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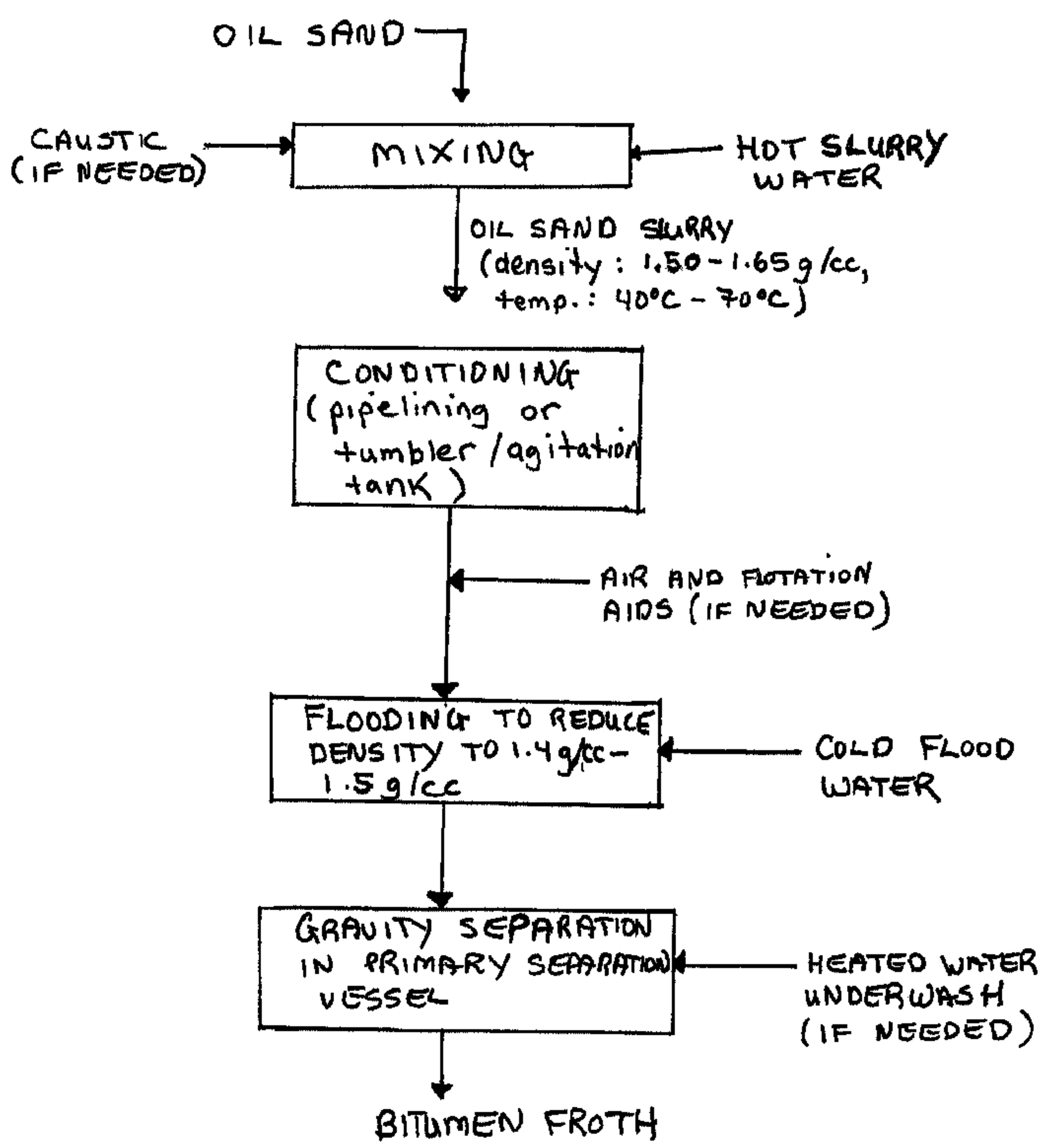

(57) Abrégé/Abstract:
An improved low energy extraction process for recovering bitumen from oil sand whereby essentially all of the thermal energy input for processing the oil sand takes place at the slurry mixing step as opposed to at both the slurry mixing step and the slurry flooding step. Mined oil sand is mixed with sufficient hot slurry water to produce an oil sand slurry having a density in the preferred range of about 1.50 g/cc to about 1.60 g/cc and a temperature in the preferred range of about 40°C to about 55°C, more preferably greater than about 43°C. The oil sand slurry is conditioned, preferably by pumping it through a pipeline for a sufficient length of time, and then flooded with cold flood water to produce a diluted slurry having a density in the range of about 1.4 g/cc to about 1.5 g/cc and a temperature generally below 40°C and typically in the range of about 30°C to about 35°C. The diluted slurry is introduced into a gravity separation vessel where bitumen froth is recovered.

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ABSTRACT

An improved low energy extraction process for recovering bitumen from oil sand whereby essentially all of the thermal energy input for processing the oil sand takes place at the slurry mixing step as opposed to at both the slurry mixing step and the slurry flooding step. Mined oil sand is mixed with sufficient hot slurry water to produce an oil sand slurry having a density in the preferred range of about 1.50 g/cc to about 1.60 g/cc and a temperature in the preferred range of about 40°C to about 55°C, more preferably greater than about 43°C. The oil sand slurry is conditioned, preferably by pumping it through a pipeline for a sufficient length of time, and then flooded with cold flood water to produce a diluted slurry having a density in the range of about 1.4 g/cc to about 1.5 g/cc and a temperature generally below 40°C and typically in the range of about 30°C to about 35°C. The diluted slurry is introduced into a gravity separation vessel where bitumen froth is recovered.

IMPROVED LOW ENERGY PROCESS FOR EXTRACTION OF BITUMEN FROM OIL SAND

The present invention relates generally to a method for extracting bitumen from oil sand. More specifically, the present invention relates to an improved low energy extraction process wherein the majority of thermal energy input in the form of hot water occurs at the slurry mixing step rather than at both the slurry mixing step and the slurry flooding step.

