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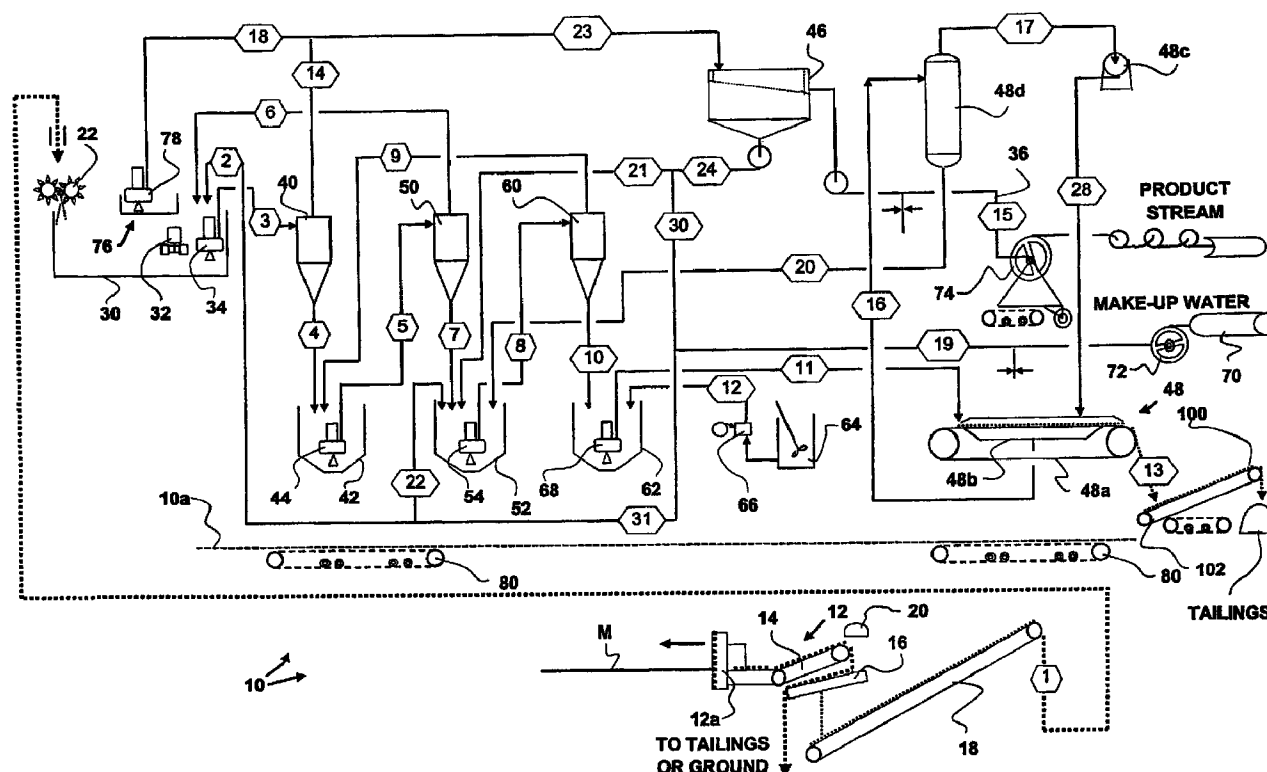
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MATÉRIEL PÉTROLIFÈRE

(54) Title: PROCESS AND APPARATUS FOR RECOVERING AN OIL-ENRICHED PRODUCT FROM AN OIL-BEARING
MATERIAL



(57) Abrégé/Abstract:

Processes and apparatuses for recovering an oil-enriched product from an oil-bearing material such as tar sand ore are disclosed. One such process includes mixing the oil-bearing material with solvent to form a slurry in a slurry feed tank, and pumping the slurry into a hydrocyclone to separate it into an overflow portion and an underflow portion, the overflow portion containing the oil-enriched product. The process further includes vacuum filtering the underflow portion to remove solvent therefrom and produce substantially

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

dewatered tailings, recycling the solvent removed from the underflow portion back into an earlier stage of the process, and adding fresh solvent into the process.

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ABSTRACT

Processes and apparatuses for recovering an oil-enriched product from an oil-bearing material such as tar sand ore are disclosed. One such process includes
10 mixing the oil-bearing material with solvent to form a slurry in a slurry feed tank, and pumping the slurry into a hydrocyclone to separate it into an overflow portion and an underflow portion, the overflow portion containing the oil-enriched product. The process further includes vacuum filtering the underflow portion to remove
15 solvent therefrom and produce substantially dewatered tailings, recycling the solvent removed from the underflow portion back into an earlier stage of the process, and adding fresh solvent into the process.

PROCESS AND APPARATUS FOR RECOVERING AN OIL-ENRICHED PRODUCT FROM AN OIL-BEARING MATERIAL

FIELD OF THE INVENTION

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The present invention relates to processes and apparatuses for recovering an oil-enriched product such as bitumen from an oil-bearing material such as tar sand ore.

10 BACKGROUND

Tar sands are deposits of loose sand or partially consolidated sandstone which are saturated with highly viscous bitumen. Tar sand is a common form of oil-bearing material. It is also sometimes called bituminous sand or oil sand. The world's largest known deposits of tar sands are located in Canada on the banks of the Athabasca River in northeastern Alberta. The Athabasca tar sands are estimated to contain some 300 billion barrels of bitumen heavy oil. Of this total, it is estimated that some 80 billion barrels are accessible for recovery through surface mining methods.

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Oil produced from the bitumen in tar sands is commonly referred to as synthetic crude oil. The only commercial projects for synthetic oil production from tar sands are being carried out in the Athabasca region. A project for a typical 100,000 barrel per day bitumen production facility is currently estimated to cost over one billion dollars to build using conventional technologies. Such a project would also cost over five dollars per barrel to operate and would have significant environmental impacts.

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Conventional technologies presently used for commercial operation of bitumen recovery from tar sand were developed in the mid-1960s and until now, have not changed dramatically. They currently involve surface mining to extract thick tar sand deposits found near the surface. Before the actual mining operations begin,

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the mine area is dewatered and overburden is removed from its surface. Earth moving equipment is used to strip and stockpile the overburden, and then remove and dispose of it. At the same time, construction of tailings pond starter dikes is undertaken using appropriate stripped overburden. Excavation was traditionally achieved using a bucketwheel or drag line excavation method. More recently, large shovels and trucks are used. Heavy truck haul roads for the transport of overburden and tar sand ore are constructed, often employing scarce granular resources. The mining of tar sand ore can begin afterwards. After mining, the tar sand ore is hauled to a preparation facility where it is crushed and mixed with water to form a slurry. The slurry is then pumped through pipelines to a processing plant.

Generally, a conventional processing plant removes bitumen from the slurry using a bitumen flotation method. Such a method involves using hot water for slurring. Bitumen froth is floated by way of thickener-type vessels and air-induced flotation cells. The bitumen froth contains a concentrated amount of bitumen. This oil-enriched product is sent to another plant where it will be upgraded to synthetic crude oil.

Since the bitumen is typically only about 7 to 12% of the total ore mass removed from the mine face, tailings are produced and are transported in massive quantities throughout the process. In conventional recovery operations, these tailings are ultimately transported out of the processing plant by hydro-transport methods and disposed in immense tailing ponds, where the fine suspended solids are allowed to settle by gravity. Over the ensuing years, fine particles in the water settle to a point where water can be removed and the solids sludge from the tailing ponds can be rehandled and mixed with coarse tailings in the manufacture of consolidated tailings. It is only then that tailing ponds can be remediated and eventually reforested. Meanwhile, tailing pond dikes need to be continuously constructed since the process generates these dilute waste products faster than the settling rate in the tailings ponds.

Conventional recovery technologies thus have many drawbacks. One of the major ones is that they require transport of massive quantities of materials such as tailings, tar sand ore and water over very long distances. Tailings ponds also have a major impact on the environment and are a concern to governments and the public.

Operating a conventional recovery process is very costly because of all the required transport equipment, support facilities, apparatuses, personnel and energy required to undertake all of the tasks. As a result, the recovery of bitumen from tar sand ore is a risky venture because profits can be easily offset by the very large fixed and variable operating costs. Projects are viable only when the price of crude oil is relatively high.

Overall, conventional technologies for mining and exploiting deposits of oil-bearing materials are limited in their applicability, environmental acceptability, cost and therefore, in their overall efficacy.

SUMMARY

In accordance with an illustrative embodiment of the invention, there is provided a process for recovering an oil-enriched product such as bitumen from an oil-bearing material such as tar sand ore. The process includes mixing the oil-bearing material with a solvent to form a slurry in a slurry feed tank, and pumping the slurry into a hydrocyclone to separate it into an overflow portion and an underflow portion, the overflow portion containing the oil-enriched product. The process further includes vacuum filtering the underflow portion to remove solvent therefrom and produce substantially dewatered tailings, recycling the solvent removed from the underflow portion back into an earlier stage of the process, and adding fresh solvent into the process.

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The solvent may be at least equal in weight with the oil-bearing material.

The process may further include conveying the tailings out for deposition in an adjacent area.

The fresh solvent may be fed into the slurry feed tank.

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In some embodiments, the process may be carried out using a mobile facility. In such an embodiment, the process may further include mining the oil-bearing material from a mine face using at least one mining head, screening the oil-bearing material to remove oversized ore lumps, feeding the oil-bearing material
10 into a crusher, conveying the tailings out of the mobile facility for deposition in an adjacent area, and repositioning the mobile facility as the mining head advances. In mixing the oil-bearing material with the solvent to form the slurry, the solvent may be in at least equal weight with the oil-bearing material, and adding fresh solvent may include adding the fresh solvent into the slurry feed tank.

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The process may further include removing some solvent from the overflow portion to obtain a further concentrated oil-enriched product, and recycling the removed solvent back into the slurry feed tank. Removing solvent from the overflow portion may include decanting.

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The solvent may include water and the slurry in the slurry feed tank may have a temperature substantially ranging from 80 to 160 degrees Fahrenheit. Heat may be supplied in the process using the fresh solvent.

25 The process may further include adding flocculant to the underflow portion before vacuum filtering the underflow portion.

The process may further include skimming a froth formed on the slurry and adding the froth to the overflow portion before the solvent is removed therefrom.

