A process line for use in an oil sands ore body mining operation is provided, which comprises: a semi-mobile crushing station for receiving as-mined oil sand ore and comminuting the oil sand ore to a size; a semi-mobile compact slurry preparation unit for receiving the comminuted oil sand ore and mixing the oil sand ore with water to form an oil sand slurry; and a semi-mobile solids removal assembly for removing a portion of the coarse solids from the oil sand slurry prior to extracting from the slurry an enriched bitumen froth.
MINING AND PROCESSING SYSTEM FOR OIL SAND ORE BODIES

FIELD OF THE INVENTION

[0001] The present invention relates to mining technology and a process line for increasing the efficiency of an ore mining operation.

BACKGROUND OF THE INVENTION

[0002] Oil sand ore, such as is mined in the Fort McMurray region of Alberta, generally comprises water-wet sand grains held together by a matrix of viscous bitumen. Typically, a “low grade” oil sand ore will contain between about 6 to 10 wt.% bitumen with about 25 to 35 wt. % fines. An “average grade” oil sand ore will typically contain at least 10 wt. % bitumen to about 12.5 wt. % bitumen with about 15 to 25 wt. % fines and a “high grade” oil sand ore will typically contain greater than 12.5 wt. % bitumen with less than 15 wt. % fines. “Fines” are generally defined as those solids having a size less about 44 μm.

[0003] Oil sand lends itself to liberation of the sand grains from the bitumen, preferably by slurrying the oil sand with heated water, allowing the bitumen to move to the aqueous phase. For many years, the bitumen in the McMurray sand has been commercially removed from oil sand using what is commonly referred to in the industry as the “hot water process”. In general terms, the hot water process involves drying mining the oil sand at a mine site that can be kilometers from an extraction plant; transporting the as-mined oil sand in large ore trucks to a primary crushing plant; conveying the crushed ore to a slurry preparation plant where the oil sand is mixed with hot water, caustic (e.g., sodium hydroxide) and naturally entrained air to yield an oil sand slurry; “conditioning” the oil sand slurry (for example, in a hydrotransport pipeline) so that lumps of oil sand are ablated or disintegrated, the released sand grains and separated bitumen flecks are dispersed in the water where the bitumen flecks coalesce and grow in size, and the bitumen flecks may contact air bubbles and coat them to become aerated bitumen; and removing the bitumen froth from the slurry in an extraction plant comprising one or more separators (for example, a primary separation vessel or PSV).

[0004] Currently, all of the applicant’s primary crushing plants are located at grade, adjacent to the mine pits, so that all ore must be trucked out of the pit and up an additional ~20 m ramp in order to dump the ore into the primary crusher hopper. This average haul distance is currently 4-5 km and future ore bodies would require truck hauls of 10-20 km to existing primary crusher locations. Once the ore is crushed, the crushed ore is conveyed from the discharge of the primary crusher to a surge pile, which is then fed to the slurry preparation plant. At present, the applicant operates both semi-mobile and fixed location slurry preparation plants. Even though the applicant’s primary crushers are semi-mobile, in order to relocate the semi-mobile crushers, a ~20 m tall Mechanically Stabilized Earth (MSE) wall needs to be constructed, which takes 12-18 months and costs a great deal of money. Thus, due to the time and expense, it is impractical to relocate the primary crushers to keep them close to the mining face.

[0005] The applicant currently operates its hydrotransport systems (pipelines) at 45-50 °C. and 100-125 mm nominal ore top size. For these systems, around 10 minutes is the minimum residence time in the pipeline to achieve sufficient oil sand conditioning in order to get acceptable primary bitumen recovery in the PSV. Thus, the equivalent minimum hydrotransport pipeline length is about 3 km, however, can be longer, for example, 4.5 km, which is equivalent to 18-20 minutes residence time. Optionally, oversize material (>50 mm) may be screened prior to the extraction plant, but other than this, all coarse solids are sent through the PSV and then must travel through coarse tailings systems to the tailings deposition areas. Oil sand is about 85% solids, which can be considered waste, and about 70% of the solids could be considered “coarse” (i.e., >44 μm). The average total travel distance for this coarse waste material is currently 15-20 km. Hence, both front-end truck haul and back-end tailings pumping distances will increase as operations move to more remote ore bodies throughout the next 8-50 years.

[0006] Operating costs for these semi-remote mineable oil sand ore bodies will increase significantly from today’s costs, due to long truck hauls and long-distance waste hydrotransport. “Semi-remote” is defined herein as an ore body having a centroid more than 6-8 km from an existing extraction plant. Thus, there is a need for improved equipment layouts in order to deal with these semi-remote sites and minimize truck haul distances and minimize waste handling. Although the equipment layouts described herein are described in relation to oil sand ore bodies, it is understood that these equipment layouts could offer benefits in almost any scenario.