BACKGROUND OF THE INVENTION

Oil sand, 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. It lends itself to liberation of the sand grains from the bitumen, preferably by slurrying the oil sand in hot process 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 the following steps:

- dry mining the oil sand at a mine site that can be kilometres from an extraction plant;
- conveying the as-mined oil sand on conveyer belts to the extraction plant;
- feeding the oil sand into a rotating tumbler where it is mixed for a prescribed retention time (generally in the range of 2 to 4 minutes) with hot

water (approximately 80-90°C), steam, caustic (*e.g.,* sodium hydroxide) and naturally entrained air to yield a slurry that has a temperature typically around 80°C. The bitumen matrix is heated and becomes less viscous. Chunks of oil sand are ablated or disintegrated. The released sand grains and separated bitumen flecks are dispersed in the water. To some extent bitumen flecks coalesce and grow in size. They may contact air bubbles and coat them to become aerated bitumen. The term used to describe this overall process in the tumbler is "conditioning"; and

- diluting the slurry so produced with additional hot water to produce a diluted slurry having a temperature of about 65°C to about 80°C. The diluted slurry is introduced into a large, open-topped, conical-bottomed, cylindrical vessel termed a primary separation vessel (PSV) where the more buoyant aerated bitumen rises to the surface and forms a froth layer. This froth layer overflows the top lip of the PSV and is received in a launder extending around the PSV's rim. The product is commonly called "primary froth" and typically has a temperature of about 65°C to about 75°C.

It is well understood in the industry that the quality of the oil sand has very significant effects on the completeness of primary bitumen recovery in the PSV and the quality of the primary froth. For example, a "low grade" oil sand typically will contain between about 6 to 10 wt.% bitumen with about 25 to 35 wt.% fines. An "average grade" oil sand 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 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 44μm. The higher fines concentrations in low to average grade oil sand contribute to the difficulty in extracting the bitumen.

The hot water process as described above generally assures good bitumen recoveries for all grades of oil sand. However, the thermal energy requirement per tonne of oil sand processed is very high. In particular, thermal energy is required to heat the hot process water, for steam production and for heating the hot flood water.

Around 1990, the known conditioning step of the hot water process was modified by eliminating the need for steam. Oil sand is mixed with sufficient hot water to yield an oil sand slurry having a temperature in the range of 40-55°C. Mixing and conditioning occurs in a tumbler, with retention times being increased to within the range of about 7-12 minutes. Conditioned slurry is flooded or diluted with additional hot water to yield a flooded slurry temperature within the range of 50-80°C. This process is referred to as the "warm slurry extraction process" and is disclosed in Canadian Patent No. 2,015,784.

Further in the early 1990s, there was another major innovation in the oil sand industry, which is commonly referred to as "pipeline conditioning". This innovation is disclosed in Canadian Patent No. 2,029,795 and United States Patent No. 5,039,227. The bitumen extraction process using pipeline conditioning, which is disclosed in the aforementioned patents, comprises the following steps:

- supplying heated water (typically at 95°C) at the mine site;
- mixing the dry as-mined oil sand with the heated water at the mine site in predetermined portions using a device known as a "cyclofeeder", to form an aerated slurry having a temperature in the range of 40-70°C, preferably about 50°C;
- screening the slurry to remove oversize solids too large to be fed to the pipeline;
- pumping the screened slurry to the extraction plant through several kilometres of pipeline, where conditioning (*i.e.*, lump digestion, bitumen liberation, coalescence and aeration) occurs; and
- diluting the slurry with heated flood water having a temperature in the range of about 50°C to about 65°C and feeding the slurry directly into a PSV for gravity separation.

Thus, the pumping of the slurry through a pipeline, over a certain minimum distance, to condition the slurry allows the slurry temperature to be reduced to about 50°C without compromising bitumen recovery. This is due to the increased conditioning time (*i.e.*, typically 10 minutes or greater) in the pipeline. If a tumbler were to be used for such a slurry, it would have to be very large, to provide a longer retention time for conditioning to occur. Hence, by using pipeline conditioning, a bitumen extraction process can be used with appreciably lower thermal energy requirements per tonne of oil sand. However, thermal energy was still needed to heat both the hot slurry water and the hot flood water.

In an attempt to further reduce the thermal energy requirement per tonne of oil sand, in the late 1990s a cold dense slurrying process for extracting bitumen from oil sand was developed, which is disclosed in Canadian patent No. 2,217,623 and United States Patent No. 6,007,708. This process is commonly referred to as the "low energy extraction process" or the "LEE process" and generally comprises the following steps:

- dry mining the oil sand;
- mixing the mined oil sand with water in predetermined proportions near the mine site to produce a slurry containing entrained air and having a controlled density in the range of 1.4 to 1.65 g/cc and preferably a temperature in the range 20-40°C;
- pumping the slurry through a pipeline having a plurality of pumps spaced along its length, preferably adding air to the slurry as it moves through the pipeline, to condition the slurry;
- diluting the slurry with flood water and introducing the diluted slurry into the PSV to float the aerated bitumen. The froth is maintained at a temperature of at least 35°C in the PSV by use of a hot water underwash, thereby assisting in removing the froth from the PSV and satisfying downstream froth temperature needs.

Thus, in an attempt to save on energy costs, the LEE process reduces the temperature of the slurry process water used in the slurry preparation and conditioning stage to produce a low temperature slurry . Thus, less thermal energy is used to heat the slurry process water.

However, more thermal energy is also expended at the later flooding stage, to ensure the overall PSV slurry temperature of at least 35°C. In other words, heated flood water is routinely used to bring up the temperature of the low temperature slurry for bitumen separation.

While the LEE process provides acceptable bitumen recovery from high grade oil sand, bitumen recovery from low and average grade oil sand is still appreciably less than optimal. Thus, the range of oil sand grades which process well at the low temperature conditions of the LEE process is limited because many low grade, high fines ore facies do not respond well to pipeline conditioning process at low temperatures.

It will therefore be appreciated that there exists a need for a low energy process that will result in improved bitumen recovery, in particular, when processing low to average grade oil sand.

SUMMARY OF THE INVENTION

In accordance with the invention, an improved low energy extraction process is provided for extracting bitumen from oil sand, comprising:

- dry mining oil sand from a deposit at a mine site;
- mixing the oil sand with sufficient hot slurry water to produce an oil sand slurry containing bitumen, sand, water and entrained air, the oil sand slurry having a density in the range of about 1.50 g/cc to about 1.65 g/cc and a temperature in the range of about 40°C to about 70°C;
- conditioning the oil sand slurry;
- flooding the conditioned oil sand slurry with cold flood water to dilute the slurry;
- introducing the diluted slurry into a gravity separation vessel wherein separate layers of bitumen froth, middlings and sand tailings are formed; and
- separately removing bitumen froth, middlings and sand tailings from the vessel.

Thus, broadly stated, the invention is an improved low energy extraction process for recovering bitumen from oil sand whereby essentially all of the thermal energy input to process the oil sand occurs at the slurry mixing step as opposed to at both the slurry mixing step and the slurry flooding step. By using essentially all of the thermal energy in the form of hot slurry water up front in the slurry mixing step, optimal slurry conditioning occurs. Further, by using cold flood water in the flooding step, thermal energy requirements are greatly reduced. Thus, the invention involves a redistribution of thermal energy input such that the majority of the thermal energy in the form of hot process water is expended at the slurry mixing step rather than at both the slurry mixing step and slurry flooding step.