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In embodiments in which the process includes mining the oil-bearing material, the oil-bearing material may be mined using rotating cutters.

At least some oversize ore lumps may be fed into a crusher to reduce their size to under a maximum limit required for slurring, and the crushed materials may thereafter be brought into the slurry feed tank.

- 5 At least some oversize ore lumps may be diverted to the tailings. Oversize ore lumps may be dumped onto the ground when not suitable for processing. The oil-bearing material may be diverted to the tailings when not suitable for processing.

The oil-bearing material may include tar sand.

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- Mixing may include agitating the solvent and the oil-bearing material to form a primary slurry, and pumping may include pumping the primary slurry into a first hydrocyclone to separate it into a first overflow portion and a first underflow portion. The process may further include pumping the first underflow portion into a second hydrocyclone to separate it into a second overflow portion and a second underflow portion, and pumping the second overflow portion into the slurry feed tank. Vacuum filtering may include vacuum filtering the underflow portion of a last of the hydrocyclones to remove solvent therefrom and produce substantially dewatered tailings. The process may further include conveying the tailings for deposition in an adjacent area, and recycling may include recycling the solvent removed from the underflow portion of the last of the hydrocyclones into the earlier stage of the process.
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The solvent may be at least equal in weight with the oil-bearing material.

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- In embodiments in which the process may be carried out using a mobile facility, the process may further include mining the oil-bearing material from a mine face using at least one mining head, and repositioning the mobile facility as the mining head advances. Conveying may include conveying the tailings out of the mobile facility for deposition in the adjacent area.
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The process may further include removing some solvent from the first overflow portion to obtain a further concentrated oil-enriched product, and recycling the solvent removed from the first overflow portion into the process. Removing solvent from the first overflow portion may include decanting.

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In embodiments that employ a mobile facility, at least a portion of the solvent may be separated from the oil-enriched product in a remote processing plant, heated therein and then recycled back into the process.

- 10 The solvent may include water, and the slurry in the slurry feed tank may have a temperature substantially ranging from 80 to 160 degrees Fahrenheit. At least a portion of the heat may be supplied in the process using the fresh solvent.

- 15 The process may further include adding flocculant to the underflow portion of the last hydrocyclone before vacuum filtering the underflow portion.

The process may further include skimming a froth formed on the primary slurry and adding the froth to the first overflow portion.

- 20 The process may further include pumping the second underflow portion into a third hydrocyclone to separate it into a third overflow portion and a third underflow portion, and adding the third overflow portion to the first underflow portion. The process may further include pumping the third underflow portion into a fourth hydrocyclone to separate it into a fourth overflow portion and a fourth underflow
25 portion, and adding the fourth overflow portion to the second underflow portion.

In embodiments that include mining, the oil-bearing material may be mined using rotating cutters.

- 30 The process may further include pre-processing the oil-bearing material before mixing it with the solvent to eliminate particles having a size above a maximum limit required for slurring. Pre-processing the oil-bearing material may include

screening it to remove oversize ore lumps. The process may further include feeding at least some of the oversize ore lumps into a crusher to reduce lump size to under the maximum limit required for slurring. The process may further include adding at least some of the oversize ore lumps to the tailings. The process may further include
5 dumping the oversize ore lumps onto the ground when the oversize ore lumps are not suitable for processing. Pre-processing the oil-bearing material may include feeding at least some of it into a crusher before mixing it with the solvent. The process may further include diverting the oil-bearing material to the tailings when not suitable for processing.

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The oil-bearing material may include tar sand.

In accordance with another illustrative embodiment of the invention, there is provided a mobile facility for mining an oil-bearing material and recovering an oil-enriched
15 product therefrom. The facility includes a supporting platform on which are mounted: (a) at least one mining head; (b) a crusher into which at least some of the mined oil-bearing material is fed; (c) an inlet conveyor to carry the mined oil-bearing material from the mining head to the crusher; (d) a slurry feed tank below the crusher in which the mined oil-bearing material is received from the crusher and is mixed with a
20 solvent to form a slurry; (e) a mixer located in the slurry feed tank; (f) a hydrocyclone having an inlet in fluid communication with the slurry feed tank, the hydrocyclone including an overflow outlet and an underflow outlet; (g) a vacuum filter having an inlet in fluid communication with the underflow outlet of the hydrocyclone, the vacuum filter further having a first outlet that outputs substantially dewatered tailings,
25 and a second outlet that outputs substantially solvent and air; (h) an air/liquid separator having an inlet in fluid communication with the second outlet of the vacuum filter, the separator further having a first outlet that outputs substantially solvent to be recycled in the facility, and a second outlet that outputs substantially air; (i) a tailings conveyor to carry the tailings from the first outlet of the vacuum filter
30 out of the mobile facility for deposition in an adjacent area; (j) a fresh solvent supply in fluid communication with the slurry feed tank; and (k) a ground-engaging

undercarriage located under the platform to support the mobile facility and reposition it as the mining head advances.

In accordance with another illustrative embodiment of the invention, there is provided
5 a mobile facility for mining an oil-bearing material and recovering an oil-enriched product therefrom. The facility includes a supporting platform on which are mounted:
(a) at least one mining head; (b) a slurry feed tank in which the oil-bearing material is mixed with a solvent to form a slurry; (c) a first conveyor to carry the oil-bearing material from the mining head; (d) a second conveyor which transports the oil-
10 bearing material from a discharge end of the first conveyor into the slurry feed tank; (e) a mixer located in the slurry feed tank; (f) a first hydrocyclone having an inlet in fluid communication with the slurry feed tank, the first hydrocyclone including an overflow outlet and an underflow outlet; (g) a second hydrocyclone having an inlet in fluid communication with the underflow outlet of the first hydrocyclone, the second
15 hydrocyclone including an overflow outlet and an underflow outlet, the overflow outlet of the second hydrocyclone being in fluid communication with the slurry feed tank; (h) a vacuum filter having an inlet in fluid communication with the underflow outlet of a last of the hydrocyclones, the vacuum filter further having a first outlet that outputs substantially dewatered tailings, and a second outlet that outputs substantially
20 solvent and air; (i) an air/liquid separator having an inlet in fluid communication with the second outlet of the vacuum filter, the separator further having a first outlet that outputs substantially solvent to be recycled in the facility, and a second outlet that outputs substantially air; (j) a tailings conveyor to carry the tailings from the first outlet of the vacuum filter out of the mobile facility for deposition in an adjacent area;
25 (k) a fresh solvent supply being at least partially in fluid communication with the slurry feed tank; and (l) a ground-engaging undercarriage to support the mobile facility and reposition it as the mining head advances.

In accordance with another illustrative embodiment of the invention, there is provided
30 an apparatus for recovering an oil-enriched product from an oil-bearing material. The apparatus includes (a) a slurry feed tank in which the oil-bearing

material is mixed with a solvent to form a slurry; (b) a hydrocyclone having an inlet in fluid communication with the slurry feed tank, the hydrocyclone including an overflow outlet and an underflow outlet; (c) a vacuum filter having an inlet in fluid communication with the underflow outlet of the hydrocyclone, the vacuum filter
5 further having a first outlet that outputs substantially dewatered tailings, and a second outlet that outputs substantially solvent and air; and (d) an air/liquid separator having an inlet in fluid communication with the second outlet of the vacuum filter, the separator further having a first outlet that outputs substantially solvent to be recycled, and a second outlet that outputs substantially air.

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In accordance with another illustrative embodiment of the invention, there is provided an apparatus for recovering an oil-enriched product from an oil-bearing material. The apparatus includes a supporting platform on which are mounted: (a) an oil-bearing material inlet; (b) a slurry feed tank in which the oil-bearing material is mixed
15 with a solvent to form a slurry; (c) a first conveyor to carry the oil-bearing material from the oil-bearing material inlet; (d) a second conveyor which transports the oil-bearing material from a discharge end of the first conveyor into the slurry feed tank; (e) a mixer located in the slurry feed tank; (f) a first hydrocyclone having an inlet in fluid communication with the slurry feed tank, the first hydrocyclone including an
20 overflow outlet and an underflow outlet; (g) a second hydrocyclone having an inlet in fluid communication with the underflow outlet of the first hydrocyclone, the second hydrocyclone including an overflow outlet and an underflow outlet, the overflow outlet of the second hydrocyclone being in fluid communication with the slurry feed tank; (h) a vacuum filter having an inlet in fluid communication with the underflow outlet of
25 a last of the hydrocyclones, the vacuum filter further having a first outlet that outputs substantially dewatered tailings, and a second outlet that outputs substantially the solvent and air; (i) an air/liquid separator having an inlet in fluid communication with the second outlet of the vacuum filter, the separator further having a first outlet that outputs substantially the solvent to be recycled, and a second outlet that outputs
30 substantially air; (j) a tailings conveyor to carry the tailings from the first outlet of the vacuum filter out of the apparatus for deposition in an adjacent area; (k) a

fresh solvent supply being at least partially in fluid communication with the slurry feed tank; and (l) a ground-engaging undercarriage to support the apparatus and reposition it.

- 5 Although such apparatuses need not be embodied in mobile facilities, a number of similar features may be provided in illustrative embodiments of either mobile facilities or of apparatuses as described above (whether mobile or otherwise).

10 For example, the solvent may include water which may be supplied in a heated state so as to provide heat to the slurry in the slurry feed tank. The slurry in the slurry feed tank may have a temperature substantially ranging from 80° to 160° Fahrenheit.

15 The apparatus or the mobile facility may further include a concentrator having an inlet in fluid communication with the overflow outlet of the hydrocyclone, the concentrator further having a first outlet that outputs a further concentrated oil-enriched product, and a second outlet that outputs substantially solvent to be recycled in the facility.

- 20 The apparatus or the mobile facility may further include a flocculant tank having an outlet in fluid communication with the inlet of the vacuum filter.

25 The apparatus or the mobile facility may further include a sump in fluid communication with the underflow outlet of the hydrocyclone and the outlet of the flocculant tank, and a vertical submersible feed pump having an inlet in the sump and an outlet in fluid communication with the inlet of the vacuum filter.