SUMMARY OF THE INVENTION

[0007] In one aspect, a process line is provided comprising a combination of three semi-mobile technologies that will minimize truck haul distances and minimize waste handling (e.g., coarse tailings disposal). In one embodiment, the process line comprises: a semi-mobile crushing station for receiving as-mined oil sand ore and comminuting the oil sand ore to a first size; a semi-mobile compact slurry preparation unit for receiving the comminuted oil sand ore and mixing the oil sand ore with water to form an oil sand slurry; and a semi-mobile solids removal assembly for removing a portion of the coarse solids from the oil sand slurry prior to extracting from the slurry an enriched bitumen froth.

[0008] In one embodiment, the semi-mobile solids removal assembly comprises a semi-mobile desanding assembly. In one embodiment, the semi-mobile solids removal assembly comprises a semi-mobile screening assembly. In one embodiment, the semi-mobile solids removal assembly comprises a semi-mobile screening assembly and a semi-mobile desanding assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] 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 following figures. It is understood that the drawings provided herein are for illustration purposes only and are not necessarily drawn to scale.

[0010] FIG. 1 is a schematic depiction of one embodiment of the process line of the present invention.

[0011] FIG. 2 is a schematic depiction of another embodiment of the process line of the present invention.
DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0012] The detailed description set forth below in connection with the appended drawings 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.

[0013] As used herein, “semi-mobile” equipment refers to equipment that is designed to be relatively easy to relocate (i.e., relocatable) but which generally does not move on a regular hourly or daily basis as mobile shovels and trucks do.

[0014] FIG. 1 illustrates one embodiment of the present process line. In this embodiment, the mine face 2 is a mine face in a mineable oil sand mine or pit. A mining shovel 3 is used to excavate the oil sand ore at the mine face 2 and it is operative to advance along the mine face 2 and deposit the as-mined oil sand ore into mobile trucks 4. The mobile trucks 4 deliver the as-mined oil sand ore to a semi-mobile crushing station 5. In the embodiment shown in FIG. 1, the semi-mobile crushing station 5 for receiving as-mined oil sand ore and comminuting the oil sand ore to a first size is a dual truck mobile sizer (DTMS) such as described in Canadian Patent No. 2,737,492. As used in the present invention, the DTMS is considered to be semi-mobile, as it is anticipated that the DTMS will only have to be relocated every year or so. It is understood, however, that other moveable crushing units known in the art can also be used in the present invention.

[0015] In the embodiment shown in FIG. 1, the DTMS generally comprises an integral rock crusher and discharge conveyor that is movable under its own power and may receive and comminute excavated/mined oil sand ore from two earth moving vehicles, in particular dump trucks, at the same time. In one embodiment, the DTMS comprises two spaced apart pivoting truck skips having hinged floors for receiving/feeding the mined ore to a sizer having two parallel oppositely rotatable rock crushing drums. The comminuted ore is then discharged onto a discharge conveyor. Because the DTMS is relocatable by using crawlers and the like, it can follow the ore body that is being mined so that there will only need to be short track hauls (e.g., 1-3 km). The DTMS serves as a Mobile Truck Conveyor Interface or MTICI. Thus, DTMS is deployed to enable perpetual short-haul.

[0016] A short conveyor 8 receives the comminuted oil sand ore from the discharge conveyor of the DTMS and delivers the comminuted oil sand ore to a semi-mobile compact slurry preparation (CSP) unit 6. In this embodiment, the semi-mobile compact slurry preparation unit 6 is a wet crushing unit as described in Canadian Patent No. 2,480,122. Semi-mobile compact slurry preparation unit 6 generally comprises a surge pile 10, apron feeders 12 or 13, ore sizing equipment 14 and slurry pumps 25, and can be moved by means of tracks 27, so that the entire unit may periodically be advanced to a new location. It is understood, however, that any semi-mobile, relocatable slurry preparation unit or assembly can be used. Thus, the feed wetting point step, or oil sand slurry preparation step, can be moved as close as possible to mine face 2, i.e., in-pit or near-pit crest.

[0017] Oil sand slurry prepared in the semi-mobile compact slurry preparation unit 6 can then be transported and conditioned in hydrotransport pipeline 28. Hydrotransport pipeline 28 is generally around 3-4.5 km in length, its length being sufficient to ensure proper conditioning of the oil sand slurry. Thus, hydrotransport pipeline 28 receives oil sand slurry from semi-mobile compact slurry preparation unit 6, transports the slurry while simultaneously conditioning it, and delivers the conditioned slurry to a semi-mobile solids removal assembly. In this embodiment, the semi-mobile solids removal assembly 29 for removing a portion of the coarse solids and sand therefrom. In one embodiment, semi-mobile desanding assembly 29 comprises a near pit desander (NPD), or separator, as described in Canadian Patent Application No. 2,809,959. In this embodiment, NPD is movable by means of tracks 27. It is understood, however, that other moveable desanders or desanding circuits can be used.