By "slurry conditioning" is meant digestion of oil sand lumps, liberation of bitumen from sand-fines-bitumen matrix, coalescence of liberated bitumen flecks into larger bitumen droplets and aeration of bitumen droplets.

By "hot slurry water" is meant process water having a temperature sufficient to yield an oil sand slurry of the desired temperature and generally refers to water that has been heated to a temperature greater than 50°C and, more preferably, to a temperature of between about 70°C and about 95°C.

By "cold flood water" is meant process water that has not been heated. It is understood that the temperature of the cold flood water can vary greatly, depending on the source of the water, the time of year, etc. Generally speaking, however, cold flood water will have a temperature less than 50°C and more likely will have a temperature between about 2°C and about 27°C. By way of example, recycled pond water could be used, which typically has a temperature in the range of about 5°C to about 10°C.

Surprisingly, it was discovered that cold flood water at a wide range of temperatures could be used to dilute the conditioned slurry without incurring any significant losses in rejects free bitumen recovery when compared to a process where approximately the same temperature is maintained in the slurry mixing step and the slurry flooding step, thereby conserving thermal energy.

In a preferred embodiment, the temperature of the hot slurry water used in the slurry mixing step is about 75°C to about 85°C, which, when mixed with the oil sand, results in an oil sand slurry having a temperature greater than 40°C, preferably greater than 43°C, and more preferably in the range of about 40°C to about 55°C, and a density in the range of about 1.5 g/cc to about 1.6 g/cc. Caustic soda (NaOH) and other processing aids can be also added at this step, if necessary or desired.

The conditioning step can be performed either by pumping the oil sand slurry through a pipeline of sufficient length (*e.g.*, typically greater than about 2.5 km), or by agitating the oil sand slurry in a tumbler or agitation tank for a sufficient period of time, so that liberation of bitumen from sand and subsequent aeration of bitumen both have time to occur. Preferably, conditioning time is about 7 to about 12 minutes when using a tumbler and/or agitation tank and 10 minutes or more when using a pipeline of sufficient length.

The cold flood water temperature used in the flooding step generally ranges between 5°C and 25°C, which results in a flooded or diluted slurry having a temperature of about 25°C to about 40°C and a density of about 1.4 g/cc to about 1.5 g/cc. More preferably, the diluted slurry will have a density of about 1.4 g/cc to about 1.45 g/cc and a temperature in the range of about 30°C to about 40°C, preferably, a temperature of about 35°C. Use of cold flood water for flooding eliminates the need to import heated water from other sources, and readily available, lower quality pond water can be used.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram setting forth the process in accordance with an embodiment of the invention.

FIG. 2 is a schematic of the pilot plant used in connection with the development of the invention.

FIG. 3 is a schematic of an industrial scale system for practicing the process.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The invention is exemplified by the following description and examples.

A schematic of the pilot plant used in the following examples is shown in FIG. 2. Oil sand, mixing (tumbler) water and, optionally, caustic (NaOH) are added to tumbler 2 where the oil sand is mixed with the water to form a slurry. Residence time of the slurry in the tumbler is generally around 2.0 minutes. The slurry is then screened through reject screen (not shown) having 5/16" square openings and rejects, *i.e.* oil sand lumps, greater than 5/16" are discarded.

The slurry is then transferred to an agitated pumpbox or mixing tank 4 to keep the slurry in suspension. Residence time of the slurry in the agitated pumpbox or mixing tank 4 is about 5 minutes. Slurry is then pumped via Moyno 3L6 pump 6 through a coriolis mass flow meter (not shown) to conditioning pipeline loop 8 comprised of 4-inch pipe where the slurry undergoes conditioning. Pipeline loop 8 is approximately 40 meters in length and was designed to provide a mean residence time of approximately 5 minutes. Thus, the total residence time of the oil sand slurry in the tumbler, the agitated pumpbox or mixing tank, and the pipeline is about 12 minutes.

After leaving the pipeline, the conditioned slurry is flooded (diluted) with flood water and additional air may be added to the diluted slurry via centrifugal pump 10 (a Warman 2" x 1.5" centrifugal pump, equipped with a 10 Hp motor) situated on slurry pipeline 12 which leads to the feedwell (not shown) of primary separation vessel (PSV) 14. The pipeline between centrifugal pump 10 and PSV feedwell is 1.25" in diameter and 15 meters long. Centrifugal pump 10 is typically operated at a constant speed of 700 RPM. Air is added to the suction side of pump 10 through a 3/8" line to a "T" junction on the 1" slurry pipeline 12'.

Froth underwash water is added to PSV 14 at a point beneath the layer of bitumen froth that forms. Optionally, caustic (NaOH) can also be added as a process aid via caustic line 16, comprising 0.25" stainless steel tubing. In addition to this caustic line, there are two more caustic lines 18 and 20 where NaOH can be added. Separated bitumen froth overflows into launder 22 and is removed into a separate froth weigh tank (not shown). This bitumen froth from the PSV is commonly referred to as primary froth.

Middlings, comprising water, bitumen and solids that collect in the mid-section of the PSV 14, are removed to one or more secondary flotation cells 20, each having impellers, to produce lean bitumen flotation froth. This lean froth is then recycled back into PSV 14 for recovery as bitumen froth.

It should be noted that the pilot plant uses a tumbler for slurry mixing, with an average slurry mixing time of approximately 2 minutes, and a rejects screen having 5/16" square openings. However, when the invention is commercially practiced (see FIG. 3), a mix box is used for slurry preparation, with 5" openings in the rejects screens and rejects reprocessing. Thus, the percent rejects free bitumen recovery values obtained in the following examples using the pilot plant more accurately reflect the values obtained on a commercial scale.

Overall bitumen recovery is calculated as shown in equation 1 and rejects free bitumen recovery is calculated as shown in equation 2, as follows:

$$R_o = \frac{M_{pf} X_{B,pf}}{M_{os} X_{B,os}} \times 100 \qquad (1)$$

$$R_{RF} = \frac{M_{pf} X_{B,pf}}{M_{os} X_{B,os} - M_r X_{B,r}} \times 100 \qquad (2)$$

where R_o is the overall bitumen recovery, R_{RF} is the rejects free bitumen recovery, M is the mass flow rate, X is the mass fraction, and the subscripts pf, r, os and B refer to PSV froth, reject, oil sand and bitumen, respectively.

Two oil sand samples having different bitumen and fines concentrations were used in the following examples. In particular, the two oil sand samples tested were estuarine ores from the Aurora mine in Alberta and are designated Oil Sand 1 and Oil Sand 2. The specifications of the two samples used are given in Table 1.