30 The apparatus or the mobile facility may further include a froth skimmer having an outlet in fluid communication with the inlet of the concentrator. The froth skimmer may include a feed pump. The froth skimmer may include an overflow weir. The froth skimmer may further include collection launders and a feed pump.

The apparatus or the mobile facility may further include a by-pass path by which the mined oil-bearing material is diverted to the tailings conveyor when not suitable for processing. Oversize ore lumps may be dumped onto the ground when not suitable for processing. The apparatus or mobile facility may include a
5 by-pass path for such dumping, which may include an exterior outlet. The apparatus or mobile facility may further include a screen to remove oversize ore lumps from the mined oil-bearing material. The apparatus or the mobile facility may further include a by-pass path by which oversize ore lumps are diverted to the tailings conveyor when not suitable for processing.

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The apparatus or the mobile facility may further include a vertical submersible feed pump having an inlet in the slurry feed tank, and an outlet in fluid communication with the inlet of the hydrocyclone.

15 The tailings conveyor may include a bridge-type pipe conveyor.

In mobile facility embodiments, the mining head may include rotating cutters. The undercarriage of the mobile facility may include motorized crawler tracks. Alternatively, the undercarriage may include motorized wheels.

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The oil-bearing material may include tar sand.

The apparatus or the mobile facility may further include a third hydrocyclone having an inlet in fluid communication with the underflow outlet of the second
25 hydrocyclone, the third hydrocyclone comprising an overflow outlet and an underflow outlet, the overflow outlet of the third hydrocyclone being in fluid communication with the inlet of the second hydrocyclone.

The apparatus or the mobile facility may further include a fourth hydrocyclone
30 having an inlet in fluid communication with the underflow outlet of the third hydrocyclone, the fourth hydrocyclone comprising an overflow outlet and an

underflow outlet, the overflow outlet of the fourth hydrocyclone being in fluid communication with the inlet of the third hydrocyclone.

Each hydrocyclone may have a corresponding sump and a corresponding vertical
5 submersible feed pump, the three of which form a subset, each sump being in fluid communication with the underflow outlet of the hydrocyclone of its subset, and each feed pump having an inlet in the sump of its subset and an outlet in fluid communication with the inlet of where the underflow outlet of the hydrocyclone of its subset is connected.

10

Illustrative embodiments of the present invention may provide a mobile facility and a novel process for mining tar sand ore and recovering bitumen therefrom, all of which are significant improvements over the conventional mining and recovery technologies. Illustrative embodiments of the present invention may reduce
15 material handling requirements significantly. Illustrative embodiments may also provide a recovery process where process water is internally recycled, avoiding the requirement for tailings ponds. Illustrative embodiments may also provide a very efficient process which allows the recovery of bitumen from tar sand ore with a lower bitumen content and/or a higher overburden stripping ratio, all of which
20 are much less economically feasible using a conventional recovery process.

One illustrative embodiment involves the use of a mobile facility that is capable of mining oil-bearing materials, processing them, and depositing the resulting tailings in the mined out area in the immediate vicinity, thereby dramatically reducing the
25 material handling undertaking. The advantages of such a mobile facility and the corresponding process over conventional recovery technologies are major.

Advantages of illustrative embodiments may include one or more of the following:

- 30
- much higher energy efficiency and consequent lower carbon dioxide generation;
 - much smaller disturbed land footprint;

- no tailings ponds with their need for eventual remediation;
- possible land reclamation and reforestation in the short term;
- no ore sterilization by tailings ponds because there are none;
- reduced air pollution from equipment because much less equipment is
5 required;
- reduced draw of fresh water resources due to the recycling of process water,
when water is used as a solvent;
- reduced consumption of granular resources;
- increased thermal efficiency due to the recycle of process solvent;
- 10 • increased value of the tar sand ore reserve and oil shale reserve because of
overall cost efficiency;
and
- much reduced possibility of environmental impact that could trigger significant
concerns to the public.

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Other aspects and features will become apparent to those ordinarily skilled in the art upon review of the following description of specific illustrative embodiments of the invention in conjunction with the accompanying figures.

20

BRIEF DESCRIPTION OF THE FIGURES

FIG. 1 is a schematic diagram showing an example of the process in accordance with an illustrative embodiment of the present invention.

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FIG. 2 is a side elevation view of the exterior of a mobile facility in accordance with an illustrative embodiment of the present invention.

FIG. 3 is a side elevation view showing the interior of the mobile facility of FIG. 2.

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FIG. 4 is a top view taken along line 4-4 in FIG. 3.

DETAILED DESCRIPTION

Referring to FIG. 1, there is shown an example of a process according to an illustrative embodiment of the present invention. It should be noted that the reference numerals in the hexagons refer only to a stream number for Table 1 at the end of this description. The numerals outside the hexagons are the reference numerals used throughout the present description.

The present embodiment is used for mining oil-bearing materials, such as tar sand, and recovering an oil-enriched product, namely, bitumen, therefrom. The oil-bearing material, in this embodiment tar sand ore, may be extracted using an open pit technique, whereby the oil-bearing material is mined with suitable mining equipment in an opened mine area. The mine area may be previously prepared, which involves tasks such as mine dewatering, muskeg removal and stacking for future use, and overburden stripping and storage for later re-deposition in the mine area.

In the present embodiment, the process involves the use of a mobile facility, although other embodiments of the process need not involve a mobile facility. In this embodiment, the mobile facility is shown generally at (10) in FIGS. 2 to 4. In the present embodiment, the mobile facility (10) includes a supporting platform (10a) on which are mounted components for carrying out the recovery process. In this embodiment, most of these elements are enclosed in a space above the platform (10a). The illustrated mobile facility (10) is only an example and other embodiments are possible.

Referring back to FIG. 1, in the present embodiment, the mining of the oil-bearing material from the mine face (M) is carried out using at least one mining head (12). More particularly, in this embodiment the mining head (12) is located at the front of the mobile facility (10) and uses rotating cutters (12a), which have been found to be very suitable for the oil-bearing materials of the present embodiment. Alternatively, other kinds of possible mining heads may be substituted.

In this embodiment, the mined oil-bearing material is carried inside the mobile facility (10) using a first conveyor (14). More particularly, in this embodiment, the first conveyor (14) is a pan conveyor.

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Referring to FIG. 1, in the present embodiment, the oil-bearing material is discharged at the end of the first conveyor (14) over a screen (16), which in this embodiment includes a scalping grizzly, in order to remove oversized ore lumps. If appropriate, these oversized ore lumps could be fed into a crusher to reduce
10 their size under a maximum limit required for slurring. Alternatively, they can be dropped to the ground beneath the mobile facility (10) or even bypassed and added directly to the tailings that are produced at the end of the process. Similarly, mined materials can be diverted to the tailings using a bypass path, such as a chute, when they are not suitable for processing. This may be desirable
15 if bitumen is not present in worthwhile quantities at a particular location in the mine.

Still referring to FIG. 1, in the present embodiment, the oil-bearing material that has passed through the screen (16) falls onto a second conveyor (18), which in
20 this embodiment includes a pipe conveyor. More particularly, in this embodiment the pipe conveyor includes a conveyor belt whose sides are wrapped into an overlapping pipe-like engagement, thereby forming a pipe enclosing the oil-bearing material until it reaches the discharge end, where the pipe opens into a conventional conveyor shape and the oil-bearing material is discharged. In this
25 embodiment, a tramp magnet (20) is held close to the surface of the first conveyor (14) to remove iron debris, if any. In the present embodiment, the second conveyor (18) discharges the oil-bearing material into a crusher (22) located above a slurry feed tank (30). Alternatively, it could also discharge the oil-bearing material directly into the slurry feed tank (30).

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The screen (16) and the crusher (22) are optional. For instance, the mining head (12) may sufficiently grind the oil-bearing material on the mine face (M) so that

subsequent crushing thereof is not required. However, in most cases, it is desirable to preprocess the raw mined material to eliminate particles having a size above a maximum limit required for slurring and which may otherwise inflict operating difficulties or damage to the equipment.

5

In this embodiment, the oil-bearing material supplied in the slurry feed tank (30) is mixed with a suitable solvent to form a slurry. Generally, the nature of the solvent depends on the kind of oil-bearing material being processed. In this embodiment, in which the oil-bearing material includes tar sand, the solvent includes water.

10 More particularly, in this embodiment the solvent includes heated water, and the water is at least of equal weight with the oil-bearing material. In the present embodiment, the temperature of the supplied heater water is such that the slurry in the slurry feed tank has a temperature ranging from about 80° to 160° Fahrenheit (about 27°C to about 71°C) in order to promote the separation of the
15 bitumen from the other constituents in the slurry. In this embodiment, the slurry is agitated continuously using an ore feed mixer (32), although alternatively, any other suitable device may be substituted to achieve the same purpose.

In the present embodiment, from the slurry feed tank (30), the slurry is pumped or
20 otherwise conveyed into the inlet of a first hydrocyclone (40). It should be noted that the term "hydrocyclone" also includes two or more hydrocyclones. A hydrocyclone is a device in which centrifugal force created by cyclone swirling action is used to separate a lighter portion of its content from a heavier portion thereof. The lighter portion is referred to as the "overflow portion" while the
25 heavier portion is referred to as the "underflow portion". The overflow portion flows through an overflow outlet located at the top and the underflow portion flows through an underflow outlet at the bottom.

In this embodiment, the slurry in the slurry feed tank (30) is brought to the inlet of
30 the first hydrocyclone (40) using a vertical submersible feed pump (34). In this embodiment, the pump (34) has an inlet in the slurry feed tank (30) and an outlet in fluid communication with the inlet of the first hydrocyclone (40). The use of this

particular kind of pump permits arrangements that eliminate the need for valves which are problematic in slurry service.

5 In this embodiment, the overflow portion flowing through the overflow outlet of the first hydrocyclone (40) is oil-enriched. In this embodiment, this oil-enriched product may then be either sent to another separation process on the mobile facility (10), or may be sent directly into a product pipeline (36). In this embodiment, the product pipeline (36) is used to send the oil-enriched product to an off-site central processing plant where it may ultimately be upgraded into
10 synthetic crude oil. In the present embodiment, pumps are located at strategic locations to convey the oil-enriched product through the pipeline (36).

