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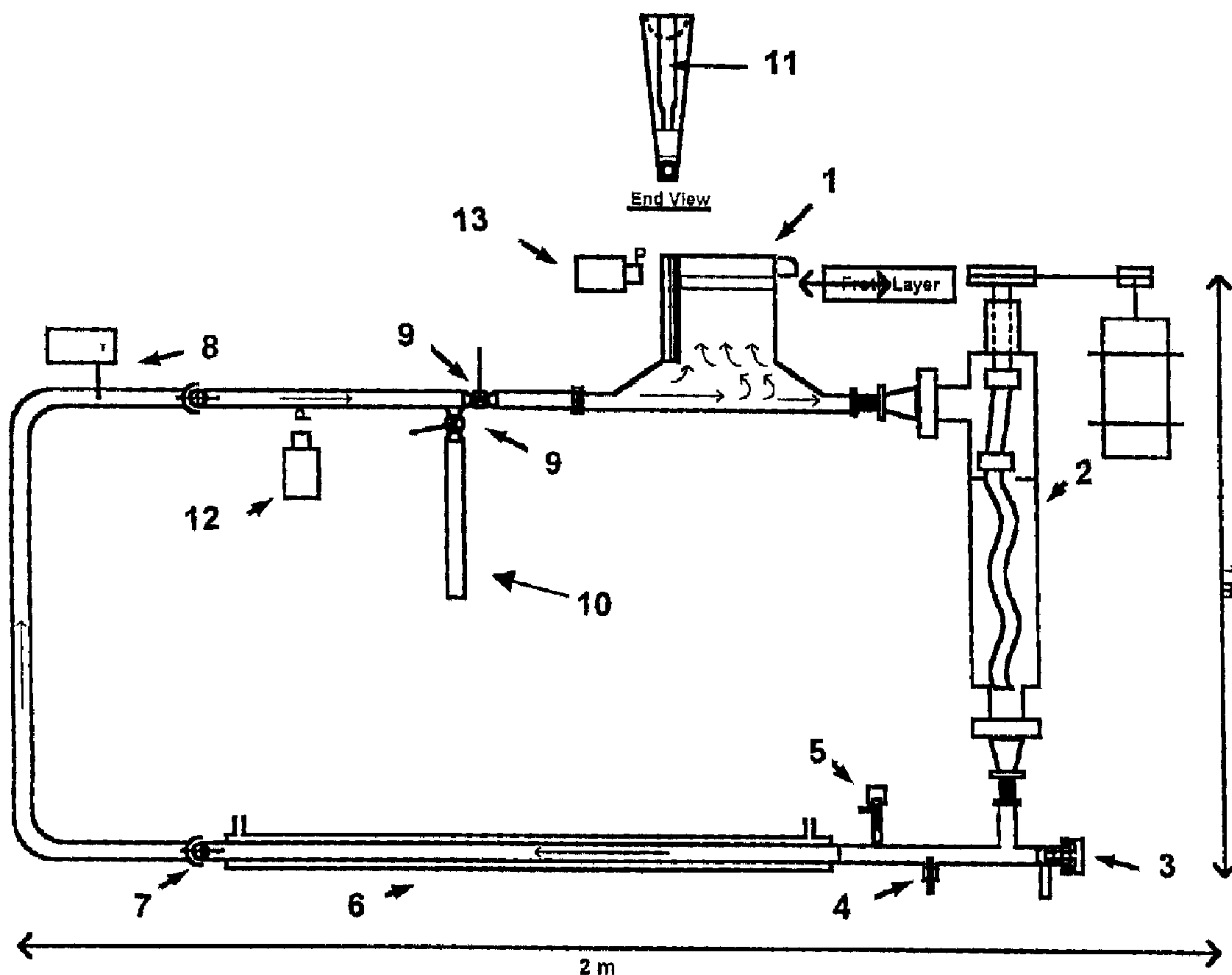
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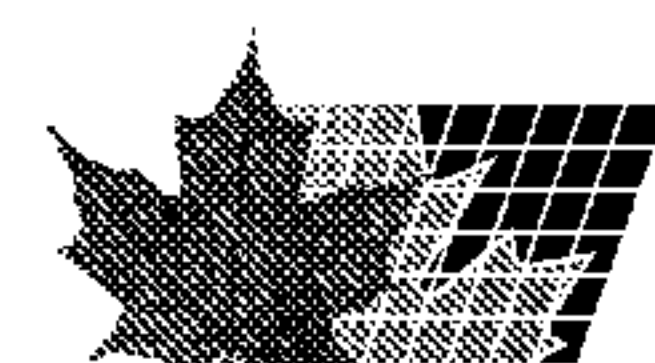
(54) Titre : METHODE DE RECUPERATION D'HYDROCARBURES PRESENTS DANS DES ECHANTILLONS

(54) Title: METHOD FOR RECOVERING HYDROCARBONS FROM SAMPLES



(57) Abrégé/Abstract:

The present invention relates to a method and system of recovering petroleum-like hydrocarbons from hydrocarbon-containing samples wherein a modifying additive, such as a hydrocarbon, is added to an accompanying gas to form bubbles that are highly suitable for separating bitumen/oil from the hydrocarbon-containing sample using aqueous-based separation techniques.