Table 1: Summary of Composition, Fines and d_{50} Data

Oil Sand	Bitumen wt.%	Water wt.%	Solids wt.%	Fines wt.%<44µm in size	Average size of solids (d_{50} µm)
Oil Sand 1	10.4	3.5	86.0	24	124
Oil Sand 2	11.5	4.5	83.7	17	131

Table 2 summarises the operating conditions used to test the two samples in Table 1 in the pilot plant described above.

Table 2: Operating Conditions of the Pilot Plant

Parameter	**Value**
Tumbler (RPM)	5
Tumbler Weir Height (%)	0
Mix Tank Agitator (RPM)	275
Mix Tank Slurry Level (%)	53
Pipeline Slurry Velocity (m/s)	4
Centrifugal Aerator Pump Speed (RPM)	700
Air/PSV Feed Slurry Ratio (vol/vol)	0.2
Number of Flotation Cells Operating	4
Flotation Cells Impeller (RPM)	800
Air/Flotation Ratio (vol/vol)	1.42

Example I

Oil Sand 1 having the composition as shown in Table 1 was tested to see what effect, if any, the redistribution of available heat would have on the overall bitumen recovery and, in particular, the rejects free bitumen recovery. The parameters tested and the results for 7 separate conditions are shown in Table 3.

Table 3: Effects of Heat Redistribution Using Oil Sand 1

Run Condition ID	1	2	3		4	5		6	7
Target Pipeline Slurry Temperature (°C)	45	45	45		35	35		25	25
Actual Pipeline Slurry Temperature (°C)	44	45	45		34	35		25	25
Pipeline Slurry Density (g/cc)	1.58	1.58	1.58		1.58	1.58		1.58	1.58
Flood Water Temperature (°C)	55	27	10		55	10		55	10
Target PSV Temperature (°C)	>45	42	<45		42	<35		>25	<25
Actual PSV Temperature (°C)	47	40	36		40	29		35	23
Target Underwash Water Temperature (°C)	60	60	60		60	60		60	60
Bitumen Recovery (Overall) (%)	94.2	95.7	96.5		93.7	93.7		86.9	89.4
Bitumen Recovery (Rejects free) (%)	98.5	98.3	98.6		97.6	97.2		94.4	93.2
Rejects Bitumen Loss (%)	4.3	2.6	2.1		4.0	3.5		8.0	4.0
PSV Froth Bitumen (%)	59.5	53.2	56.2		59.5	53.3		53.7	53.1
PSV Froth Solid (%)	16.7	14.9	15.4		16.6	16.2		14.6	16.9
PSV Middlings Bitumen (%)	0.13	0.13	0.10		0.50	1.09		2.07	4.43
PSV Tails Bitumen (%)	0.11	0.13	0.10		0.18	0.21		0.48	0.50
Flotation Unit Bitumen Recovery (%)	56.5	35.0	26.9		73.1	90.8		93.8	94.2
Flotation Tails Bitumen (%)	0.07	0.08	0.08		0.09	0.12		0.14	0.30

Run condition **1** is comparable to conditions used in the warm slurry extraction process as described above, wherein the pipeline slurry (*i.e.*, oil sand slurry) temperature is between 40°C and 55°C (preferably ~50°C) and flood water temperature is about 50°C to about 65°C to give a diluted slurry (*i.e.*, PSV temperature) having a temperature around 50°C. However, as discussed above, the warm slurry extraction process still requires considerable thermal energy, in particular, to heat the flood water to maintain a diluted slurry temperature of 50°C.

In an attempt to determine if cold flood water could be used to conserve energy ordinarily used to heat the flood water without a significant reduction in bitumen recovery, run conditions **2** and **3** were performed using much lower temperature flood water.

Run conditions **2** and **3** used essentially the same temperature pipeline slurry as in run condition **1** (*i.e.*, around 45°C). However, run condition **2** used cold flood water at a temperature of 27°C, to give a diluted slurry having a final temperature of 40°C (*i.e.*, actual PSV temperature), and run condition **3** used cold flood water having an even lower temperature of 10°C to give a diluted slurry temperature of 36°C.

Surprisingly, the results in Table 3, in particular, the percent bitumen recovery (rejects free) values, show that the use of lower flood water temperatures did not result in lower rejects free bitumen recovery but rather the rejects free bitumen recovery remained comparatively constant as the temperature of the flood water decreased. Rejects free bitumen recovery was 98.5% when using run condition **1** and 98.6% when using the coldest flood water of run condition **3**. Hence, by using cold flood water, the cost of thermal energy is reduced without a reduction in the rejects free bitumen recovery.

Run condition **6** uses an oil sand slurry temperature at the lower end of the temperature range of the LEE process as described above. Pipeline slurry temperature in this run is 25°C and flood water temperature is around 55°C to give a diluted slurry having a temperature around 35°C. Rejects free bitumen recovery using the LEE process at the lower temperature range was 94.4%.

The pipeline slurry temperature in run condition **7** was also 25°C, as in run condition **6**. However, in this run, cold flood water at a temperature of 10°C was used instead of hot water to give a diluted slurry having a final temperature of 23°C. Surprisingly, the use of cold flood water did not significantly reduce the rejects free bitumen recovery (*i.e.*, 93.2% in run **7** versus 94.4% for run **6**). Thus, the rejects free bitumen recovery using the LEE process was not significantly affected by the use of cold flood water.

Run condition **4** uses an oil sand slurry temperature at the upper end of the temperature range of the LEE process. Pipeline slurry temperature is 35°C and flood water temperature is around 55°C to give a diluted slurry having a temperature around 40°C. Rejects free bitumen recoveries using the LEE process at the higher temperature were improved from those in run condition **6** (*i.e.*, 97.6% for run **5** versus 94.4% for run **6**). This is likely due to better pipeline conditioning when higher slurry temperatures are used.

Run condition **5** also used a pipeline slurry temperature of 35°C, as in run condition **4**. However, in this run, cold flood water at a temperature of 10°C, was used instead of hot water to give a diluted slurry having a final temperature of 29°C. Once again, the use of cold flood water did not result in a decrease in rejects free bitumen recoveries; the rejects free bitumen recoveries were the same for run conditions **4** and **5**. Thus, the rejects free bitumen recoveries were not affected by use of cold flood water to dilute the conditioned slurry.

One of the most surprising observations came from the comparison of run condition **6** and run condition **3**. The overall heat inputs were the same for these two runs. However, the rejects free bitumen recoveries were significantly different. Run condition **6**, using the LEE process, gave a rejects free bitumen recovery of only 94.4%. However, using essentially the same thermal energy, run condition **3** gave a rejects free bitumen recovery of 98.6%, an increase of more than 4%. Those in the industry will appreciate the economic significance of such an increase in overall bitumen recovery.