In the embodiment illustrated in FIG. 1, the process includes removing the solvent from the oil-enriched product, or more particularly, removing water from the
15 overflow portion of the first hydrocyclone (40), so that the product stream contains less water, thereby increasing the concentration of bitumen in the product stream before it exits the mobile facility (10). One of the advantages of removing this solvent from the oil-enriched product is that it can be recycled back into an earlier stage of the process, thereby reducing the amount of fresh solvent that has to be
20 supplied to the extraction process, and reducing the expenditure of energy to heat the fresh solvent. In this embodiment, the solvent is removed using a product separator or concentrator. More particularly, in this embodiment the product separator includes a decanter (46), as illustrated in FIG. 1. Alternatively, the product separator could be another hydrocyclone in which the overflow portion is
25 the further concentrated oil-enriched product, and the underflow portion contains the solvent to be recycled.

In this embodiment, the underflow portion from the first hydrocyclone (40) is a dense slurry containing mainly solvent and solids. However, it still contains some
30 amount of kerogen, bitumen or other oil-carrying product which could be recovered with further processing. If this is not desired, the underflow portion may proceed directly to a vacuum filtering stage to remove solvent therefrom.

In this embodiment, the vacuum filtering is achieved using a vacuum belt filter system (48). More particularly, in this embodiment the vacuum belt filter system (48) includes a porous endless conveyor belt (48a) under which is located a vacuum chamber (48b). The vacuum is provided by a vacuum pump (48c). In this embodiment, the slurry to be filtered is continuously laid on the conveyor belt (48a) at one end and the solvent is removed therefrom as it is conveyed towards the discharge end. The solvent enters the vacuum chamber (48b) and is thereafter sent with the retrieved air into an air/liquid separator (48d) through corresponding lines. In the present embodiment, the solvent removed from the underflow portion is recycled back into an earlier stage of the process. In this embodiment, the air/liquid separator (48d) includes an air outlet in fluid communication with the vacuum pump (48c). Also in this embodiment, the vacuum pump (48c) includes an air outlet in fluid communication with a region in the vicinity of the belt (48a) of the vacuum filter (48). This has the advantage of conserving heat energy when the mobile facility (10) operates in cold weather.

In this embodiment, substantially dewatered tailings (100) come out of the vacuum filter system (48). These tailings are said to be substantially dewatered since most of the solvent is removed therefrom and only enough solvent remains to provide geotechnical strength of the tailings (100) for stability of the deposition. In this embodiment, the dewatered tailings (100) fall on a tailings stacker (102). More particularly, in this embodiment the tailings stacker (102) includes a pipe conveyor arranged as a bridge, which conveys the dewatered tailings out of the mobile facility (10) for deposit in an adjacent area. In the present embodiment, the tailings (100) are eventually used to backfill the mine area. In this embodiment, the tailings stacker (102) is a track-supported bridge-type pipe conveyor. Other variants are also possible. The bridge-type pipe conveyor is known in the art and does not need to be further described herein.

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Referring again to FIG. 1, in the present embodiment, the underflow portion coming out of the first hydrocyclone (40) falls into a corresponding sump (42). In

this embodiment, a vertical submersible feed pump (44) is located in the sump (42). The feed pump (44) has an inlet in the sump (42) and an outlet in fluid communication with the inlet of a second hydrocyclone (50). The second hydrocyclone (50) is used to separate the content of the first sump (42) into an overflow portion and an underflow portion.

In this embodiment, in the second hydrocyclone (50), the overflow portion flows out through a corresponding overflow outlet and is sent back to the slurry feed tank (30). Also in this embodiment, the underflow portion of the second hydrocyclone (50) flows out through a corresponding underflow outlet and into a second sump (52).

The embodiment illustrated in FIG. 1 further includes a third hydrocyclone (60). In this embodiment, the content of the second sump (52) is then supplied to the inlet of the third hydrocyclone (60) using a corresponding vertical submersible feed pump (54). In the present embodiment, the third hydrocyclone (60) separates the content of the second sump (52) into an overflow portion and an underflow portion. In this embodiment, the overflow portion of the third hydrocyclone (60) flows out through an overflow outlet in fluid communication with the first sump (42). This allows a countercurrent washing circuit to be created. Also in this embodiment, the underflow portion of the third hydrocyclone (60) flows out through the underflow outlet and into a third sump (62).

It is further possible to use a fourth or even more additional hydrocyclones in the process. If a fourth hydrocyclone is used, its overflow outlet may be in fluid communication with the inlet of the third hydrocyclone (60). In other words, the overflow portion coming out a fourth hydrocyclone would be sent to the second sump (52). More generally, the overflow portion of a hydrocyclone, beginning with the third hydrocyclone (60), may be sent to the sump below the hydrocyclone which is two stages earlier. In this embodiment, it is the underflow portion of the last of the hydrocyclones which is sent to the vacuum filter system (48).

The content of the second sump (52) or the third sump (62) may be diluted with recycled solvent, such as solvent from the decanter (44) or another source, as the concentration of solids increases from one hydrocyclone to another.

In the embodiment illustrated in FIG. 1, the third sump (62) is the final station
5 before the vacuum filtering. In this embodiment, a flocculant agent is advantageously added into the third sump (62) before its contents are sent to the vacuum filter system (48). This allows fine particles to agglomerate, making the vacuum filtering more effective. In this embodiment, the flocculant agent is stored
10 in an agitated tank (64) and is supplied into the third sump (62) using a corresponding pump (66). In the present embodiment, the contents of the third sump (62) are sent to the vacuum filter system (48) using a vertical submersible feed pump (68) having an inlet in the sump (62) and an outlet in fluid communication with the inlet of the vacuum filter system (48).

Advantageously, the process of the present embodiment only requires the use of
15 a relatively small amount of fresh solvent. In this embodiment, fresh solvent is added into the process to replace solvent that is consumed or lost in the process, i.e., residual solvent that remains in the oil-enriched product and in the tailings (100) as they exit the process. In this embodiment, the fresh solvent is supplied through a fresh solvent supply line (70) connected to a suitable source. In the
20 present embodiment, most of the fresh solvent is sent into the slurry feed tank (30) following a network of lines. Some of this solvent can also be combined with recycled solvent. It can further be used to dilute the contents of some of the sumps. In the embodiment of FIG. 1, some of the fresh solvent could be sent into the second sump (52), for example.

25 In this embodiment, the fresh solvent supply line (70) advantageously includes a hose and a hose reel (72) and is in the form of a flexible line to be connected to a service facility outlet. Similarly, in this embodiment the product pipeline (36) advantageously includes a flexible hose line and a hose reel (74) to be connected to an appropriate outlet. In the present embodiment, the product hose reel (74)
30 and solvent supply hose reel are mounted on transport crawler tracks and/or

wheels. Electrical powerlines (not shown) could be mounted the same way. All of these flexible connections provide relocatable umbilical connections for an efficient operation of the mobile facility (10) of the present embodiment. Of course, other arrangements are possible, including the design of a mobile facility
5 having fully independent systems. In that case, the power could be supplied using generators while the fresh solvent and oil-enriched products may be stored in corresponding tanks to be serviced from time to time.

In this embodiment, a froth skimmer (76) is provided in the slurry feed tank (30) in order to collect a froth which usually forms over the slurry. This primary froth is
10 advantageously oil-enriched and can be combined with the stream coming out of the overflow outlet of the first hydrocyclone (40). In the present embodiment, the froth skimmer (76) includes a pump (78) having an outlet in fluid communication with the inlet of the decanter (44) or a location which is itself in fluid communication with the inlet thereof. Similarly, froth skimmers can be employed
15 on each of the hydrocyclone underflow sumps and the recovered froth can be combined with the product stream exiting the overflow outlet of the first hydrocyclone (40).

In the present embodiment, the mobile facility (10) is moved using a ground-
20 engaging undercarriage (80), which may be controlled by an operator at the front section. In this embodiment, the ground-engaging undercarriage (80) supports the mobile facility (10) and repositions it as the mining head or heads (12) advances. In the present embodiment, the undercarriage (80) includes motorized crawler tracks, which are generally more suitable for moving very large and heavy
25 equipment over unpaved surfaces. Alternatively, the undercarriage (80) may include wheels.

In this embodiment, heat is provided to the system using the fresh solvent. Hence, in this embodiment, the fresh solvent is supplied in a heated state so as to
30 provide heat for the slurry in the slurry feed tank (30). Alternatively, or in addition to the heated fresh solvent supply, a solvent heater (not shown) can be used in order to increase the temperature of the solvent or the slurry in the process. A

further alternative is that the solvent in the oil-enriched product may be recovered in a base plant or remote processing plant, may be heated there with available heating media, such as waste heat, and may then be returned to the mobile facility (10) via flexible hoses and hose reels together with, or separate from, the
5 fresh solvent. This will be a matter for capital and operating cost optimization with the fixed plant infrastructure on a site-specific basis.

EXAMPLE

- 10 Table 1 shows an illustrative example of a material balance using a process such as that shown in FIG. 1 for recovering bitumen from tar sand. The various stream numbers are identified throughout the drawing with the reference numerals in hexagons.