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ABSTRACT OF THE DISCLOSURE

The present invention relates to a method and system of recovering
5 petroleum-like hydrocarbons from hydrocarbon-containing samples wherein a
modifying additive, such as a hydrocarbon, is added to an accompanying gas
to form bubbles that are highly suitable for separating bitumen/oil from the
hydrocarbon-containing sample using aqueous-based separation techniques.

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TITLE: Method for Recovering Hydrocarbons from Samples**FIELD OF THE INVENTION**

The present invention relates to a method and system for recovering
5 petroleum-like hydrocarbons from hydrocarbon-containing samples.

BACKGROUND OF THE INVENTION

Bitumen reserves in northern Alberta that are recoverable via surface
mining techniques are estimated at 152 billion barrels (Alberta Energy and
Utilities Board, 1996). Open pit mines operated by Suncor Energy Inc. and
10 Syncrude Canada Ltd. in the Fort McMurray region produce in excess of
200,000 barrels of bitumen a day. By 2010, expansion of existing plants and
new construction will increase crude oil production from oil sands to meet 50
percent of Canada's total energy needs. Temperature, chemistry, surfactants,
mechanical energy and composition have all been identified as contributing
15 factors to bitumen processing characteristics (Clark, 1944; Clark and
Pasternack, 1932, 1949; Sanford and Seyer, 1979; Bichard, 1987; Sanford
1983; Schramm et al., 1984 and 1985; Kasongo et al. 2000). As the density
of bitumen is nearly the same as that of water, bitumen-air attachment and
subsequently, bitumen flotation, plays a major role in a successful bitumen
20 recovery process. Kasongo et al. (2000) found that the presence of
montmorillonite clays together with high levels of calcium hinders the bitumen-
air attachment process. A more recent study by Liu et al. (2002a), using
electrophoretic mobility measurements showed that calcium ions bridge
themselves to the bitumen and the clays thereby rendering the bitumen
25 surface hydrophilic. The resultant hydrophilic bitumen surface becomes less
susceptible to air attachment. When normal oil sands, containing little clays
and low calcium ions, are processed high bitumen recovery can be achieved.
In this case, bitumen and air have a strong affinity to each other and the air
attachment to bitumen takes place quite effectively.

30 Oil sands water-based extraction technologies depend on either
entrained air or injected air to float liberated petroleum product, for example
bitumen, from the oil sand grains during extraction processes. The bitumen

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becomes attached to air bubbles and floats to be recovered. In some cases, the bitumen-air attachment step is not efficient or is hindered due to factors related to either the oil sands ore itself or to the water slurry where oil sands digestion takes place. In today's technology, additives are added to the water
5 slurry itself to assist bitumen-air attachment. For example, one known process for recovering bitumen from tar sands requires the use of caustic and hot water or steam. This process has several shortcomings, including inefficient recovery of the hydrocarbons contained in the sands (especially for hard-to-process ores) and the highly caustic nature of both the aqueous and
10 sand/clay residue which means that these residues can not be spread on the land or impounded in lagoons without extensive and expensive neutralization.

Another known method of petroleum recovery from hydrocarbonaceous deposits involves the use of heat to drive the high molecular weight asphaltic or kerogenic material out of the sands. Such a process is highly energy
15 intensive and inefficient.

Bitumen recovery from poor processing ores, often referred to as either oxidized ores or transitional ores, has been found to be generally low, posing a great challenge to the oil sands industry. It should be noted that the term "oxidized ore" has been used rather loosely in industry. Its use mainly reflects
20 that the oxidation of bitumen may be the cause for some poor processing ores. The use of the term "oxidized ore" is acceptable by the industry although its characterization remains a challenge. For such ores, the traditional addition of sodium hydroxide is normally ineffective, except at high dosages, to improve bitumen-air attachment and hence bitumen recovery. As
25 well, results from the addition of light hydrocarbons, such as kerosene, directly to the oil sands slurring liquid medium have not been encouraging.

There remains a need for an improved method of recovering petroleum-like hydrocarbons from hydrocarbon-containing samples, for example geological reservoirs, that allows a much higher percent recovery
30 and improved residue quality. Further, there remains a need for a method for the efficient recovery of petroleum-like hydrocarbons from poor processing ores, such as oxidized ores.

