through the upper zone with reduced hindrance from the solids.

15. The process as claimed in claim **14**, whereby the separation zone is present in a bitumen separation vessel and the at least one intercepting surface is at least one inclined plate.

16. The process as claimed in claim **15**, further comprising at least two inclined plates which form an inclined plate assembly.

17. The process as claimed in claim **14**, wherein the oil sand slurry is introduced into the separation zone so that the solids contact the at least one intercepting surface at or near the center of the at least one intercepting surface.

18. The process as claimed in claim **16**, wherein the at least two inclined plates are substantially parallel to each other.

19. The process as claimed in claim **16**, wherein the at least two inclined plates are angled downwardly and to one side.

20. The process as claimed in claim **16**, wherein the at least two inclined plates are angled downwardly and towards the center of the separation zone.

* * * * *