TABLE 1: MATERIAL BALANCE

Stream No.		1	2	3	4	5	6	7
Bitumen	t/h	240	1	124	37	49	34	15
Water	t/h	100	885	2228	669	2194	1536	658
Solids	t/h	1660	91	1919	1688	1903	228	1675
Total	t/h	2000	978	4271	2394	4146	1798	2348
Bitumen	wt%	12.0	.01	2.9	1.9	1.2	1.9	0.6
Water	wt%	5.0	90.6	51.3	27.9	52.9	85.4	28.0
Solids	wt%	83.0	9.3	44.9	70.5	45.9	12.7	71.3
Heat capacity	Btu/lb/F	0.271	0.924	0.629	0.440	0.633	0.886	0.440
Specific gravity		2.24	1.06	1.41	1.83	1.41	1.09	1.84
Total Volume	USGP M	3568	3694	12124	5231	11716	6613	5107
Temp	°F	32	94	78	78	85	85	85

Stream No.	8	9	10	11	12	13	14
Bitumen	16	11	5	5	0	5	87
Water	2179	1525	654	656	2	273	1560
Solids	1792	215	1577	1577	0	1577	230
Total	3987	1752	2235	2237	2	1854	1877
Bitumen	0.4	0.7	0.2	0.2	0.0	0.3	4.6
Water	54.7	87.1	29.2	29.3	100.0	14.7	83.1
Solids	44.9	12.3	70.5	70.5	0.0	85.0	12.3
Heat capacity	0.646	0.897	0.449	0.449	0.997	0.336	0.871
Specific gravity	1.40	1.08	1.81	1.81	1.00	2.18	1.09
Total Volume	11399	6475	4924	4932	8	3394	6900
Temp	90	90	90	90	80	90	78

Stream No.	15	16	17	18	19	20	21
Bitumen	235	0	0	151	0	0	-
Water	109	383	0	293	280	383	-
Solids	83	0	0	61	0	0	-
Total	427	383	0	505	280	383	-
							-
Bitumen	55.0	0.0	0.0	30.0	0.0	0.0	-
Water	25.5	100.0	100.00	58.0	100.0	100.0	-
Solids	19.5	0.0	0.0	12.0	0.0	0.0	-
Heat capacity	0.480	0.997	0.245	.0704	1.003	0.997	-
Specific gravity	1.19	1.00	0.88	1.11	0.96	1.00	-
Total Volume	1429	1538	407	1822	1157	1538	-
Temp	78	90	140	78	195	90	-

Stream No.	22	23	24	26	27	28	30	31
Bitumen	2	238	3	0.00	0.00	0	3	3
Water	1138	1853	1744	0.00	0.00	1	1744	2023
Solids	117	291	207	0.00	0.00	0	207	207
Total	1256	2382	1954	0	0	10	1954	2234
Bitumen	0.4	10.0	.02	0.0		0.0	0.2	.01
Water	84.4	77.8	89.2	100.0		100.0	89.2	90.6
Solids	15.2	12.2	10.5	0.0		0.0	10.5	10.5
Heat capacity	0.924	0.835	0.914	0.245	1		0.914	0.924
Specific gravity	1.06	1.09	1.07	0.96	0.96	0.96	1.07	1.06
Total Volume	4746	8724	7294	373			7294	8440
Temp	94	78	78	90	165	160	78	94

- 5 As can be appreciated, the process of the present embodiment allows a very efficient recovery of bitumen from tar sand.

While specific embodiments of the invention have been described and illustrated, such embodiments should be considered illustrative of the invention only and not as limiting the invention as construed in accordance with the accompanying
5 claims.

**THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE
PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:**

- 5 1. A mobile facility for mining an oil-bearing material and recovering an oil-enriched product therefrom, the facility comprising a supporting platform on which are mounted:
- (a) at least one mining head;
 - 10 (b) a crusher into which at least some of the mined oil-bearing material is fed;
 - (c) an inlet conveyor to carry the mined oil-bearing material from the mining head to the crusher;
 - (d) a slurry feed tank below the crusher, in which the mined oil-bearing material is received from the crusher and is mixed with a solvent to
15 form a slurry;
 - (e) a mixer located in the slurry feed tank;
 - (f) a hydrocyclone having an inlet in fluid communication with the slurry feed tank, the hydrocyclone comprising an overflow outlet and an underflow outlet;
 - 20 (g) a vacuum filter having an inlet in fluid communication with the underflow outlet of the hydrocyclone, the vacuum filter further having a first outlet that outputs substantially dewatered tailings, and a second outlet that outputs substantially solvent and air;
 - (h) an air/liquid separator having an inlet in fluid communication with the
25 second outlet of the vacuum filter, the separator further having a first outlet that outputs substantially solvent to be recycled in the facility, and a second outlet that outputs substantially air;
 - (i) a tailings conveyor to carry the tailings from the first outlet of the vacuum filter out of the mobile facility for deposition in an adjacent
30 area;
 - (j) a fresh solvent supply in fluid communication with the slurry feed tank; and

- (k) a ground-engaging undercarriage located under the platform to support the mobile facility and reposition it as the mining head advances.

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2. A mobile facility according to claim 1, wherein the solvent comprises water which is supplied in a heated state so as to provide heat to the slurry in the slurry feed tank.

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3. A mobile facility according to claim 2, wherein the slurry in the slurry feed tank has a temperature substantially ranging from 80° to 160° Fahrenheit.

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4. A mobile facility according to any one of claims 1 to 3, further comprising a concentrator having an inlet in fluid communication with the overflow outlet of the hydrocyclone, the concentrator further having a first outlet that outputs a further concentrated oil-enriched product, and a second outlet that outputs substantially solvent to be recycled in the facility.

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5. A mobile facility according to claim 4, further comprising a flocculant tank having an outlet in fluid communication with the inlet of the vacuum filter.

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6. A mobile facility according to claim 5, further comprising:
a sump in fluid communication with the underflow outlet of the hydrocyclone and the outlet of the flocculant tank; and
a vertical submersible feed pump having an inlet in the sump and an outlet in fluid communication with the inlet of the vacuum filter.

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7. A mobile facility according to any one of claims 4 to 6, further comprising a froth skimmer having an outlet in fluid communication with the inlet of the concentrator.

8. A mobile facility according to claim 7, wherein the froth skimmer comprises a feed pump.
- 5 9. A mobile facility according to claim 7, wherein the froth skimmer comprises an overflow weir, collection launders and a feed pump.
- 10 10. A mobile facility according to any one of claims 1 to 9, further comprising a by-pass path by which the mined oil-bearing material is diverted to the tailings conveyor when not suitable for processing.
11. A mobile facility according to any one of claims 1 to 10, wherein oversize ore lumps are dumped onto the ground when not suitable for processing.
- 15 12. A mobile facility according to any one of claims 1 to 11, further comprising a screen to remove oversize ore lumps from the mined oil-bearing material.
- 20 13. A mobile facility according to claim 12, further comprising a by-pass path by which oversize ore lumps are diverted to the tailings conveyor when not suitable for processing.
- 25 14. A mobile facility according to any one of claims 1 to 13, further comprising a vertical submersible feed pump having an inlet in the slurry feed tank, and an outlet in fluid communication with the inlet of the hydrocyclone.
15. A mobile facility according to any one of claims 1 to 14, wherein the tailings conveyor includes a bridge-type pipe conveyor.
- 30 16. A mobile facility according to any one of claims 1 to 15, wherein the mining head comprises rotating cutters.

17. A mobile facility according to any one of claims 1 to 16, wherein the undercarriage comprises motorized crawler tracks.
- 5 18. A mobile facility according to any one of claims 1 to 16, wherein the undercarriage comprises motorized wheels.
19. A mobile facility according to any one of claims 1 to 17, wherein the oil-bearing material comprises tar sand.
- 10 20. A mobile facility for mining an oil-bearing material and recovering an oil-enriched product therefrom, the facility comprising a supporting platform on which are mounted:
- (a) at least one mining head;
 - 15 (b) a slurry feed tank in which the oil-bearing material is mixed with a solvent to form a slurry;
 - (c) a first conveyor to carry the oil-bearing material from the mining head;
 - (d) a second conveyor which transports the oil-bearing material from a discharge end of the first conveyor into the slurry feed tank;
 - 20 (e) a mixer located in the slurry feed tank;
 - (f) a first hydrocyclone having an inlet in fluid communication with the slurry feed tank, the first hydrocyclone comprising an overflow outlet and an underflow outlet;
 - (g) a second hydrocyclone having an inlet in fluid communication with the underflow outlet of the first hydrocyclone, the second hydrocyclone comprising an overflow outlet and an underflow outlet, the overflow outlet of the second hydrocyclone being in fluid communication with the slurry feed tank;
 - 25 (h) a vacuum filter having an inlet in fluid communication with the underflow outlet of a last of the hydrocyclones, the vacuum filter further having a first outlet that outputs substantially dewatered
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- tailings, and a second outlet that outputs substantially solvent and air;
- 5 (i) an air/liquid separator having an inlet in fluid communication with the second outlet of the vacuum filter, the separator further having a first outlet that outputs substantially solvent to be recycled in the facility, and a second outlet that outputs substantially air;
- (j) a tailings conveyor to carry the tailings from the first outlet of the vacuum filter out of the mobile facility for deposition in an adjacent area;
- 10 (k) a fresh solvent supply being at least partially in fluid communication with the slurry feed tank; and
- (l) a ground-engaging undercarriage to support the mobile facility and reposition it as the mining head advances.
- 15 **21.** A mobile facility according to claim **20**, wherein the solvent comprises water supplied in a heated state so as to provide heat for the slurry in the slurry feed tank.
- 22.** A mobile facility according to claim **21**, wherein the slurry in the slurry feed tank has a temperature substantially ranging from **80°** to **160°** Fahrenheit.
- 20 **23.** A mobile facility according to any one of claims **20** to **22**, further comprising a concentrator having an inlet in fluid communication with the overflow outlet of the first hydrocyclone, the concentrator further having a first outlet that outputs a further concentrated oil-enriched product, and a second outlet that outputs substantially solvent to be recycled in the facility.
- 25 **24.** A mobile facility according to claim **23**, further comprising a froth skimmer in fluid communication with the inlet of the concentrator.
- 30 **25.** A mobile facility according to claim **24**, wherein the froth skimmer comprises a feed pump.

- 26.** A mobile facility according to claim **24** or **25**, wherein the froth skimmer comprises an overflow weir.
- 5 **27.** A mobile facility according to any one of claims **20** to **26**, further comprising a flocculant tank having an outlet in fluid communication with the inlet of the vacuum filter.
- 10 **28.** A mobile facility according to any one of claims **20** to **27**, further comprising a by-pass path by which the oil-bearing material is diverted to the tailings when not suitable for processing.
- 15 **29.** A mobile facility according to any one of claims **20** to **28**, further comprising a screen to remove oversize ore lumps from the oil-bearing material.
- 20 **30.** A mobile facility according to claim **29**, further comprising a by-pass path by which oversize ore lumps are deviated to the tailings conveyor when not suitable for processing.
- 25 **31.** A mobile facility according to claim **29**, wherein the oversize ore lumps are dumped onto the ground when not suitable for processing.
- 30 **32.** A mobile facility according to any one of claims **20** to **31**, further comprising a vertical submersible feed pump having an inlet in the slurry feed tank, and an outlet in fluid communication with the inlet of the first hydrocyclone.
- 30 **33.** A mobile facility according to any one of claims **20** to **32**, further comprising a third hydrocyclone having an inlet in fluid communication with the underflow outlet of the second hydrocyclone, the third hydrocyclone comprising an overflow outlet and an underflow outlet, the overflow outlet of the third hydrocyclone being in fluid communication with the inlet of the second hydrocyclone.