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SUMMARY OF THE INVENTION

A novel method involving the addition of one or more additives to gas (including air) bubbles to assist bitumen flotation and recovery in water-based oil sands extraction techniques has been developed. A hydrocarbon is vaporized and/or atomized into gas and then the gas-carrying-hydrocarbon is injected into the oil sands-water extraction slurry. Hydrocarbon-containing gas bubbles are formed. Due to the addition of the hydrocarbon to the gas, bitumen-bubble attachment is greatly improved thereby increasing bitumen flotation and bitumen recovery. This new method can be applied to the separation of any petroleum-like hydrocarbon from hydrocarbon-containing samples.

Accordingly, the present invention relates to a method of recovering petroleum-like hydrocarbons from hydrocarbon-containing samples using aqueous-based separation techniques comprising:

- (a) providing an aqueous slurry comprising a hydrocarbon-containing sample;
- (b) introducing into the aqueous slurry, a gas comprising an additive, wherein the additive is present in amount sufficient to improve the separation of the hydrocarbons from the hydrocarbon-containing sample; and
- (c) recovering the petroleum-like hydrocarbons.

Using the method of the present invention, the configuration of the petroleum-hydrocarbon recovery process can be made much simpler with a much higher recovery and better froth quality. The chemical additives that are currently injected directly into the slurry can be eliminated to simplify water chemistry and downstream processing. The method is applicable to water-based hot, warm and low temperature (low energy) extraction processes. In addition to normal oil sands ores, the new method is suitable for the recovery of poorly processing oil sand ores, those termed in the oil industry as transitional, oxidized and generally difficult processing ores.

The present invention further relates to a hydrocarbon separation system comprising:

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- (a) a vessel comprising an aqueous slurry, said vessel being any container, pipe, tube or other means that can comprise an aqueous slurry;
- (b) a hydrocarbon-containing sample in the aqueous slurry;
- 5 (c) a gas comprising an additive, wherein the additive is present in amount sufficient to improve the separation of the hydrocarbons from the hydrocarbon-containing sample; and
- (d) a means for introducing said gas into said vessel to enable said gas to pass through and/or circulate within said vessel in a sufficient amount
- 10 and at a sufficient rate to promote recovery of said petroleum-like hydrocarbon from said aqueous slurry.

In an embodiment, the hydrocarbon separation system further comprises a means for separating and/or recovering said petroleum-like hydrocarbon from said aqueous slurry.

- 15 Other features and advantages of the present invention will become apparent from the following detailed description. It should be understood, however, that the detailed description and the specific examples while indicating preferred embodiments of the invention are given by way of illustration only, since various changes and modifications within the spirit and
- 20 scope of the invention will become apparent to those skilled in the art from this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described in relation to the drawings in which:

- 25 Figure 1 is a schematic of an exemplary apparatus that may be used to generate air-additive bubbles for the method of the invention. The produced air bubbles are termed "oily bubbles".
- Figure 2 is a schematic of the Laboratory Hydrotransport Extraction System (LHES) used for the bitumen recovery tests described herein.
- 30 Figure 3 is a graph showing that a large improvement in recovery is demonstrated with the use of air bubbles impregnated with kerosene as an

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additive to recover bitumen from Athabasca oil sand (oxidized ore). The test was performed on a 1 Kg oil sand sample.

Figure 4 is a graph showing that a large improvement in recovery is demonstrated with the use of air bubbles impregnated with kerosene as an
5 additive to recover bitumen from Athabasca oil sand (high fines ore: 30% -44 μm solid size fraction). The test was performed on a 1 Kg oil sand sample.

DETAILED DESCRIPTION OF THE INVENTION

(i) Method

The present inventors have shown that the addition of a surface
10 modifying substance, such as hydrocarbons and/or any suitable liquid or vapor, to an accompanying gas to form bubbles is highly suitable for extracting bitumen/oil using density separation techniques. One advantage of the present invention is that the additives are included in the air and/or other suitable gases prior to or at its injection point into the slurry. The current
15 common practice in the art of bitumen extraction is to add the additives to the slurry itself. As used herein, the words air and gas are used interchangeably.

Accordingly, the present invention relates to a method of recovering petroleum-like hydrocarbons from hydrocarbon-containing samples using aqueous-based separation techniques comprising:

- 20 (a) providing an aqueous slurry comprising a hydrocarbon-containing sample;
- (b) introducing into the aqueous slurry, a gas comprising an additive, wherein the additive is present in amount sufficient to improve the separation of the hydrocarbons from the hydrocarbon-containing
25 sample; and
- (c) recovering the petroleum-like hydrocarbons.

As used herein, hydrocarbon-containing sample is to be taken to include any hydrocarbon-containing medium, for example geological samples such as tar sands, oil sands, oil sandstones, and all other naturally-occurring
30 geologic materials having hydrocarbons contained within a generally porous rock-like inorganic matrix. The sample may also be any hydrocarbon-containing process stream in a hydrocarbon extraction process that contains

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bitumen or other petroleum-like hydrocarbons. Examples of such process streams include tailings and middlings process streams related to bitumen recovery from oil sands.