[0018] The semi-mobile desanding assembly 29 produces a relatively clean (i.e., relatively free from bitumen) coarse solids underflow 31, which only needs to be transported a short distance to sand storage 32. The reduced solids upper zone or overflow 30 comprises bitumen, fines and water and is amenable to long distance transport through a pipeline to a bitumen extraction plant for polishing/water reheat and return. It was discovered that desanded oil sand slurry could be pumped long distances, has a lower power constraint and produces low wear on downstream equipment.

[0019] The inherent operating cost of haul trucks is over three times that of conveying or hydrotransport, due to differences in many factors such as energy efficiency, maintenance requirements and workforce. However, trucks provide a mobile, flexible front end to the mining process, so it is not likely optimal to eliminate them entirely. One key advantage provided by trucks is the ability to seamlessly deal with interburden in the ore body and ore blending for recovery, simply by dispatching the trucks appropriately. Second, a short front-end haul serves to minimize the number of relocations required for the crushing and slurry preparation plants, which may weigh several thousand tonnes—without trucks, this weight would need to be moved continuously, to follow the shovels.

[0020] The DTMS system, which was developed by FLSmidth™, is well-suited to minimizing oil sand hauling distances. The average haul distance could be reduced, for example, to about 2 km or less and multiple DTMS systems may be deployed in an oil sand mine. The DTMS is a semi-mobile truck/conveyor interface, which includes primary crushing to allow for reliable conveyor operation. One of the advantages of DTMS is that it eliminates the need for an MSE wall because it uses hydraulics to lift the ore into the crusher hopper, rather than an earthworks ramp and the track engines.

[0021] To remain close to the active mine faces, it is contemplated that one would be able to relocate the DTMS system and extend the take-away conveyor network within a two-week window, and this could be conducted on an annual basis. On the other hand, it is contemplated that the semi-mobile compact slurry preparation unit and the semi-mobile desanding assembly would be more costly and complex moves and may stay in one location for a longer period.

[0022] The lowest operating cost for the present process line is achieved when the hydrotransport process is started as soon as possible. Once the optimal hydrotransport distance/residence time is reached, there is negative value in moving the coarse solids any further. Thus, a desander may be implemented to reduce the solid content of the oil sand slurry prior to bitumen extraction. In one embodiment, a desander similar
to a Primary Separation Vessel (PSV) can be used. In one embodiment, using an 8000 m² vessel, up to 90% of the feed solids in the conditioned oil sand slurry from the hydrotransport system can be separated from the bitumen and fines, with about a 3.5% bitumen loss to tailings.

[0023] Operating cost for a slurry pumping system is relative to the mass transported. Thus, by removing 70% to 90% of the solids, the required energy, wear and capital costs all decline significantly. The resulting de-sanded slurry is also much easier to transport over long distances. The desanding vessel would be optimally located near the tailings deposition area, which may be an exhausted mine pit, to minimize the total transport distance of the coarse solids. In addition, by removing much of the sand prior to bitumen extraction, a higher quality and lower solids product would be delivered to extraction facilities. This would result in a higher residence time in separation vessels (such as existing PSVs) due to a reduction of flow rate, as a large fraction of flow has been diverted at the desander. In turn, this would result in bitumen yield uplift, as product quality is improved down the entire process stream.

[0024] FIG. 2 illustrates another embodiment of the present process line. In this embodiment, the mine face 102 is a mine face in a mineable oil sand mine or pit. A mining shovel 103 is used to excavate the oil sand ore at the mine face 102 and it is operative to advance along the mine face 102 and deposit the as-mined oil sand ore into mobile trucks 104. The mobile trucks 104 deliver the as-mined oil sand ore to a semi-mobile crushing station 105. In the embodiment shown in FIG. 2, semi-mobile crushing station 105 for receiving as-mined oil sand ore and comminuting the oil sand ore to a first size is a dual truck mobile sizer (DTMS) such as described in Canadian Patent No. 2,737,492.

[0025] A short conveyor 108 receives the comminuted oil sand ore from the discharge conveyor of the semi-mobile crushing station 105 and delivers the comminuted oil sand ore to a semi-mobile compact slurry preparation (CSP) unit 106. In this embodiment, the semi-mobile compact slurry preparation unit 106 is a wet crushing unit as described in Canadian Patent No. 2,480,122. Oil sand slurry prepared in the semi-mobile compact slurry preparation unit 106 can then be transported and conditioned in hydrotransport pipeline 128. Hydrotransport pipeline 128 is generally around 3-4.5 km in length, its length being sufficient to ensure proper conditioning of the oil sand slurry.