Further when comparing the results obtained in run **3** and run **6**, it should also be noted that increased temperature during slurry preparation (as in run **3**) resulted in reduced reject bitumen losses (*i.e.*, 2.1% in run **3** versus 8.0% in run **6**) and, consequently, even greater gains in overall bitumen recovery (*i.e.*, 96.5 % in run **3** versus 86.9 % in run **6**). Yet, the process in run **3** is still a low energy process.

In summary, the results in Table 3, and, in particular, the comparison of runs **3** and **6**, demonstrate that, by redistributing the overall thermal energy input up front in the slurry mixing step, improved bitumen recovery can be obtained without expending any additional thermal energy.

Example 2

Oil Sand 2 having the composition as shown in Table 1 was also tested to see what effect, if any, the redistribution of available heat would have on the rejects free bitumen recovery. The parameters tested and the results for 6 separate conditions are shown in Table 4.

Table 4: Effects of Heat Redistribution Using Oil Sand 2

Run Condition ID	1	2		3	4		5	6
Target Pipeline Slurry Temperature (°C)	45	45		35	35		25	25
Actual Pipeline Slurry Temperature (°C)	45	44		35	35		25	25
Pipeline Slurry Density (g/cc)	1.58	1.58		1.58	1.58		1.58	1.58
Flood Water Temperature (°C)	55	10		55	10		55	10
Target PSV Temperature (°C)	>45	<45		42	<35		>25	<25
Actual PSV Temperature (°C)	47	36		41	30		34	24
Target Underwash Water Temperature (°C)	60	60		60	60		60	60
Bitumen Recovery (Overall) (%)	98.0	98.6		97.4	95.7		91.6	92.6
Bitumen Recovery (Rejects free) (%)	98.7	98.9		98.4	97.8		97.2	97.4
Rejects Bitumen Loss (%)	0.7	0.3		0.9	2.2		5.8	4.9
PSV Froth Bitumen (%)	62.0	59.9		59.2	65.5		73.0	64.9
PSV Froth Solid (%)	15.1	15.4		16.8	17.3		13.6	14.0
PSV Middlings Bitumen (%)	0.31	0.33		0.50	0.48		1.33	1.85
PSV Tails Bitumen (%)	0.11	0.07		0.13	0.18		0.22	0.19
Flotation Unit Bitumen Recovery (%)	95.5	69.8		87.8	87.2		95.2	90.9
Flotation Tails Bitumen (%)	0.02	0.13		0.07	0.08		0.09	0.19

The results shown in Table 4 confirm that the use of cold flood water when extracting bitumen from oil sand with either the warm slurry extraction process (run condition **1**) or the LEE process (run condition **3** and **5**) does not result in reduced rejects free bitumen recovery. In fact, when one again compares run condition **5** with run condition **2**, where the overall heat inputs were the same, the use of the thermal energy up front when preparing the pipeline slurry resulted in an increase in rejects free bitumen recovery. Run condition **5**, the LEE process at the lower temperature range, gave a rejects free bitumen recovery of 97.2%. However, using essentially the same thermal energy, run condition **2** gave a rejects free bitumen recovery of 98.9%, an increase of 1.6%. Such an increase in rejects free bitumen recovery is still economically significant.

As was the case in example 1, increased temperature during slurry preparation in run **2** also resulted in reduced reject bitumen losses and therefore further gains in overall bitumen recovery (*i.e.*, 98.6% in run **2** versus 91.6% in run **5**).

Example 3

The effect of increasing pipeline slurry density on extraction performance using Oil Sand 1 was determined using the improved low energy extraction process of run condition **3** of Table 3. Results are shown in Table 5.

Table 5: Effects of Increasing Pipeline Slurry Density Using Oil Sand 1

Run Condition ID	1	2
Target Pipeline Slurry Temperature (°C)	45	45
Actual Pipeline Slurry Temperature (°C)	44	45
Pipeline Slurry Density (g/cc)	1.58	1.65
Flood Water Temperature (°C)	10	10
Target PSV Temperature (°C)	<45	32
Actual PSV Temperature (°C)	36	34
Target Underwash Water Temperature (°C)	60	60
Bitumen Recovery (Overall) (%)	96.5	95.6
Bitumen Recovery (Rejects free) (%)	98.6	95.9
Rejects Bitumen Loss (%)	2.1	0.3
PSV Froth Bitumen (%)	56.2	48.6
PSV Froth Solid (%)	15.4	16.4
PSV Middlings Bitumen (%)	0.10	9.20
PSV Tails Bitumen (%)	0.10	0.23
Flotation Unit Bitumen Recovery (%)	26.9	94.8
Flotation Tails Bitumen (%)	0.08	0.59

Increasing the density of the pipeline slurry from 1.58 g/cc to 1.65 g/cc resulted in significant increase in PSV middlings bitumen content (from 0.1 to 9.2%). Overall bitumen recovery was not significantly reduced due to good performance of flotation and middlings displacement. However, in commercial practice, the flotation system may not work as efficiently. Thus, a high middling bitumen content may result in higher bitumen losses.

Increasing the density of the pipeline slurry from 1.58 g/cc to 1.65 g/cc, however, resulted in a decrease in rejects free bitumen recovery of 2.7 %. Thus, a slurry density of 1.58 g/cc resulted in better rejects free bitumen recovery.

Example 4

The effect of increasing pipeline slurry density on extraction performance using Oil Sand 2 was determined using the improved low energy extraction process of run condition **2** of Table 4. Results are shown in Table 6.

Table 6: Effects of Increasing Pipeline Slurry Density Using Oil Sand 2

Run Condition ID	1	2
Target Pipeline Slurry Temperature (°C)	45	45
Actual Pipeline Slurry Temperature (°C)	44	45
Pipeline Slurry Density (g/cc)	1.58	1.65
Flood Water Temperature (°C)	10	10
Target PSV Temperature (°C)	<45	32
Actual PSV Temperature (°C)	36	35
Target Underwash Water Temperature (°C)	60	60
Bitumen Recovery (Overall) (%)	98.6	95.3
Bitumen Recovery (Rejects free) (%)	98.9	96.5
Rejects Bitumen Loss (%)	0.3	2.3
PSV Froth Bitumen (%)	59.9	63.6
PSV Froth Solid (%)	15.4	15.4
PSV Middlings Bitumen (%)	0.33	7.77
PSV Tails Bitumen (%)	0.07	0.19
Flotation Unit Bitumen Recovery (%)	69.8	94.0
Flotation Tails Bitumen (%)	0.13	0.59

Increasing the density of the pipeline slurry from 1.58 g/cc to 1.65 g/cc resulted in significant increase in PSV middlings bitumen content (from 0.33 to 7.77%). Further, the rejects free bitumen recovery was reduced from 98.9% to 96.5%. Once again, a slurry density of 1.58 g/cc resulted in better bitumen recovery.