- 5 **34.** A mobile facility according to claim **33**, further comprising a fourth hydrocyclone having an inlet in fluid communication with the underflow outlet of the third hydrocyclone, the fourth hydrocyclone comprising an overflow outlet and an underflow outlet, the overflow outlet of the fourth hydrocyclone being in fluid communication with the inlet of the third hydrocyclone.
- 10 **35.** A mobile facility according to any one of claims **20** to **34**, wherein each hydrocyclone has a corresponding sump and a corresponding vertical submersible feed pump, the three of which form a subset, each sump being in fluid communication with the underflow outlet of the hydrocyclone of its subset, and each feed pump having an inlet in the sump of its subset and an outlet in fluid communication with the inlet of where the underflow outlet
- 15 of the hydrocyclone of its subset is connected.
- 36.** A mobile facility according to any one of claims **20** to **35**, wherein the tailings conveyor includes a bridge-type pipe conveyor.
- 20 **37.** A mobile facility according to any one of claims **20** to **36**, wherein the mining head comprises rotating cutters.
- 38.** A mobile facility according to any one of claims **20** to **37**, wherein the undercarriage comprises motorized crawler tracks located under the
- 25 platform.
- 39.** A mobile facility according to any one of claims **20** to **37**, wherein the undercarriage comprises motorized wheels located under the platform.
- 30 **40.** A mobile facility according to any one of claims **20** to **39**, wherein the oil-bearing material comprises tar sand.

41. An apparatus for recovering an oil-enriched product from an oil-bearing material, the apparatus comprising:
- 5 (a) a slurry feed tank in which the oil-bearing material is mixed with a solvent to form a slurry;
 - (b) a hydrocyclone having an inlet in fluid communication with the slurry feed tank, the hydrocyclone comprising an overflow outlet and an underflow outlet;
 - 10 (c) a vacuum filter having an inlet in fluid communication with the underflow outlet of the hydrocyclone, the vacuum filter further having a first outlet that outputs substantially dewatered tailings, and a second outlet that outputs substantially solvent and air; and
 - 15 (d) an air/liquid separator having an inlet in fluid communication with the second outlet of the vacuum filter, the separator further having a first outlet that outputs substantially the solvent to be recycled, and a second outlet that outputs substantially air.
42. The apparatus according to claim 41, wherein the solvent comprises water which is supplied in a heated state so as to provide heat to the slurry in the slurry feed tank.
- 20 43. The apparatus according to claim 42, wherein the slurry in the slurry feed tank has a temperature substantially ranging from 80° to 160° Fahrenheit.
- 25 44. An apparatus according to any one of claims 41 to 43, further comprising a concentrator having an inlet in fluid communication with the overflow outlet of the hydrocyclone, the concentrator further having a first outlet that outputs a further concentrated oil-enriched product, and a second outlet that outputs substantially solvent to be recycled.
- 30 45. The apparatus according to claim 44, further comprising a flocculant tank having an outlet in fluid communication with the inlet of the vacuum filter.

46. The apparatus according to claim **45**, further comprising:
a sump in fluid communication with the underflow outlet of the hydrocyclone and the outlet of the flocculant tank; and
5 a vertical submersible feed pump having an inlet in the sump and an outlet in fluid communication with the inlet of the vacuum filter.
47. The apparatus according to any one of claims **44** to **46**, further comprising a froth skimmer having an outlet in fluid communication with the inlet of the concentrator.
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48. The apparatus according to claim **47**, wherein the froth skimmer comprises a feed pump.
- 15 49. The apparatus according to claim **47**, wherein the froth skimmer comprises an overflow weir, collection launders and a feed pump.
50. The apparatus according to any one of claims **41** to **49**, further comprising a bypass path by which the oil-bearing material is diverted to a tailings conveyor when not suitable for processing.
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51. The apparatus according to any one of claims **41** to **49**, further comprising a vertical submersible feed pump having an inlet in the slurry feed tank, and an outlet in fluid communication with the inlet of the hydrocyclone.
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52. The apparatus according to any one of claims **41** to **49**, wherein the oil-bearing material comprises tar sand.
53. An apparatus for recovering an oil-enriched product from an oil-bearing material, the apparatus comprising a supporting platform on which are mounted:
30 (a) an oil-bearing material inlet;

- (b) a slurry feed tank in which the oil-bearing material is mixed with a solvent to form a slurry;
- 5 (c) a first conveyor to carry the oil-bearing material from the oil-bearing material inlet;
- (d) a second conveyor which transports the oil-bearing material from a discharge end of the first conveyor into the slurry feed tank;
- (e) a mixer located in the slurry feed tank;
- 10 (f) a first hydrocyclone having an inlet in fluid communication with the slurry feed tank, the first hydrocyclone comprising an overflow outlet and an underflow outlet;
- (g) a second hydrocyclone having an inlet in fluid communication with the underflow outlet of the first hydrocyclone, the second hydrocyclone comprising an overflow outlet and an underflow outlet, the overflow outlet of the second hydrocyclone being in fluid communication with the slurry feed tank;
- 15 (h) a vacuum filter having an inlet in fluid communication with the underflow outlet of a last of the hydrocyclones, the vacuum filter further having a first outlet that outputs substantially dewatered tailings, and a second outlet that outputs substantially the solvent and air;
- 20 (i) an air/liquid separator having an inlet in fluid communication with the second outlet of the vacuum filter, the separator further having a first outlet that outputs substantially the solvent to be recycled, and a second outlet that outputs substantially air;
- 25 (j) a tailings conveyor to carry the tailings from the first outlet of the vacuum filter out of the apparatus for deposition in an adjacent area;
- (k) a fresh solvent supply being at least partially in fluid communication with the slurry feed tank; and
- 30 (l) a ground-engaging undercarriage to support the apparatus and reposition it.

- 54.** The apparatus according to claim **53**, wherein the solvent comprises water supplied in a heated state so as to provide heat for the slurry in the slurry feed tank.
- 5 **55.** The apparatus according to claim **54**, wherein the slurry in the slurry feed tank has a temperature substantially ranging from **80°** to **160°** Fahrenheit.
- 10 **56.** The apparatus according to any one of claims **53** to **55**, further comprising a concentrator having an inlet in fluid communication with the overflow outlet of the first hydrocyclone, the concentrator further having a first outlet that outputs a further concentrated oil-enriched product, and a second outlet that outputs substantially the solvent to be recycled.
- 15 **57.** The apparatus according to claim **56**, further comprising a froth skimmer in fluid communication with the inlet of the concentrator.
- 58.** The apparatus according to claim **57**, wherein the froth skimmer comprises a feed pump.
- 20 **59.** The apparatus according to claim **57** or **58**, wherein the froth skimmer comprises an overflow weir.
- 25 **60.** The apparatus according to any one of claims **53** to **59**, further comprising a flocculant tank having an outlet in fluid communication with the inlet of the vacuum filter.
- 30 **61.** The apparatus according to any one of claims **53** to **60**, further comprising a bypass path by which the oil-bearing material is diverted to the tailings when not suitable for processing.
- 62.** The apparatus according to any one of claims **53** to **61**, further comprising a screen to remove oversize ore lumps from the oil-bearing material.

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63. The apparatus according to claim 62, further comprising a by-pass path by which oversize ore lumps are diverted to the tailings conveyor when not suitable for processing.
64. The apparatus according to claim 62, wherein the by-pass path comprises an exterior outlet so that the oversize ore lumps are dumped onto the ground when not suitable for processing.
- 10 65. The apparatus according to any one of claims 53 to 64, further comprising a vertical submersible feed pump having an inlet in the slurry feed tank, and an outlet in fluid communication with the inlet of the first hydrocyclone.
- 15 66. The apparatus according to any one of claims 53 to 65, further comprising a third hydrocyclone having an inlet in fluid communication with the underflow outlet of the second hydrocyclone, the third hydrocyclone comprising an overflow outlet and an underflow outlet, the overflow outlet of the third hydrocyclone being in fluid communication with the inlet of the second hydrocyclone.
- 20 67. The apparatus according to claim 66, further comprising a fourth hydrocyclone having an inlet in fluid communication with the underflow outlet of the third hydrocyclone, the fourth hydrocyclone comprising an overflow outlet and an underflow outlet, the overflow outlet of the fourth hydrocyclone being in fluid communication with the inlet of the third hydrocyclone.
- 25 68. The apparatus according to any one of claims 53 to 67, wherein each hydrocyclone has a corresponding sump and a corresponding vertical submersible feed pump, the three of which form a subset, each sump being in fluid communication with the underflow outlet of the hydrocyclone of its subset, and each feed pump having an inlet in the sump of its subset and
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an outlet in fluid communication with the inlet of where the underflow outlet of the hydrocyclone of its subset is connected.

- 5 **69.** The apparatus according to any one of claims **53** to **68**, wherein the tailings conveyor includes a bridge-type pipe conveyor.
- 70.** The apparatus according to any one of claims **53** to **69**, wherein the oil-bearing material comprises tar sand.
- 10 **71.** A process for recovering an oil-enriched product from an oil-bearing material, the process comprising:
- (a) mixing the oil-bearing material with a solvent to form a slurry in a slurry feed tank;
- 15 (b) pumping the slurry into a hydrocyclone to separate it into an overflow portion and an underflow portion, the overflow portion containing the oil-enriched product;
- (c) vacuum filtering the underflow portion to remove solvent therefrom and produce substantially dewatered tailings;
- 20 (d) recycling the solvent removed from the underflow portion back into an earlier stage of the process; and
- (e) adding fresh solvent into the process.
- 72.** The process according to claim **71**, wherein the solvent is at least equal in weight with the oil-bearing material.
- 25 **73.** The process according to claim **71** or **72**, further comprising conveying the tailings out for deposition in an adjacent area.
- 74.** The process according to any one of claims **71** to **73**, wherein the fresh solvent is fed into the slurry feed tank.
- 30

75. The process of claim **71**, wherein the process is carried out using a mobile facility and further comprises:

mining the oil-bearing material from a mine face using at least one mining head;

5 screening the oil-bearing material to remove oversized ore lumps;

feeding the oil-bearing material into a crusher;

conveying the tailings out of the mobile facility for deposition in an adjacent area; and

repositioning the mobile facility as the mining head advances;

10 wherein in mixing the oil-bearing material with the solvent to form the slurry, the solvent is in at least equal weight with the oil-bearing material; and

wherein adding fresh solvent comprises adding the fresh solvent into the slurry feed tank.

