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(54) Title: WATER INTEGRATION BETWEEN AND IN-SITU RECOVERY OPERATION AND A BITUMEN MINING OPERATION

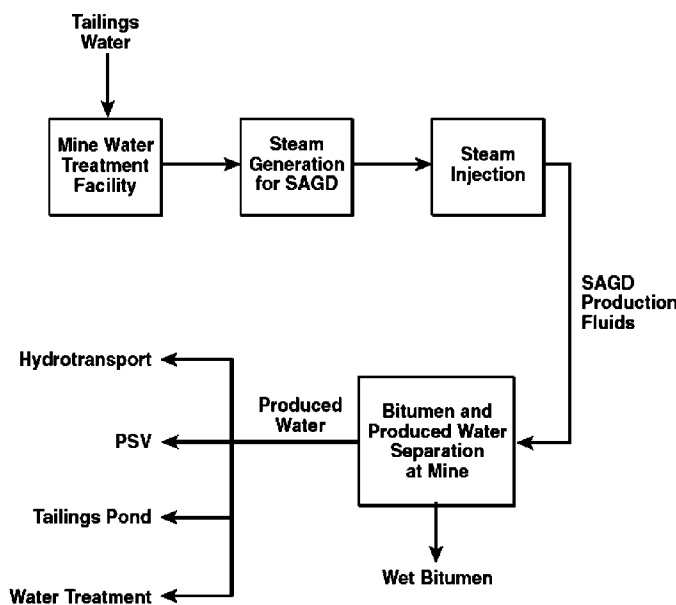


Fig. 3

(57) Abstract: The present invention relates to a method and system for integrating water between an in-situ bitumen recovery operation and a bitumen mining operation for improving efficiencies and synergies there between. A method of integrating water between a bitumen mining and extraction operation and an in-situ bitumen recovery operation comprises a) providing water associated with the bitumen mining and extraction operation; and b) directing the water, or boiler feed water or steam generated therefrom, to the in-situ bitumen recovery operation for use therein. Steam generated is used to assist in bitumen recovery at the in-situ facility. A basic system for integrating water between a bitumen mining and extraction operation and an in-situ bitumen recovery operation comprises a) a bitumen mining and extraction facility having a source of water; b) an in-situ bitumen recovery facility; c) a transporter for transporting the water, or boiler feed water or steam generated therefrom, to the in-situ bitumen recovery facility for use in an in-situ bitumen recovery operation.

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## **WATER INTEGRATION BETWEEN AN IN-SITU RECOVERY OPERATION AND A BITUMEN MINING OPERATION**

### **CROSS-REFERNCE TO RELATED APPLICATIONS**

[0001] This application claims priority from Canadian Patent Application number 2,610,230 which was filed on 13 November 2007, which is incorporated herein by reference.

### **FIELD OF THE INVENTION**

[0002] Generally, the present invention relates to the bitumen and heavy oil industry. More particularly, the present invention relates to in-situ bitumen recovery operations and bitumen mining operations.

### **BACKGROUND OF THE INVENTION**

[0003] Oil sand deposits, located in many regions of the world, comprise mixtures of sand, water, clay, minerals, and crude bitumen that can be extracted and processed for fuel. The oil sands of Alberta, Canada, contain some of the largest deposits of hydrocarbons in the world.

[0004] Bitumen is classified as an "extra heavy oil", referring to its gravity as measured in degrees on the American Petroleum Institute (API) Scale. Bitumen has an API gravity of about 10° or less. The bitumen mined from the Athabasca oil sands of Alberta has an API gravity of about 8°. "Heavy oil" has an API gravity in the range of about 22.3° to about 10°. Heavy oil or bitumen extracted from oil sand is processed or upgraded to produce light synthetic crude oil having an API gravity of about 31° to about 33°. The terms heavy oil and bitumen are used interchangeably herein since they may be extracted using the same processes.

[0005] Bitumen can be recovered from oil sands by various methods, the most common of which include surface or strip mining and in-situ bitumen recovery methods, including thermal in-situ recovery methods. The operations for recovery and extraction of bitumen are highly water intensive, thus facilities must generally draw from a dedicated water source, such as a nearby river or lake. The waste, including water waste, produced during these operations, is disposed of in tailings ponds, sludge lagoons, disposal wells and the

like. There is a demand in the industry to reduce water consumption and waste associated with bitumen recovery and extraction processes and to minimize the overall land footprint and environmental impact of these operations.