Example 5

The effect of decreasing pipeline slurry density on extraction performance using Oil Sand 2 was determined using a target pipeline slurry temperature of 27°C. Results are shown in Table 7.

Table 7: Effects of Decreasing Pipeline Slurry Density Using Oil Sand 2

Run Condition ID	1	2
Target Pipeline Slurry Temperature (°C)	27	27
Actual Pipeline Slurry Temperature (°C)	27	26
Pipeline Slurry Density (g/cc)	1.58	1.49
Flood Water Temperature (°C)	47	4
Flooded Slurry Density (g/cc)	1.46	1.46
Actual PSV Temperature (°C)	32	27
Target Underwash Water Temperature (°C)	N/A	47
Bitumen Recovery (Overall) (%)	95.5	92.8
Bitumen Recovery (Rejects free) (%)	98.6	96.6
Rejects Bitumen Loss (%)	3.2	4.0
PSV Froth Bitumen (%)	59.7	54.9
PSV Froth Solid (%)	13.5	14.0
PSV Middlings Bitumen (%)	0.64	2.69
PSV Tails Bitumen (%)	0.13	0.29
Flotation Unit Bitumen Recovery (%)	90.1	95.3
Flotation Tails Bitumen (%)	0.09	0.15

Decreasing the density of the pipeline slurry from 1.58 g/cc to 1.49 g/cc resulted in a reduction of rejects free bitumen recovery from 98.6% to 96.6%. Again, a slurry density of 1.58 g/cc resulted in better overall bitumen recovery.

Turning now to FIG. 3, a schematic is shown of an industrial scale system for practicing the invention.

More particularly, oil sand is surface mined and fed into a primary crusher 30 of the double roller type, to reduce the oversize to less than 24". The crushed oil sand is carried by conveyer to surge pile 34 of oil sand. Oil sand from surge pile 34 is fed by conveyer 36 to a mix box 38, comprising a plurality of inclined plates 40. Hot slurry water is also added to the mix box to form an oil sand slurry. Mixing can also occur in a cyclofeeder as is known in the art.

Product slurry 54 leaves the bottom outlet 56 of mix box 38 and passes through screen 42 and, optionally, more hot slurry water is added. Product slurry enters a pump box 52 and rejects 44 are fed to an impact crusher 46 and screened again through screen 48. Oversize rejects 58 are discarded but screened material enters pump box 50, where more hot slurry water is added and then oil sand slurry is pumped into pump box 52.

Oil sand slurry in pump box 52 is then pumped by a series of pumps 60 through conditioning pipeline 62 and, optionally, air, frother and other process aids may be added. Conditioned oil sand slurry is then pumped via pump through a second section 66 of pipeline where cold flood water is added and, optionally, more air is added. Diluted slurry is then introduced into primary separation vessel 68 and retained under quiescent conditions, to allow the solids to settle and the bitumen froth to float to the top. A froth underwash of hot water is added directly beneath the layer of bitumen froth to aid in the separation. Bitumen froth, which is called primary froth, is removed from the top of the primary separation vessel 68 and then deaerated in froth deaerator 72. Once deaerated, primary froth is retained in froth tank 74.

Middlings from primary separation vessel 68 are removed and undergo flotation in flotation cells 70 to produce secondary froth. Secondary froth is recycled back to the primary separation vessel 68. Tailings, the solids, water, etc. that collects at the bottom of the primary separation vessel 68 are removed and deposited into tailings pond 76.

WE CLAIM:

1. A method for recovering bitumen from oil sand, comprising:

dry mining oil sand at a mine site;

mixing the oil sand with sufficient hot slurry water to produce an oil sand slurry containing bitumen, sand, water and entrained air, the oil sand slurry having a density in the range of about 1.50 g/cc to about 1.65 g/cc and a temperature in the range of about 40°C to about 70°C;

conditioning the oil sand slurry;

flooding the conditioned oil sand slurry with cold flood water to produce a diluted slurry; and

introducing the diluted slurry into a gravity separation vessel wherein separate layers of bitumen froth, middlings and sand tailings are formed; and

separately removing bitumen froth, middlings and sand tailings from the vessel.

2. The method as set forth in claim 1 wherein the hot slurry water has a temperature in the range of about 70°C to about 95°C.

3. The method as set forth in claim 1 wherein the oil sand slurry has a temperature in the range of about 40°C to about 55°C.

4. The method as set forth in claim 3 wherein the oil sand slurry has a temperature greater than about 43°C.

5. The method as set forth in claim 1 wherein the oil sand slurry has a temperature in the range of about 40°C to about 50°C.

6. The method as set forth in claim 1 wherein the oil sand slurry has a temperature in the range of about 40°C to about 45°C.

7. The method as set forth in claim 1 wherein caustic is added during the mixing step.

8. The method as set forth in claim 1 wherein the conditioning step comprises pumping the oil sand slurry through a pipeline.

9. The method as set forth in claim 8 wherein the pipeline has sufficient length so that a slurry retention time therein is at least 10 minutes.

10. The method as set forth in claim 1 wherein the conditioning step comprises retaining the oil sand slurry in a tumbler or agitation tank.

11. The method as set forth in claim 10 wherein the slurry retention time in the tumbler and/or agitation tank is between about 7 minutes to about 12 minutes.

12. The method as set forth in claim 1 wherein the oil sand slurry has a density in the range of about 1.50 g/cc to about 1.60 g/cc.

13. The method as set forth in claim 1 wherein the diluted slurry has a density in the range of about 1.4 g/cc to about 1.5 g/cc.

14. The method as set forth in claim 13 wherein the diluted slurry has a density in the range of about 1.45 g/cc to about 1.5 g/cc.

15. The method as set forth in claim 1 wherein the cold flood water has a temperature in the range of about 2°C to about 50°C.

16. The method as set forth in claim 1 wherein the cold flood water has a temperature in the range of about 2°C to about 27°C.

17. The method as set forth in claim 1 wherein the flood water has a temperature in the range of about 5°C to about 10°C.

18. The method as set forth in claim 1 wherein the diluted slurry has a temperature in the range of about 25°C to about 40°C.

19. The method as set forth in claim 1 wherein the diluted slurry has a temperature in the range of about 30°C to 35°C.

20. The method as set forth in claim 1 comprising:

heating bitumen in the vessel by adding heated water as an underwash layer immediately beneath the bitumen froth layer.