Tar sands or oil sands are naturally-occurring geological formations found in, for example, Canada (Alberta). Such sands have potential for yielding large amounts of petroleum. Tar sands are unconsolidated sands generally containing substantial amounts of clay and filled with heavy, relatively solid asphaltic hydrocarbons. Most of these tar-like bituminous materials are residues remaining in reservoir rocks after lighter (lower molecular weight) crude oils have escaped. The largest of the world's tar sand deposits occur in northern Alberta along the Athabaska River. Tar sand layers in this area may be more than 60 meters thick and lie near the surface over a total area of about 50,000 km². They are estimated to contain a potential yield in excess of 1.6 trillion barrels of oil.

Additives that may be used in conjunction with air or gases include hydrocarbons, and inorganic and polymeric additives. Additionally a mixture or combination of additives may be used. Any low-viscosity, water-immiscible liquid having some degree of solubility for bitumen can be used as the additive. In an embodiment of the invention, the additive is a hydrocarbon or an inorganic or polymer additive that acts as a hydrocarbon. In another embodiment, the additive is selected from kerosene, toluene and naphtha. In a further embodiment of the invention, the additive is kerosene.

By an "amount sufficient to improve the separation of the hydrocarbons from the hydrocarbon-containing sample" it is meant that the additive is present in the gas in an amount sufficient to achieve such an improvement in hydrocarbon recovery as compared to the recovery obtained without the presence of the additive. In an embodiment of the invention, the additive is present in amounts sufficient to form a thin additive layer on gas bubbles formed in the aqueous slurry. By "thin layer", it is meant as thin as possible, typically on the order of a few nanometres thick, based on the air to kerosene ratio and the size of the formed air bubbles. A person skilled in the art would understand that the amount of additive to be used will depend on water

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chemistry and ore characteristics as well as air injection systems. In the results reported herein, the ratio of liquid additive/air (v/v) was on the order of 0.00075. A lower limit of the ratio of liquid additive/air (v/v) may be on the order of 0.0005. In oil sands extractions, the air addition rate can be between
5 5% and 20% (sometimes higher) by volume in a hydrotransport pipeline. This would equate to about 100-400 ppm of additive per tonne of sample in a hydrotransport pipeline. In other applications, such as flotation cells and secondary recovery applications, the amount of additive would depend on amount of air added.

10 It is important to note that the method of the invention may be applied to a variety of oil sand ores and oily waters at various stages in the extraction process regardless of specific equipment. The additional advantage of using the method of the present invention includes potential simplification of process configuration, ease of tailings and all other bitumen- or petroleum
15 hydrocarbon-bearing stream processing, improved quality of froth product, and elimination of undesirable process additives. Additionally, this method works equally well on all types of oil sand ores at both elevated and low temperatures.

It should be emphasized that the technique is not limited to air bubbles.
20 Any other gases can be used to separate bitumen, or other petroleum hydrocarbons, from water and/or slurries, including nitrogen.

Potential applications of the method of the invention include, but are not limited to, bitumen recovery from oil sand, oil or bitumen extraction from oily waste water, and bitumen/oil extraction from oil sands tailings, middlings
25 or any other bitumen bearing stream. The technique is applicable to all the streams-in-oil sand extraction processes where the attachment of bitumen or other petroleum hydrocarbons to a gas or air bubble is desirable.

(ii) System

The present invention also relates to a hydrocarbon separation
30 system for separating petroleum-like hydrocarbons from hydrocarbon-containing samples using aqueous-based separation techniques. In an embodiment, the invention provides a hydrocarbon separation system for

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separating petroleum-like hydrocarbons from hydrocarbon-containing samples using aqueous-based separation techniques comprising:

- 5 (a) a vessel comprising an aqueous slurry, said vessel being any container, pipe, tube or other means that can comprise an aqueous slurry;
- (b) a hydrocarbon-containing sample in the aqueous slurry;
- (c) a gas comprising an additive, wherein the additive is present in amount sufficient to improve the separation of the hydrocarbons from the hydrocarbon-containing sample; and
- 10 (d) a means for introducing said gas into said vessel to enable said gas to pass through and/or circulate within said vessel in a sufficient amount and at a sufficient rate to promote liberation and recovery of said petroleum-like hydrocarbon from said aqueous slurry.

15 In yet another embodiment, the hydrocarbon separation system further comprises a means for separating and/or recovering said petroleum-like hydrocarbon from said aqueous slurry.

In a further embodiment of the present invention, the hydrocarbon separation system also comprises a means to generate the gas comprising an additive. A variety of devices can be used for this purpose. One such device
20 is shown in Figure 1 although this invention is not restricted to the use of this device. Devices such as atomizers, nebulizers, injectors, evaporators, that can add the air-modifying substance or substances to the gas phase for delivery would be suitable.