[0006] In a bitumen mining operation, the oil sand is mined, for example using trucks and shovels, and the mined ore is transported to the extraction plant for bitumen extraction. The mine site may be a distance from the extraction plant and, in recent years, the preferred mode of transport for mined oil sand has been by way of a slurry pipeline. The mined oil sand is transported to a crusher to break up chunks and rocks. The oil sand is then mixed with water, which must be warmed, to form a slurry that is capable of being pumped through a pipeline to the extraction plant. This process is referred to as hydrotransport. Bituminous slurry is generally pumped at temperatures of about 25°C to 65°C, typically about 35°C to 50°C, at a sufficient flow rate to prevent the sand particulate from settling out. During hydrotransport, the bitumen begins to separate from the sand, water, and other minerals in the slurry. Hydrotransport is highly water-intensive but is more cost effective and efficient than previous modes of transport. It also “conditions” the slurry for bitumen separation, such that less processing is required at the plant prior to extracting the bitumen.

[0007] In operations where conveyors are still in use, the mined oil sand is dumped into large rotating tumblers where it is slurried by steam, hot water, and optionally caustic chemicals, to condition it for separation. The rotary action also aerates the slurry. The slurry is then discharged onto vibrating screens to remove rocks and lumps of clay. The slurry may then be blended with slurry from the hydrotransport process for transport to the extraction facility.

[0008] One of the most common extraction techniques is bitumen froth flotation. The conditioned slurry is introduced into a primary separation vessel (PSV) at the extraction facility. Warm water, air and other agents, added to the slurry for conditioning, aid in the formation of a bitumen-rich froth that floats or rises to form a distinct upper hydrocarbon phase that can be separated from the lower aqueous layers. The middlings, containing water and residual bitumen, are pumped off and may be further processed, for example, to extract more bitumen. The tailings, containing water, sand and particulate, may be further treated and is ultimately disposed of in tailings ponds.

[0009] The bitumen froth, typically comprising about 60% bitumen, about 30% water and about 10% solids, is next treated in a froth separation unit (FSU) to promote separation of the bitumen from other components of the froth. In a paraffinic froth treatment (PFT) process, a paraffinic solvent is mixed with the froth, resulting in the formation of bitumen globules that separate from the aqueous layer and float to the top of the FSU to form a bitumen-rich upper layer that is recovered and may be further treated. The lower aqueous layer, containing water, solids, and residual bitumen enriched in asphaltenes, may be treated in subsequent separation vessels to recover residual bitumen or asphaltenes, and is ultimately disposed of.

[0010] The extracted bitumen is then pumped via pipeline to an upgrader on site or to a refinery for cleaning, treatment and upgrading. Upgrading of bitumen or heavy oil to a light synthetic crude oil is generally accomplished via carbon rejection (i.e. coking) or hydrogen addition. The latter process is typically a two-stage process involving hydrocracking to break down the large hydrocarbon molecules and hydrotreating to stabilize the hydrocarbon compounds and remove impurities. The upgraded synthetic crude oil can be sold to refineries, petrochemical manufacturers or other consumers.

[0011] Bitumen mining operations require expensive and elaborate processing facilities and an abundance of water, as well as energy for heat generation. On average, one and a half to two tons of oil sand must be processed to produce one 159-liter barrel of synthetic crude oil from bitumen. Large quantities of oil sand must be mined and processed each day in order to supply the high demand for synthetic crude oil.

[0012] In-situ oil recovery methods, such as thermal in-situ recovery methods, are applied when the bitumen is buried deep within a reservoir and cannot be mined economically due to the depth of the overburden. In-situ production methods may recover between about 25 and 75 percent of the bitumen initially present in a reservoir. In general, the focus of an in-situ recovery process is to reduce the viscosity of the bitumen or heavy oil to enable it to flow and be produced from a well.

[0013] Thermal in-situ recovery processes use heat, typically provided by steam, to reduce the viscosity of the bitumen in a reservoir and thereby render it more flowable. Examples of thermal in-situ recovery processes include but are not limited to steam-assisted gravity drainage (SAGD), cyclic steam stimulation (CSS), and various derivatives thereof, such as solvent-assisted SAGD (SA-SAGD), steam and gas push (SAGP),

combined vapor and steam extraction (SAVEX), expanding solvent SAGD (ES-SAGD), constant steam drainage (CSD), and liquid addition to steam enhancing recovery (LASER), as well as water flooding and steam flooding processes.