21. The method as set forth in claim 1 wherein the oil sand is of about low to average grade.

22. The method as set forth in claim 1 wherein the oil sand slurry has a density in the range of about 1.55 g/cc to about 1.60 g/cc.

23. The method as set forth in claim 1 wherein the mixing step occurs in a mix box or cyclofeeder.

Application number/numéro de demande: 2,506,398

Figures: 3.

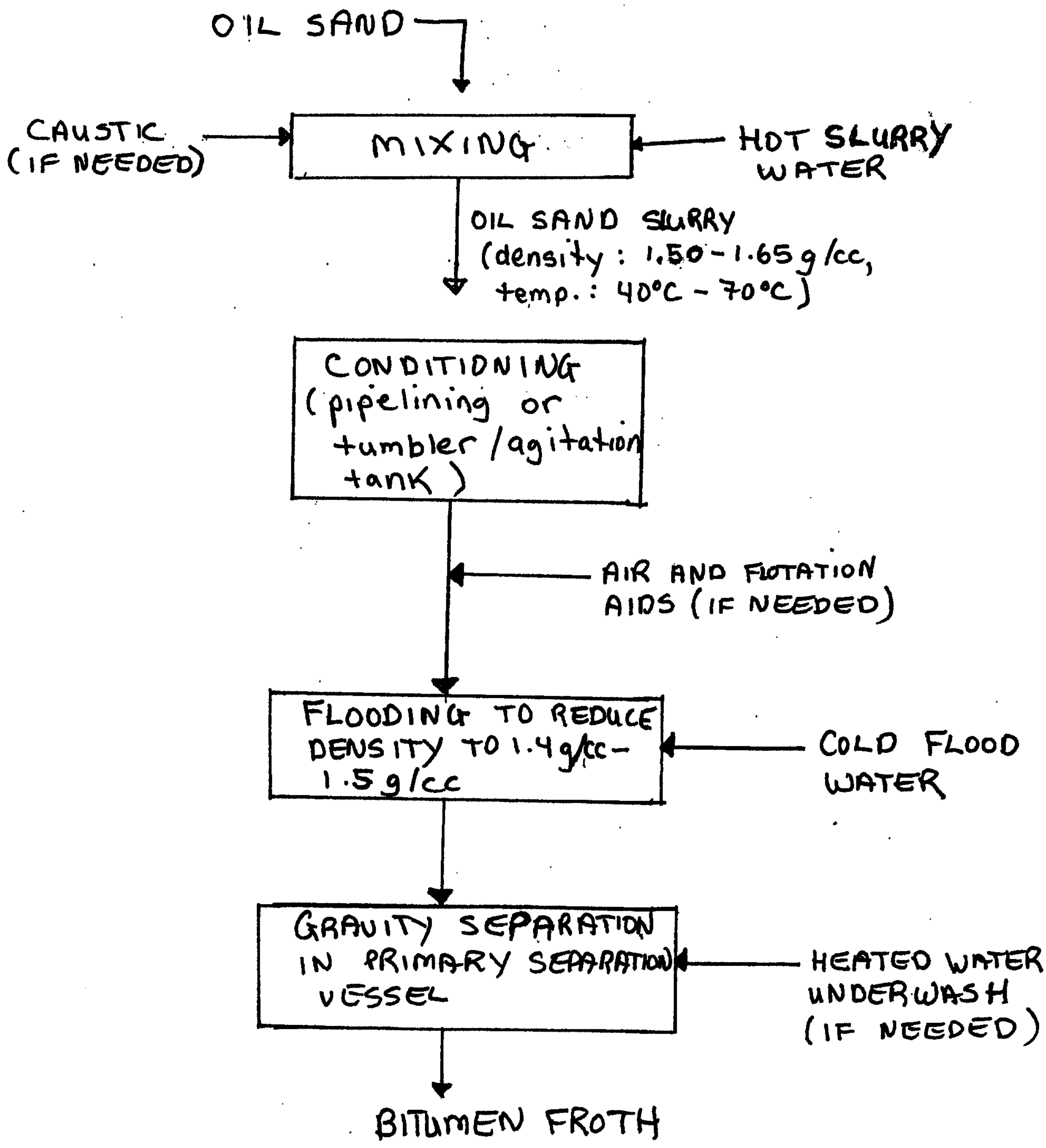
Pages: 3

DRW-1P

Unscannable items
received with this application
(Request original documents in File Prep. Section on the 10th Floor)

Documents reçus avec cette demande ne pouvant être balayés
(Commander les documents originaux dans la section de préparation des dossiers au 10ième étage)

FIG. 1


OIL SAND
CAUSTIC (IF NEEDED)
MIXING
HOT SLURRY WATER
OIL SAND SLURRY (density: 1.50-1.65 g/cc, temp.: 40°C - 70°C)
CONDITIONING (pipelining or tumbler/agitation tank)
AIR AND FLOTATION AIDS (IF NEEDED)
FLOODING TO REDUCE DENSITY TO 1.4 g/cc - 1.5 g/cc
COLD FLOOD WATER
GRAVITY SEPARATION IN PRIMARY SEPARATION VESSEL
HEATED WATER UNDERWASH (IF NEEDED)
BITUMEN FROTH