A person skilled in the art would understand that the amount and rate
25 at which the gas would need to be introduced into the vessel containing the aqueous slurry will vary depending on the size of the system, the type of sample, the system temperature, the type of gas, the type of additive, the presence of other additives (in particular in the aqueous slurry) and the chemistry of process water.

30 The following non-limiting examples are illustrative of the present invention:

EXAMPLES

Example 1: Pipeline test loop

To carry out a wide range of experiments on bitumen recovery from oil sands a Laboratory Hydrotransport Extraction System (LHES) was designed and constructed. This was the first bench scale testing equipment which reflects more on the newly developed oil sands industrial conditions of using a hydrotransport pipeline to liberate bitumen from oil sand grains and to aerate the liberated bitumen. A schematic view of the slurry flow loop is shown in Figure 2. The LHES was constructed using a 17-mm inside diameter heavy wall glass pipe with an outside diameter of 25mm. The unit is approximately 3 meters in total pipe length and holds a total volume of 4 liters. A sample size ranging from 1 kg to 3 kg oil sands can be used depending on the desired slurry density of operation. Figure 2 shows the various components of the LHES. One of the primary components of the LHES was the loading/flotation container (1). The open top container (trough) allowed the addition of dry oil sand feed to the circulating water in the unit to form slurry. As the bitumen was liberated and aerated, the open slot allowed the aerated bitumen to float to form a froth layer at the top of the trough, where bitumen froth was collected/removed. The trough was wedge-shaped so that there would be less circulation at the wider top but circulation remained strong at the narrow bottom of the trough. This allowed a quiescent froth layer to form at the top while suspending the coarse solids at the bottom and at the same time maintained a minimum container size. The slurry was transported into the loop with a low speed progressive cavity pump (2). Compared with a centrifugal pump the progressive cavity pump (2) imparted very low shear forces on the slurry. The linear flow velocities in the pump were much smaller than that in the pipe section of the equipment. This design minimized the undefined "conditioning" of the slurry by the pump. The pump was driven by a 3 HP variable AC drive which allowed precise control of pump rotation speed. The flow rate was controlled by setting the speed of the positive displacement pump. The pump was coupled to the glass pipe sections with flexible PTFE connectors, allowing flexibility between the rigid pump and the glass pipe, and

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hence reducing the stress on the glass. At the pump discharge, a lower drain valve (3) was installed at the lowest point in the loop. A port (4) allowed injection of air through an 18-gauge needle into the flowing slurry stream. Next to the air injection port was a pressure relief valve (5). This valve was
5 inserted to protect the glass tubing from being over pressured, which might occur by continuous pumping of the positive displacement pump when the downstream line plugs. The bottom glass section included a double pipe heat exchanger section (6) which was connected to a programmable circulating thermal bath. With this bath, either cooling or heating of the slurry was
10 accomplished as needed. The vertical end section was connected with glass ball and socket joints (7) to allow flexibility and minimize stress on the sections of pipe. A second port was positioned at the top left of the loop for a thermocouple (8) to be inserted into the slurry stream. The thermocouple (8) was interfaced with the circulating bath to control the slurry temperature. A
15 set of ball valves (9) was positioned to redirect the slurry stream. These valves were set at the end of the test to divert the slurry out of the loop into a collection container (10). Clean water was poured in the loading container to flush the slurry out of the system. Approximately 2 to 3 L of water was needed to clean the loop thoroughly. Any remaining water was then drained
20 out of the system via the lower drain valve (3). The process was monitored by visualization slot (11), slurry visualization camera (12) and bubble visualization camera (13).

The LHES loop is quite different from the commercial hydrotransport pipeline used for oil sands bitumen liberation, aeration and transportation. In
25 the commercial pipelines, the oil sand ore together with slurring water and any additives are introduced to the pipeline. The air present in the oil sand slurry is assumed to be due to entrainment. In some commercial pipelines, additional air is added. Bitumen recovery takes place after introducing the conditioned slurry, at the pipeline *exit*, to a gravity separation vessel where
30 the aerated bitumen floats to the top of the gravity separation vessel and collected as bitumen froth. In the present design of the LHES, the oil sand slurry was continuously circulated in the pipeline loop. Air with or without

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additives was continuously injected into the slurry while aerated bitumen was being continuously recovered in an open trough. At the same time, any air that was not attached to bitumen escaped through the trough. Consequently, although air was continuously injected into the oil sand slurry, the ratio of
5 slurry volume to air volume in the pipeline remained relatively constant throughout an experimental test.

Some of the mixtures of kerosene-air used in this study are likely to run the risk of auto-ignition. Appropriate design of the kerosene-air device would need attention. As a safety consideration nitrogen can replace the air used in
10 the studies reported here.