**[0014]** In typical gravity-driven thermal in-situ oil recovery processes, two horizontal wells are drilled into the reservoir. A lower horizontal well, ideally located near the bottom of the reservoir, serves as a production well and a horizontal well located above the production well serves as an injection well. Dry or wet steam is injected into the injection well from the surface to heat the bitumen trapped in the reservoir and lower its viscosity. An enormous volume of steam must be generated for this process and the water used for steam generation must meet boiler feed water specifications. As the viscosity of the bitumen is lowered, it flows into the production well, along with condensed steam, and these liquids are pumped to the surface. A hydrocarbon solvent or other agent may optionally be injected to assist the process.

**[0015]** The hot production fluids, typically comprising about 70% produced water and about 30% bitumen and produced gases, are recovered to the surface via the production well and are separated into their individual components on site. Production fluids from the wellhead are sent to a flow splitter to separate the bitumen, produced water and optionally produced gas into individual streams. A diluent or condensate is added to the bitumen stream to facilitate the removal of residual water from the oil. The diluted bitumen (“dilbit”) may be further treated or stored on site before being transported to an upgrader or pipelined to a refinery. The produced gas stream may be used to provide gas for the steam generators.

**[0016]** The produced water (PW) stream is typically sent to water treatment facilities to make boiler feed water of suitable quality for steam generation. In this process, the PW stream is first deoiled and is then sent for softening treatment. The conventional approach used to treat or soften the produced water to meet boiler feed water specifications is a two-step process involving primary hardness removal followed by secondary hardness removal to polish the water.

**[0017]** This conventional configuration results in numerous waste streams that must be handled and the residual waste is ultimately sent to a disposal well or costly sludge lagoon on site.

[0018] While it is recognized that in-situ bitumen recovery techniques disturb considerably less land than mining operations, and therefore require less land reclamation activity, the process to treat the water to the desired boiler quality specification is highly complex, capital intensive and prone to operational upsets, requires a significant number of vessels and disposal areas that occupy a large land footprint, and results in significant waste disposal, typically at multiple locations on site. Currently, the commercial development of smaller sized thermal operation plants (e.g. < 20,000 bbl/d bitumen) may not be feasible due to high capital investment costs of the existing commercial technologies.

[0019] Current challenges associated with oil sand mining and in-situ bitumen recovery operations in general include, intense capital investment and operating costs, large land footprint, vulnerability to operational upsets, and environmental impact due to water consumption and waste disposal. There has been a lack of success in achieving effective improvements in these areas, despite the progress made in oil sand extraction technologies and the increasing global awareness of industrial environmental impacts.

[0020] There is an economic incentive for improving efficiencies in the bitumen and heavy oil industry in general and, in particular, for reducing capital and operating costs, water consumption, land footprint and environmental impact associated with bitumen recovery operations. While attempts to reuse and recycle water for improved efficiency within an in-situ recovery operation, or within a mining operation, have been made, advantages to be achieved by integrating an in-situ operation with a mining operation have not been fully appreciated.

[0021] It has recently been proposed that produced water from a SAGD operation could be used in the hydrotransport line at a mining facility to reduce the demand for fresh heated water for hydrotransport at the mine. This would also reduce the amount of waste stored at the SAGD site resulting in a net reduction in ground disturbance.

[0022] It is desirable to provide new and improved methods and systems for improving efficiencies in water and energy consumption and also to reduce environmental impact of water consumption and waste disposal associated with bitumen mining and in-situ recovery operations, reduce capital and operational costs, and reduce the large land footprint required for stand-alone facilities.

**SUMMARY OF THE INVENTION**

**[0023]** There is an economic incentive for improving efficiencies in the bitumen and heavy oil recovery and extraction industry. The present invention is generally directed to a novel method and system for integrating an in-situ oil recovery operation with a bitumen mining operation. More particularly, the present invention is directed to an innovative new method and system to integrate water between an in-situ bitumen recovery operation and a bitumen mining operation. By integrating water handling and processing between the two operations, many previously unrecognized efficiencies and synergies may be achieved.

**[0024]** In one aspect, there is provided a method of integrating water between a bitumen mining and extraction operation and an in-situ bitumen recovery operation comprising a) providing water associated with the bitumen mining and extraction operation; and b) directing the water, or boiler feed water or steam generated therefrom, to the in-situ bitumen recovery operation for use therein. Steam generated is used to assist in bitumen recovery at the in-situ facility.

**[0025]** In another aspect, there is provided a system for integrating water between a bitumen mining and extraction operation and an in-situ bitumen recovery operation. The system comprises a) a bitumen mining and extraction facility having a source of water; b) an in-situ bitumen recovery facility; and c) a transporter for transporting the water, or boiler feed water or steam generated therefrom, to an in-situ bitumen recovery facility for use in an in-situ bitumen recovery operation.