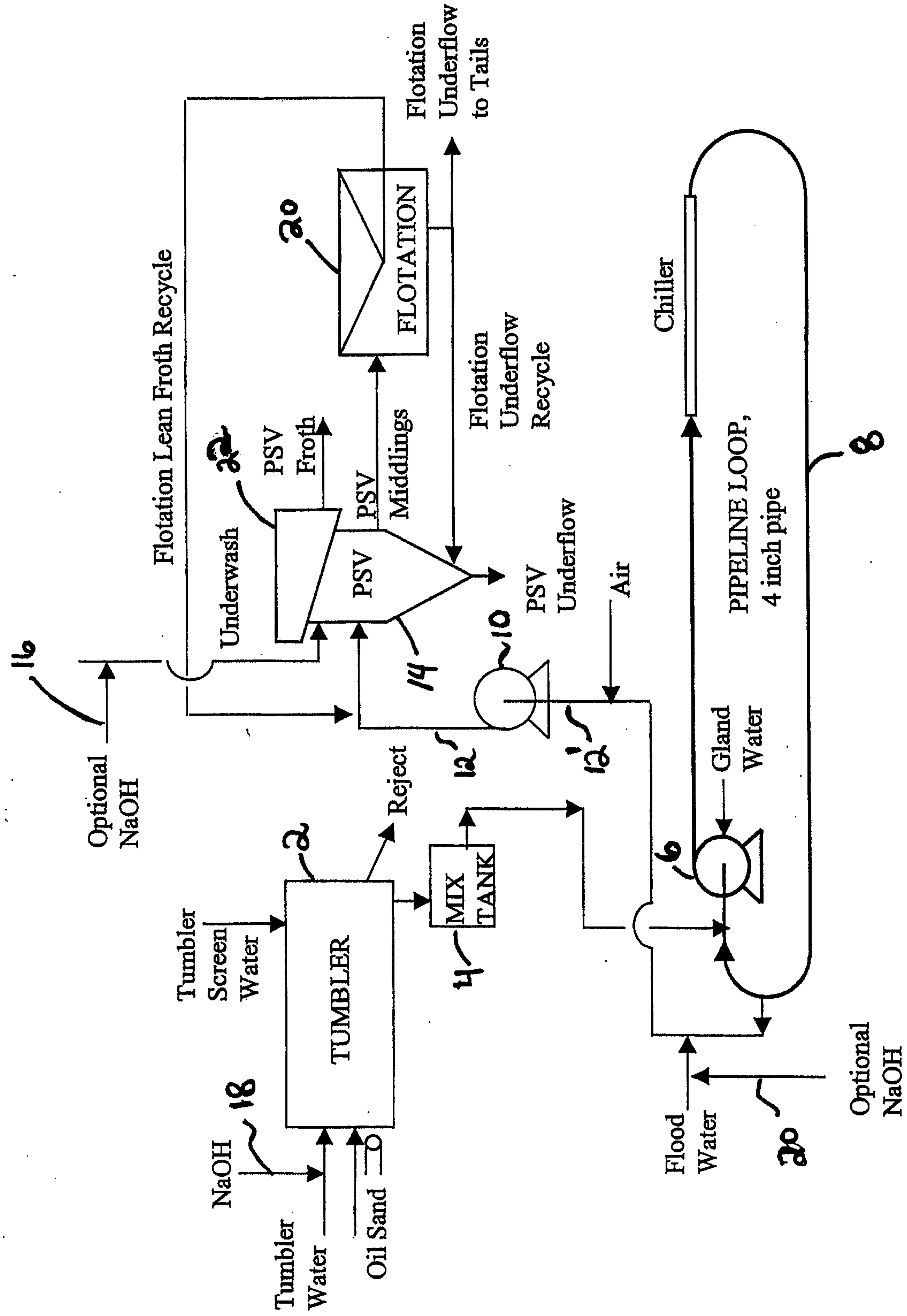
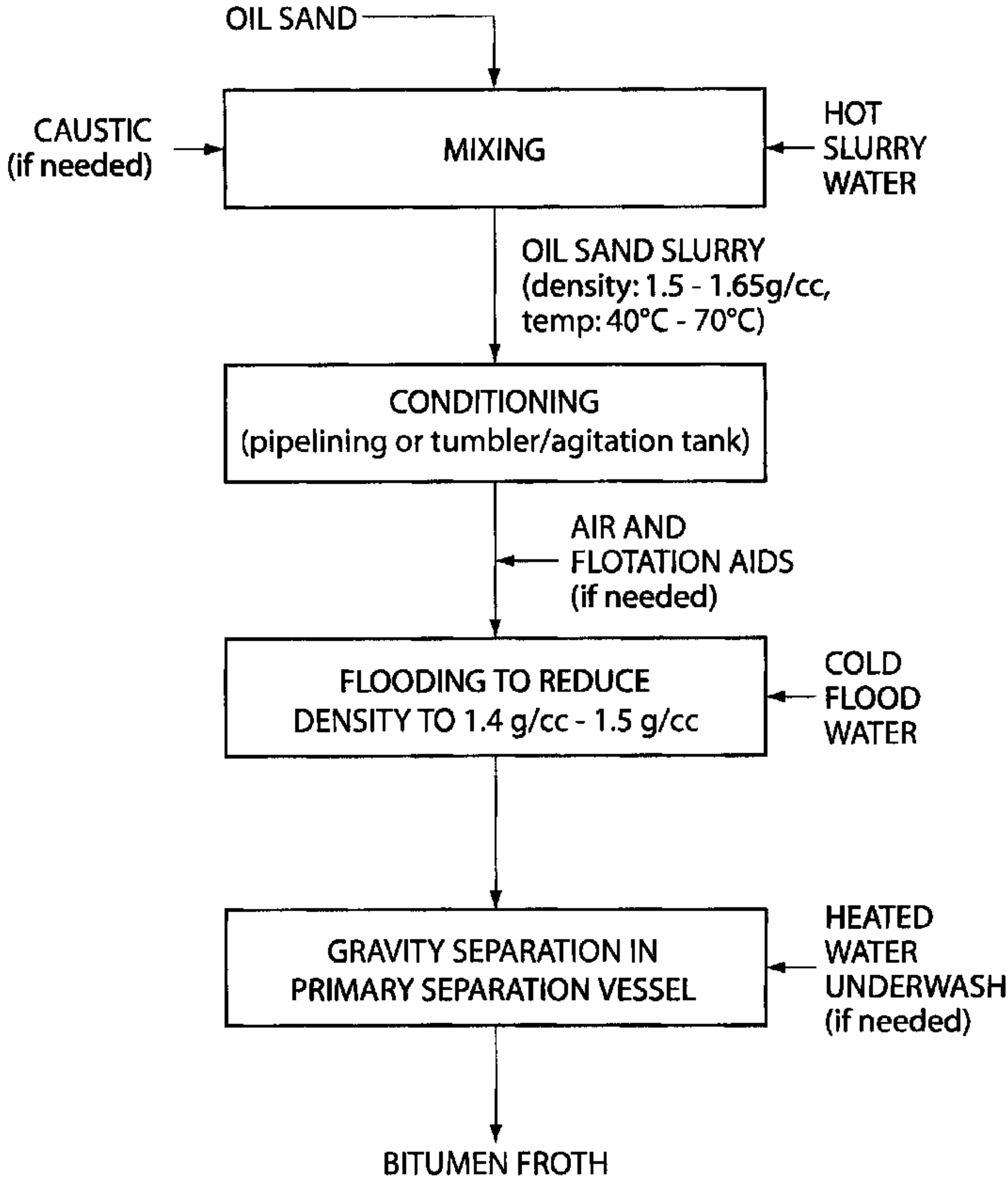

Flotation Lean Froth Recycle
Flotation Underflow to Tails
FLOTATION
20
Chiller
Flotation Underflow Recycle
PSV Froth
22
PSV Middlings
Underwash
PSV
PSV Underflow
Air
PIPELINE LOOP, 4 inch pipe
8
16
14
10
12
12
Optional NaOH
Reject
2
MIX TANK
4
Gland Water
6
Tumbler Screen Water
TUMBLER
18
NaOH
Tumbler Water
Oil Sand
Flood Water
Optional NaOH
20

FIG. 2



OIL SAND
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