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76. The process according to any one of claim **71** to claim **75**, further comprising removing some solvent from the overflow portion to obtain a further concentrated oil-enriched product, and recycling the removed solvent back into the slurry feed tank.

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77. The process according to claim **76**, wherein the step of removing solvent from the overflow portion comprises decanting.

78. The process according to any one of claims **71** to **77**, wherein the solvent comprises water and the slurry in the slurry feed tank has a temperature substantially ranging from **80** to **160** degrees Fahrenheit.

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79. The process according to claim **78**, wherein heat is supplied in the process using the fresh solvent.

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80. The process according to any one of claims 71 to 79, further comprising the step of adding flocculant to the underflow portion before vacuum filtering the underflow portion.
- 5 81. The process according to any one of claims 71 to 80, further comprising the step of skimming a froth formed on the slurry and adding the froth to the overflow portion before the solvent is removed therefrom.
- 10 82. The process according to any one of claims 71 to 81, wherein the oil-bearing material is mined using rotating cutters.
- 15 83. The process according to any one of claims 71 to 82, wherein at least some oversize ore lumps are fed into a crusher to reduce their size to under a maximum limit required for slurring, the crushed materials being thereafter brought into the slurry feed tank.
- 20 84. The process according to any one of claims 71 to 83, wherein at least some oversize ore lumps are diverted to the tailings.
- 25 85. The process according to any one of claims 71 to 83, wherein oversize ore lumps are dumped onto the ground when not suitable for processing.
86. The process according to any one of claims 71 to 85, wherein the oil-bearing material is diverted to the tailings when not suitable for processing.
87. The process according to any one of claims 71 to 86, wherein the oil-bearing material comprises tar sand.
- 30 88. The process of claim 71:
wherein mixing comprises agitating the solvent and the oil-bearing material to form a primary slurry;

wherein pumping comprises pumping the primary slurry into a first hydrocyclone to separate it into a first overflow portion and a first underflow portion;

5 further comprising pumping the first underflow portion into a second hydrocyclone to separate it into a second overflow portion and a second underflow portion;

further comprising pumping the second overflow portion into the slurry feed tank;

10 wherein vacuum filtering comprises vacuum filtering the underflow portion of a last of the hydrocyclones to remove solvent therefrom and produce substantially dewatered tailings;

further comprising conveying the tailings for deposition in an adjacent area; and

15 wherein recycling comprises recycling the solvent removed from the underflow portion of the last of the hydrocyclones into the earlier stage of the process.

89. The process according to claim 88, wherein the solvent is at least equal in weight with the oil-bearing material.

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90. The process of claim 89, wherein the process is carried out using a mobile facility and further comprises:

mining the oil-bearing material from a mine face using at least one mining head; and

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repositioning the mobile facility as the mining head advances; and

wherein conveying comprises conveying the tailings out of the mobile facility for deposition in the adjacent area.

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91. The process according to any one of claims 88 to 90, further comprising the step of removing some solvent from the first overflow portion to obtain a further concentrated oil-enriched product, and recycling the solvent removed from the first overflow portion into the process.

- 92.** The process according to claim **91**, wherein the step of removing solvent from the first overflow portion comprises decanting.
- 5 **93.** The process according to any one of claims **88** to **92**, wherein at least a portion of the solvent in the oil-enriched product is separated in a remote processing plant, heated therein and then recycled back into the process.
- 10 **94.** The process according to any one of claims **88** to **93**, wherein the solvent comprises water and the slurry in the slurry feed tank has a temperature substantially ranging from **80** to **160** degrees Fahrenheit.
- 15 **95.** The process according to claim **94**, wherein at least a portion of the heat is supplied in the process using the fresh solvent.
- 20 **96.** The process according to any one of claims **88** to **95**, further comprising the step of adding flocculant to the underflow portion of the last hydrocyclone before vacuum filtering the underflow portion.
- 25 **97.** The process according to any one of claims **88** to **96**, further comprising the step of skimming a froth formed on the primary slurry and adding the froth to the first overflow portion.
- 30 **98.** The process according to any one of claims **88** to **97**, further comprising the step of pumping the second underflow portion into a third hydrocyclone to separate it into a third overflow portion and a third underflow portion, the third overflow portion being added to the first underflow portion.
- 30 **99.** The process according to claim **98**, further comprising the step of pumping the third underflow portion into a fourth hydrocyclone to separate it into a fourth overflow portion and a fourth underflow portion, the fourth overflow portion being added to the second underflow portion.

- 100.** The process according to any one of claims **88** to **99**, wherein the oil bearing material is mined using rotating cutters.
- 5 **101.** The process according to any one of claims **88** to **100**, further comprising the step of pre-processing the oil-bearing material before mixing it with the solvent to eliminate particles having a size above a maximum limit required for slurring.
- 10 **102.** The process according to claim **101**, wherein the step of pre-processing the oil-bearing material comprises screening it to remove oversize ore lumps.
- 15 **103.** The process according to claim **102**, wherein at least some of the oversize ore lumps are fed into a crusher to reduce lump size to under the maximum limit required for slurring.
- 20 **104.** The process according to claim **102**, wherein at least some of the oversize ore lumps are by-passed and added to the tailings.
- 25 **105.** The process according to claim **102**, wherein the oversize ore lumps are dumped onto the ground when not suitable for processing.
- 30 **106.** The process according to any one of claims **101** to **105**, wherein the step of pre-processing the oil-bearing material comprises feeding at least some of it into a crusher before mixing it with the solvent.
- 35 **107.** The process according to any one of claims **88** to **106**, wherein the oil-bearing material is diverted to the tailings when not suitable for processing.
- 40 **108.** The process according to any one of claims **88** to **107**, wherein the oil-bearing material comprises tar sand.