Example 2: Oily bubble generation

A variety of devices can be used to generate oily bubbles. The device used in this study is shown in Figure 1. Metered kerosene was allowed to drip through injection line (14) onto a hot, inside metal tubing (15) surface held at
15 200 °C by an electric heating coil. The tubing (15) was wrapped with heat tape (16) to help maintain the inside temperature. A given volume of air (17) was allowed to flow into the heated tubing. The air carrying the evaporated/atomised kerosene was flowed out through port (18) and then injected into the pipeline loop via port (4) (Figure 2) using an 18-gauge tubing.
20 A thermocouple (19) was also inserted into tube (15) to control the inside temperature. The condensation of kerosene on the formed air bubbles to generate oily bubbles was confirmed visually.

Example 3: Use of liquid/vapor-containing gas bubbles (oily bubbles) for the flotation and recovery of bitumen from oil sands

25 *Materials and Methods*

(a) Froth Collection

The open trough A as shown in Figure 2 allows bitumen droplets that have been liberated and aerated to float and form a froth layer at the top of the trough. The froth is collected at suitable time intervals in order to
30 determine bitumen recovery rate with time. A small spatula is used to transfer the froth to the collection thimbles. Whatman filtration thimbles from Fisher Scientific are used as the collection containers so that the samples can be

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placed directly into modified Dean Stark extractors for froth composition analysis (Hepler, 1989 and 1994, Bulmer 1979).

(b) Froth Composition Assays

The froth samples are separated into bitumen, water and solid
5 components by refluxing with toluene in a modified Dean Stark extraction apparatus. Co-distilled water and toluene are condensed into a trap whereby the water is collected in a graduated section while the toluene is allowed to reflux through the extraction thimble. The filtered solids are dried and the resulting bitumen/solvent solution is centrifuged to separate non-filterable
10 solids. An aliquot of the centrifuge supernatant is evaporated to remove the solvent. The mass of the water, solids and bitumen is determined gravimetrically. It should be noted that bitumen flotation kinetics obtained with this setup and current analysis procedures are highly reproducible.

Results

15 Two difficult-to-process Athabasca oil sand ore samples obtained from Suncor Energy Inc. and Syncrude Canada Ltd. were used as demonstration tests for bitumen extraction using oily bubbles. The oil sand loadings were 1kg together with 3 kg of process water obtained from Syncrude Canada commercial oil sand extraction plant. The ore from Suncor was a heavily
20 oxidized ore with a bitumen content of 11.5% by weight and 13% of solids in the -44 micron size fraction. This ore is known to be very difficult to process where bitumen recovery is fairly low. Syncrude's oil sand ore sample was an esturarian ore with 9.5% by weight bitumen and 30% of solids in the -44 micron particle size fraction. The slurry was circulated in the loop at a rate of
25 3m/s. Air with and without kerosene was continuously injected into the slurry. The diameter of air bubbles formed as such was less than 1 mm. Aerated bitumen was allowed to continuously float inside the open trough, A, located in the pipeline loop as shown in Figure 2. The floated bitumen in the trough was collected at pre-determined time intervals. The amount of recovered
30 bitumen at a given time was determined using Dean-Stark analytical method. Plots of bitumen recovery kinetics were then established.

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(a) Control test

Bitumen recovery test from the oxidized ore obtained from Suncor was first carried out. This ore contains approximately 11.5% bitumen by weight and is known in the industry as a heavily oxidized ore, i.e., it is a typical hard-to-process ore. In the control test, no kerosene was added to the injected air. Air was injected at a rate of 200ml/minute. The test was carried out at 35°C. Bitumen recovery for the control test is shown in Figure 3 by open triangles. It is evident that bitumen recovery was very poor, with less than 40% bitumen being recovered after 80 minutes of circulation inside the pipeline loop. A repeat control test shows by open circles poor flotation results akin to the first test with less than 20% bitumen being recovered after 80 minutes. The results of the two tests fall on the same trend line, indicating an excellent reproducibility of the bitumen extraction test with the LHES. This is a unique feature of the equipment and experimental procedures.

(b) Kerosene-containing air bubble test: Oily bubbles

In this test, air was added at the same rate as in the control test, i.e., 200 ml per minute to the system. However, kerosene was added to the air prior to its injection into the slurry in the pipeline. The kerosene was added by vaporizing 0.3 ml per minute kerosene at 200°C into the air stream. The device used to add the kerosene to the air stream is shown in Figure 1. Solid symbols in Figure 3 show the bitumen recovery for the case where kerosene was used as an additive. After 80 minutes, nearly 100% bitumen recovery was obtained. For comparison, test was also conducted with a typical good processing ore under the identical operating condition but without kerosene addition. The good ore contains 9% of total solids in the -44 µm size fraction and has a bitumen content of approximately 14% by weight. The results shown by solid circles in Figure 3 suggest that bitumen recovery kinetics for the oxidized ore with the kerosene-air addition becomes comparable and exceeds that for good processing ores without kerosene addition, provided that a sufficient flotation time (greater than 45 minutes) is allowed. The recovery rate for the good processing ore is initially higher due to the faster liberation rate for that ore, compared to the oxidized ore. It should be noted

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that the bitumen recovery rate of the oxidized ore is found to match its bitumen liberation rate when flotation is carried out with kerosene-containing air bubbles. The results presented here demonstrate that the addition of kerosene to the air bubbles is capable of increasing bitumen recovery of difficult-to-process ores, e.g., oxidized ores, to an acceptable level that is comparable to "good" processing ores.