[0026] In this embodiment, the hydrotransport pipeline 128 receives oil sand slurry from semi-mobile compact slurry preparation unit 106, transports the slurry while simultaneously conditioning it, and delivers the conditioned slurry to a semi-mobile solids removal assembly which comprises a screening assembly 140 for removing a portion of the coarse solids, in particular, lumps and rocks, therefrom. Screening assembly 140 comprises a slurry screen for scalping/removal of wear-inducing lumps in the conditioned slurry down to a nominal size (e.g. about 12 to 15 mm and larger is removed). Screening assembly 140 may be relocatable by means of tracks 127. In one embodiment, the screening assembly 140 may be positioned further upstream, i.e., along the hydrotransport pipeline 128, before the oil sand slurry is fully conditioned. There may be instances where it is more desirable to remove the clay lumps and rocks as soon as possible, so there will be an optimal screening assembly location, where oil sand lumps have been ablated just below the screen cut size, for example, 1.5-2.5 km from the start of the hydrotransport pipeline 128.

[0027] In one embodiment, about 10% of solids in the conditioned slurry are removed by use of the screening assembly. Removal of larger rocks and clay lumps may provide one or more of the following benefits: lower wear on downstream equipment; improved (unhindered) settling at sand separation stage; reduce solids (including clay clumps) directed to tailings ponds; and residual value of screenings (lumpy waste) in context of viable construction materials for temporary haul routes. Generally, rocks/lumps above 12 mm cause the majority of pump, pipeline and vessel wear. By removing these lumps, it will allow for cost-effective long-distance pipeline transport to extraction, which is especially important if bitumen extraction equipment such as a primary separation vessel (PSV) is far from the mine. Also, removal of the clay lumps at this stage means less fluid fine tailings (which are primarily clay) are formed in tailings ponds. The lumps 142 (rejects) removed from the conditioned slurry can be transported a short distance to a lump storage facility.

[0028] In one embodiment, the screened slurry 144, which still includes sand, may be directly transported to bitumen extraction facilities. In another embodiment, the semi-mobile solids removal assembly further comprises a semi-mobile desanding assembly 129 for removing a portion of the sand still present in screened slurry 144. The semi-mobile desanding assembly 129 may comprise a near pit desander (NPD), or separator, as described in Canadian Patent Application No. 2,809,959, which is moveable by means of tracks 127. It is understood, however, that other moveable desanders or desanding circuits can be used. In this embodiment, a relatively clean (i.e., relatively free from bitumen) sand underflow 148 is produced which only needs to be transported a short distance to sand storage. The reduced solids upper zone or overflow 146 comprises bitumen, fines and water and is amenable to long distance transport through a pipeline to a bitumen extraction plant for polishing/water reheat and return.

[0029] From the foregoing description, one skilled in the art can easily ascertain the essential characteristics of this invention. However, the scope of the claims should not be limited by the preferred embodiments set forth in the examples, but should be given the broadest interpretation consistent with the description as a whole.

We claim:

1. A process line for use in an oil sand ore body mining operation, comprising:
   a semi-mobile crushing station for receiving as-mined oil sand ore and comminuting the oil sand ore to a first size;
   a semi-mobile compact slurry preparation unit for receiving the comminuted oil sand ore and mixing the oil sand ore with water to form an oil sand slurry; and
   a semi-mobile solids removal assembly for removing a portion of the coarse solids from the oil sand slurry prior to extracting from the slurry an enriched bitumen froth.

2. The process line as claimed in claim 1, wherein the semi-mobile crushing station is relocatable in about two weeks.

3. The process line as claimed in claim 1, wherein the semi-mobile crushing station is relocated about every year.

4. The process line as claimed in claim 1, wherein the semi-mobile crushing station comprises an integral rock crushe
5. The process line as claimed in claim 1, wherein as-mined oil sand ore is delivered to the semi-mobile crushing station by means of mobile trucks.

6. The process line as claimed in claim 1, wherein more than one semi-mobile crushing station is used in an oil sand mine.

7. The process line as claimed in claim 1, wherein the semi-mobile solids removal assembly comprises a semi-mobile desanding assembly.

8. The process line as claimed in claim 1, wherein the semi-mobile solids removal assembly comprises a semi-mobile screening assembly.

9. The process line as claimed in claim 1, wherein the semi-mobile solids removal assembly comprises a semi-mobile screening assembly and a semi-mobile desanding assembly.

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