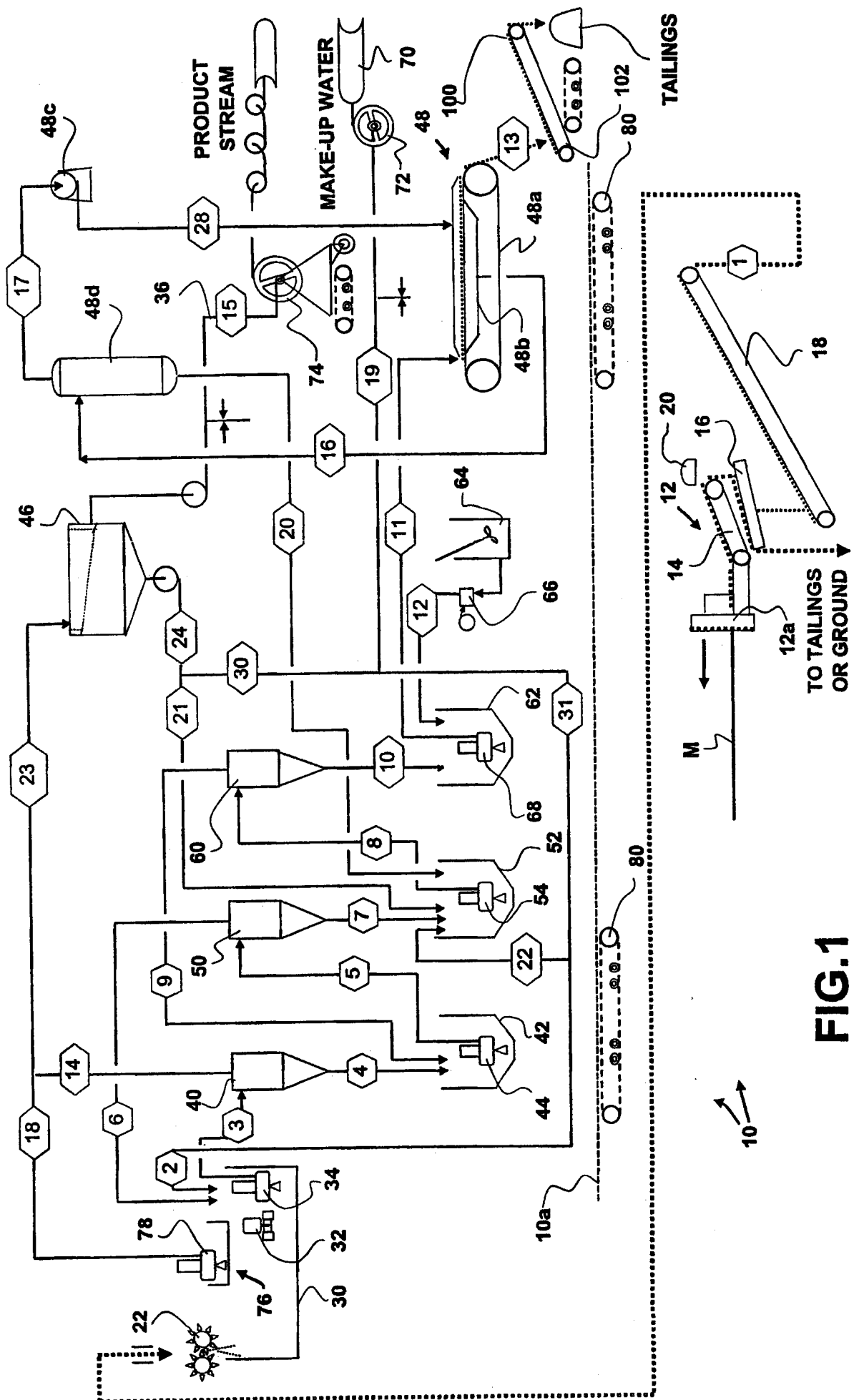


FIG.1

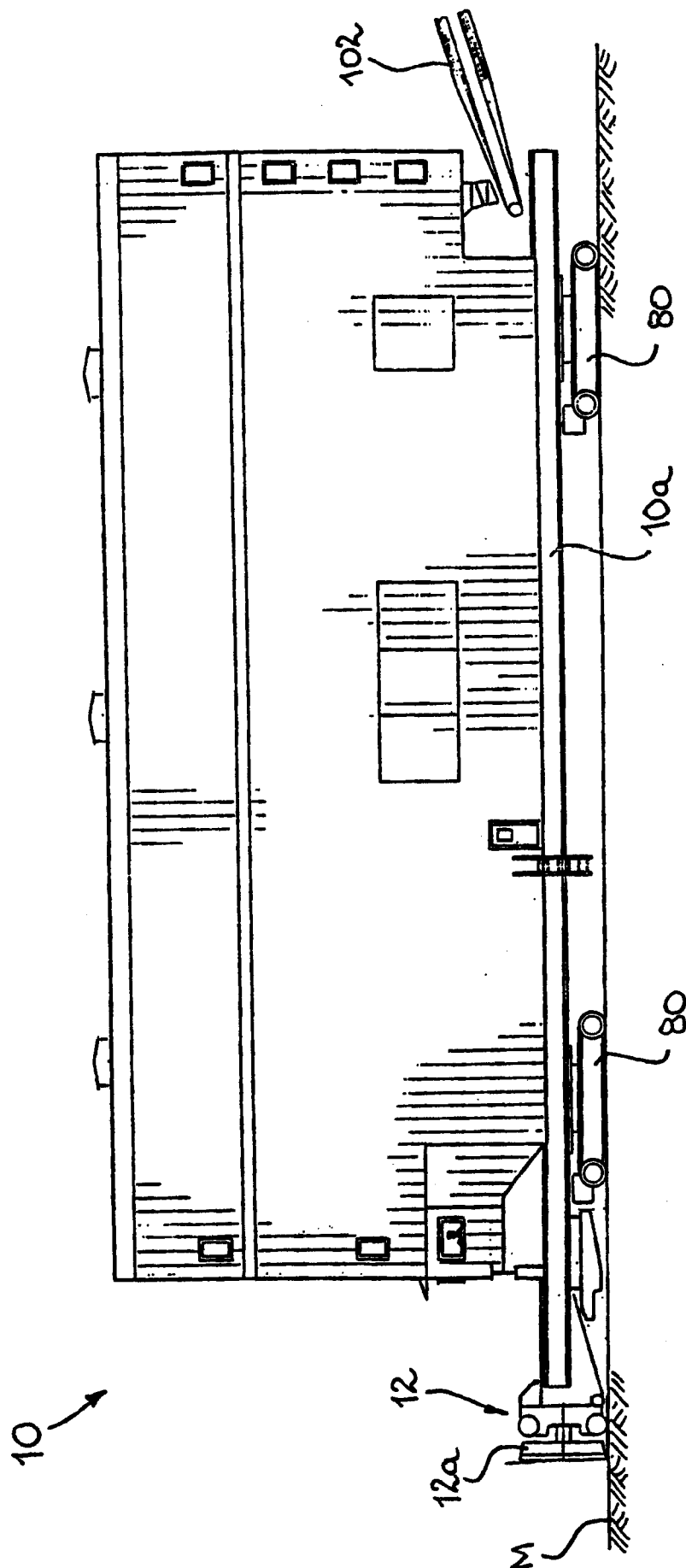


FIG.2

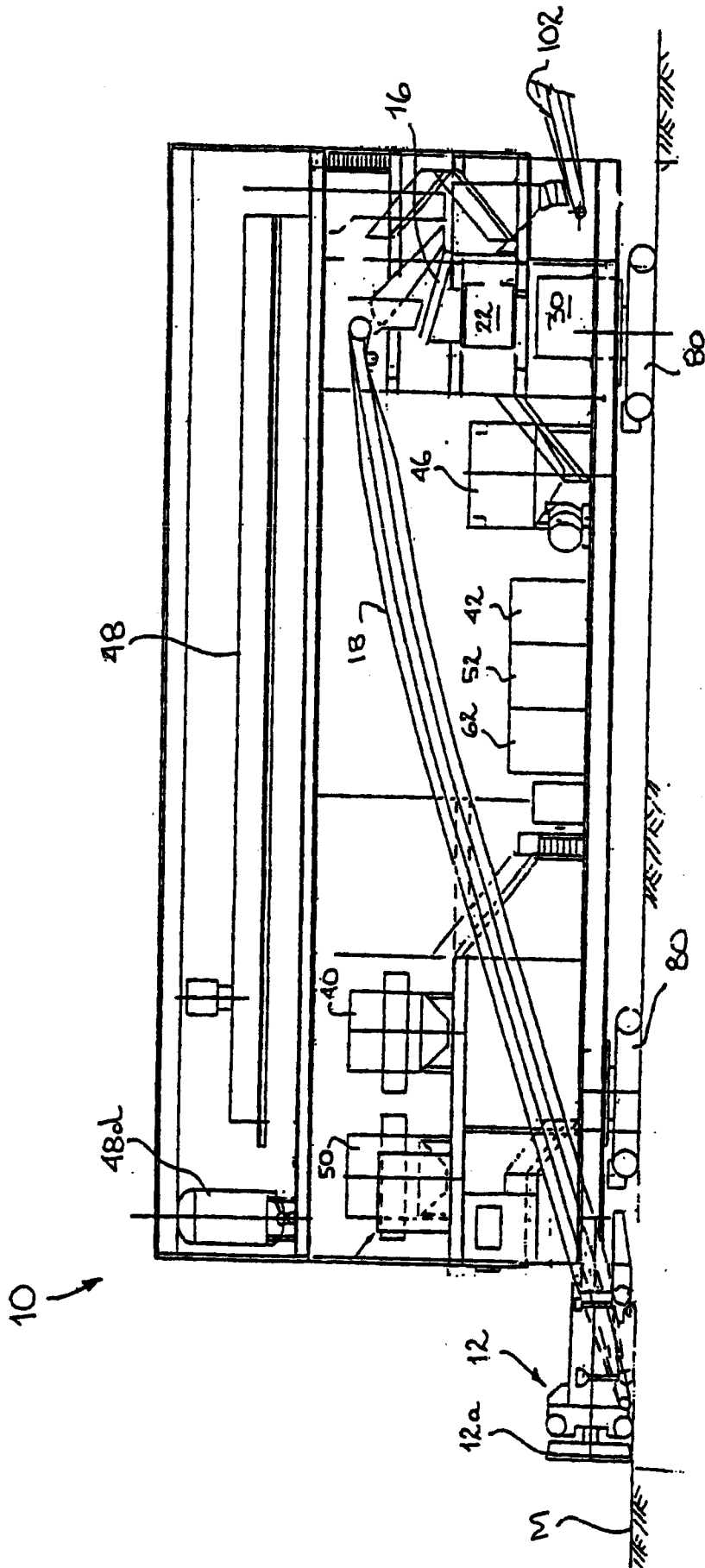


FIG.3

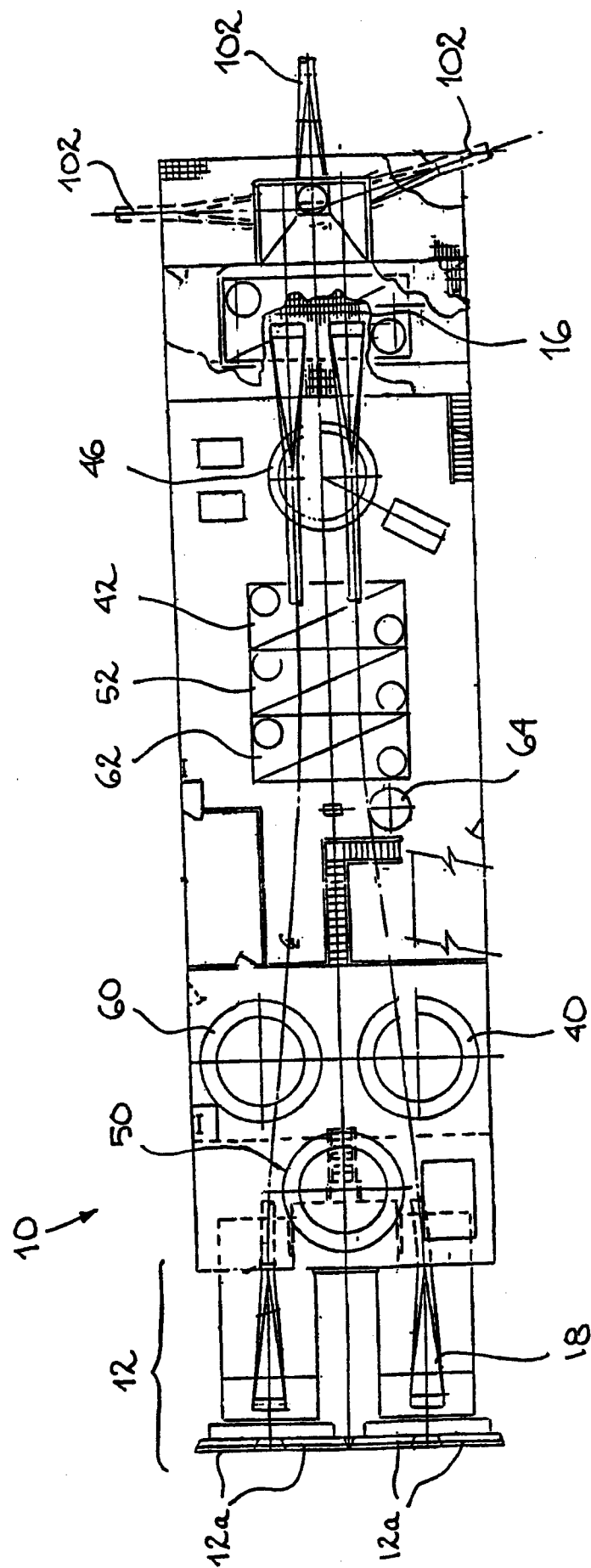


FIG. 4