Using the same ore, a test was performed under the same conditions but using half the amount of kerosene at a rate of 0.15 ml/min. The results shown in Figure 3 by solid squares confirmed equally beneficial impact of oily bubbles for bitumen recovery.

To test the general applicability of oily bubble technology in bitumen recovery from poor processing ores, a second ore, known as difficult-to-process ore, was also tested at a lower processing temperature (23°C). This second ore contains a high fine content that is known to interfere with bitumen recovery process. The ore contains 30% of total solids in the -44 µm size fraction and has a grade of approximately 9.5% by weight. The results are shown in Figure 4. After 60 minutes of circulation, bitumen recovery increased from about 10% to 80% by kerosene addition in generating oily bubbles as compared to the control test. The results further confirm the benefit of using oily bubble in bitumen recovery from poor processing ores.

Discussion

While not wishing to be limited by theory, the mechanism for the substantial increase in bitumen recovery could be due to the alteration in the surface characteristics of the air bubbles. The vaporized kerosene in the air stream would condense on the air bubble surface when the bubbles are contacted with the colder flowing slurry. The micron-thick kerosene at the air-slurry interface would act as a good collector for the liberated bitumen. Attachment of the air bubbles to the bitumen is enhanced due to the presence of the kerosene film.

Recently, Liu et al., 2002b measured contact angle of kerosene-containing air bubbles on sulfide minerals in water. Compared with the maximum attainable contact angle values (<100°) of air bubbles on

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mineral surfaces, a much higher contact angle value (160°) was observed for air bubbles covered with a thin layer of kerosene containing potassium dodecyl xanthate, suggesting a stronger air-mineral attachment. Bitumen extraction is an extremely complex physicochemical system. On one hand, various types of surfactant are known to release into the process water. These surface active molecules accumulate at air/water interface more effectively than at kerosene/water interface due to a higher potency of interfacial energy (72 mJ/m^2) for air/water interface than that (ca. 50 mJ/m^2) for kerosene/water interface. As a result, the surfactant-covered air bubble surface is more rigid compared with kerosene surface in water. Bitumen, on the other hand, is known to be highly soluble in kerosene and hence a reduced viscosity at the contact region can be achieved. Kerosene film on an air bubble therefore assists the mobility of surface contact area thereby enhances the spreading kinetics within the contact area and hence flotation kinetics. Other type of low viscosity water-immiscible liquids such as toluene or naphtha could be used in this process, so long as the liquid additive itself has some degree of solubility for bitumen.

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WE CLAIM:

1. A method of recovering petroleum hydrocarbons from hydrocarbon-containing samples using aqueous-based separation techniques comprising:
 - 5 (a) providing an aqueous slurry comprising a hydrocarbon-containing sample;
 - (b) introducing into the aqueous slurry, a gas comprising an additive, wherein the additive is a vapourized liquid hydrocarbon or a gaseous hydrocarbon and is present in an amount sufficient to improve the
10 separation of the petroleum hydrocarbons from the hydrocarbon-containing sample; and
 - (c) recovering the petroleum hydrocarbons.
2. The method according to claim 1, wherein the hydrocarbon-containing
15 sample is selected from the group consisting of tar sands, oil sands, oil sandstones and oil shales.
3. The method according to claim 2, wherein the hydrocarbon-containing
20 sample is tar sands.
4. The method according to claim 1, wherein the additive is selected from vapourized kerosene, toluene and naphtha.
5. The method according to claim 4, wherein the additive is vapourized
25 kerosene.
6. The method according to any one of claims 1-5, wherein the additive is present in sufficient amounts to form a thin additive layer on gas bubbles formed in the aqueous slurry.
30
7. The method according to any one of claims 1-6 wherein the gas is air.

8. The method according to any one of claims 1-7, wherein the petroleum hydrocarbon is bitumen.
9. A petroleum hydrocarbon separation system comprising:
- 5 (a) a vessel comprising an aqueous slurry, said vessel being any container, pipe, tube or other means that can comprise an aqueous slurry;
- (b) a hydrocarbon-containing sample in the aqueous slurry;
- (c) a gas comprising an additive, wherein the additive is a vapourized
10 liquid hydrocarbon or a gaseous hydrocarbon and is present in an amount sufficient to improve the separation of petroleum hydrocarbons from the hydrocarbon-containing sample; and
- (d) a means for introducing said gas into said vessel to enable said gas to pass through and/or circulate within said vessel in a sufficient amount
15 and at a sufficient rate to promote liberation and recovery of said petroleum hydrocarbons from said aqueous slurry.
10. The system according to claim 9, further comprising a means for separating and/or recovering said petroleum hydrocarbons from said aqueous
20 slurry.
11. A use of a composition comprising a gas and an additive, for separating and/or recovering petroleum hydrocarbons from hydrocarbon containing samples, wherein the additive is a vapourized liquid hydrocarbon
25 or a gaseous hydrocarbon.
12. A use of an oily bubble for separating and/or recovering petroleum hydrocarbons from hydrocarbon containing samples, wherein said oily bubble comprises a gas bubble having an additive-containing coating and the
30 additive is a hydrocarbon.