**[0026]** The in-situ recovery operation may be a thermal operation, such as steam-assisted gravity drainage (SAGD), cyclic steam stimulation (CSS), or a derivative thereof. Examples of thermal in-situ recovery processes include but are not limited to steam-assisted gravity drainage (SAGD), cyclic steam stimulation (CSS), and various derivatives thereof, such as solvent-assisted SAGD (SA-SAGD), steam and gas push (SAGP), combined vapor and steam extraction (SAVEX), expanding solvent SAGD (ES-SAGD), constant steam drainage (CSD), and liquid addition to steam enhancing recovery (LASER), as well as water flooding and steam flooding processes. Examples of such operations are disclosed in U.S. Patent No. 4,116,275; 4,280,559; 4,344,485; 5,899,274; 6,230,814; 6,662,872; and 6,708,759 the disclosures of which are each incorporated herein by reference in their entirety.

[0027] The integrated method and system of the present invention provide the potential to reduce water consumption, water waste, energy consumption, capital investment, operating costs and overall land footprint, compared with stand-alone in-situ recovery and mining and extraction operations and facilities. The integrated method and system of the invention also provide the potential for commercial development of smaller scale in-situ bitumen recovery operations.

[0028] Other aspects and features of the present invention will become apparent to those ordinarily skilled in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

[0029] Embodiments of the present invention will now be described, by way of example only, with reference to the attached Figures, wherein:

[0030] Fig. 1 is a schematic illustrating an exemplary commercial facilities processing configuration for separating and processing production fluids from an in-situ thermal recovery operation;

[0031] Fig. 2 is a schematic illustrating an embodiment of an integrated mining-SAGD operation; and

[0032] Fig. 3 is a schematic illustrating an embodiment of an integrated mining-SAGD operation.

### **DETAILED DESCRIPTION**

[0033] Generally, the present invention is directed to a novel method and system for integrating an in-situ oil recovery operation with a bitumen mining operation. More particularly, the present invention is directed to an innovative new method and system to integrate produced water treatment needs and waste generated in an in-situ bitumen recovery operation with water treatment and disposal options in a bitumen mining operation. By integrating water between the two operations, many previously unrecognized efficiencies and synergies may be achieved. Efficiencies to be achieved include, reductions in overall capital and operating costs compared to stand-alone facilities, reductions in water and energy consumption, reductions in overall land footprint, and reductions in environmental impact and water waste.

[0034] Mining and extraction facilities and in-situ oil recovery and processing facilities currently exist in distinct locations and operate entirely exclusively of one another. The present invention provides an innovative new process configuration that integrates water between an in-situ recovery facility and a mining and extraction facility. The facilities themselves may be existing, modified, retrofit or newly constructed facilities. The term “mining”, as used herein, refers to mining of oil sand and extraction of bitumen. Thus, the expressions “mining operation” and “mining facility” are meant to encompass both oil sand mining and bitumen extraction.

[0035] Integration of water handling and processing between an in-situ bitumen recovery operation and a bitumen mining operation has the potential to eliminate substantial capital requirements for the in-situ plant, including water treatment facilities, to minimize land footprint by reducing the requirement for costly sludge lagoons, and to improve overall water usage in the operation, thereby allowing for the economic development of smaller scale thermal production operations with improved environmental performance.

[0036] In one embodiment, an existing thermal in-situ facility is integrated with an existing mining facility. In another embodiment, a small scale thermal in-situ facility is constructed and integrated with an existing mining facility. The thermal in-situ facility may be nearby or may be a distance from the mining facility.

[0037] The method and system of the present invention can be used to integrate any suitable in-situ oil recovery operation with a bitumen mining operation. Integration of a thermal in-situ bitumen recovery operation, such as SAGD, with a bitumen mining operation is specifically exemplified herein for illustrative purposes, however the invention is clearly not limited to the illustrative examples provided herein. While reference is made to particular exemplary facilities configurations, a skilled person will appreciate that variations and modifications can be made without departing from the scope of the invention.

[0038] An exemplary commercial facilities processing configuration for separating the production fluids from an in-situ thermal recovery operation and treating the produced water to make boiler feed water of suitable quality for steam generation is depicted in Figure 1. The exemplified facilities configuration is described to provide an illustrative

example only and the present invention is therefore not limited to an in-situ operation having the exemplified facilities configuration.