Application number / numéro de demande: 2421474

Figures: one

Pages: _____

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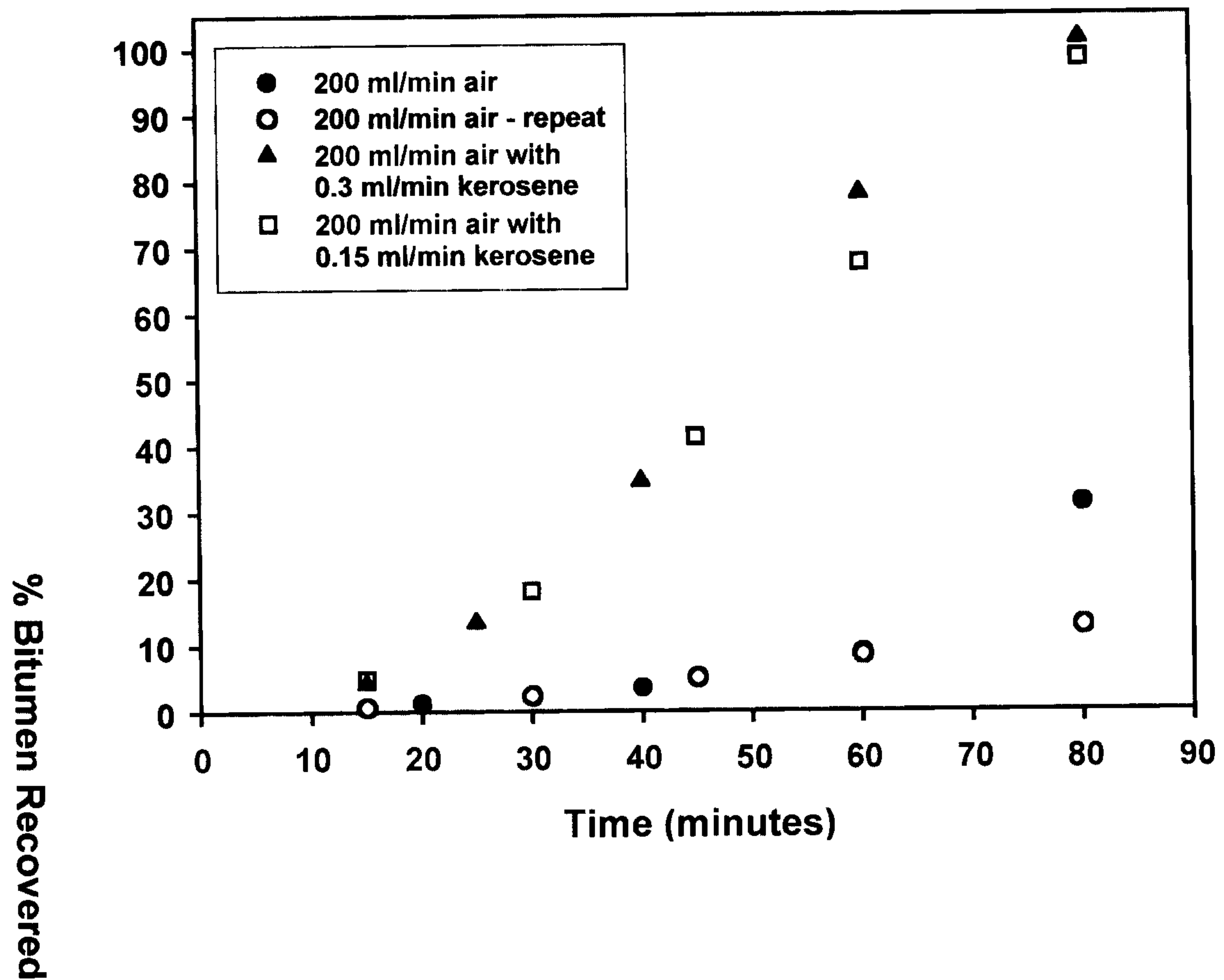
Figure 3**Comparison of Bitumen Flotation Using Air and
Flotation Using Hydrocarbon (kerosene) Aerosol**

Figure 4**Hydrocarbon Aerosol (kerosene) Flotation of
A High Fines, Poorly Processing Ore At 23°C**