[0039] In reference to Figure 1, steam 12 and optionally solvent are injected into the injection well and the hot production fluids 14 are recovered to the surface via the production well and are separated into their individual components on site. The production fluids typically comprise about 70% produced water and about 30% bitumen and produced gases, although the proportions can vary. The production fluids generally have an inlet temperature in the range of about 80°C to 250°C, more typically about 120°C to 220°C. An exemplary inlet temperature is about 200°C. The production fluids have an inlet pressure of about 450 kPa to 3000 kPa, typically about 450 kPa to 2300 kPa. A exemplary inlet pressure for conventional (bitumen less dense than water) treating is about 600 kPa. These values can vary depending on the particular operation.

[0040] The hot production fluids 14 from the wellhead are generally cooled somewhat and the cooled production fluids 16 sent to a flow splitter or Free Water Knock Out (FWKO). The hot production fluids may be cooled via conventional heat exchange 17 or by any other suitable method. The heat captured may be used to heat a fluid for the operation, such as glycol. The flow splitter typically separates the production fluids into two or three separate streams. In the exemplary embodiment, the production fluids are split into a wet bitumen stream 18, a produced water stream 20 and a produced gas stream 22. The individual streams each undergo further processing on site.

[0041] The wet bitumen stream 18, which contains residual water, is sent to the treaters, which may contain electrostatic grids, wherein diluent 24, such as a light hydrocarbon, or condensate is added to the bitumen stream 18 to facilitate the removal of residual water from the oil. The diluted bitumen (“dilbit”) stream 26 may or may not be further treated before being sent to an upgrader or transported to a refinery. The dilbit is generally stored on site in storage tanks prior to being pipelined to market.

[0042] The process to treat the produced water (PW) stream to generate boiler feed water (BFW) suitable for steam generation is complex and capital intensive. The produced PW stream 20, which comprises some residual bitumen (i.e. <5%), is first deoiled, via resident time in a skim tank, passage through an Induced Gas Flootation (IGF) or another suitable method, such as Induced Static Flootation (ISF), and optionally subjected to oil removal filters (ORF). The oil free water stream 28 is then sent to primary hardness

removal vessels, such as Hot Lime Softeners (HLS), Warm Lime Softeners (WLS), or the like, for softening treatment. The application of the HLS process results in a significant reduction of divalent cations, typically of about 90%, that if not treated will result in boiler tube scaling. In this process, divalent cations are precipitated from solution as sludge, which is discharged to storage lagoons and eventually landfilled.

**[0043]** Following primary hardness removal, the softened water stream 29 is directed through the afterfilters to secondary hardness polishing vessels, for example, vessels for Weak Acid Cation Exchange (WAC) or Strong Acid Cation Exchange (SAC), to produce boiler feed water (BFW) 30 of suitable quality for steam generation. The WAC Exchange units facilitate secondary hardness removal via exchange of hardness ions onto a charged resin site. This process serves as a polishing step to remove residual cations and generate water that meets boiler feed water specification for steam generation.

**[0044]** This conventional set up is highly capital intensive and also results in numerous waste streams (energy, water, solids, etc.) that must be handled appropriately.

**[0045]** Table 1 highlights some general compositions of various inlet waters and water products. The values exemplified are merely typical estimates and exact properties may vary. Table 1 indicates that there are many viable sources of water that would allow for the successful and reliable generation of boiler feed water for an in-situ thermal oil recovery operation if the in-situ and mining operations were integrated. Moreover, water needs for both operations could be optimized with integration of an in-situ oil recovery operation and a mining operation.

Table 1. Some Typical Properties of Various Water Sources

Property	Deoiled PW (CSS)	Deoiled PW (SAGD)	Fresh Water	Extraction Water	HLS Effluent	BFW (for OTSG, SAGD or CSS)
pH	6.5-7.5	8.30	7.2-7.4	8.1-8.6	9.2-9.4	9.2-9.4
Ca (ppm)	150-300	5	20-50	50-75	20-30	<0.4
Mg (ppm)	5-25	<0.5	10	40-60	3-15	<0.1
Alkalinity (ppm)	300-400	322	150	200-300	<150	<150
Silica (ppm)	200-350	250	<5	<5	40-60	40-60
TDS	10,000	1000	275	300	10,000	10,000 (CSS)

(ppm)					(CSS)	1,000 (SAGD)
Residual Oil (ppm)	<30 mg	1060	NA	NA	<30	N.D.

**[0046]** In accordance with the present invention, water from any suitable water source associated with the mining and extraction operation, including surface, subsurface or process affected water, is utilized to support an in-situ bitumen recovery operation. In particular, water from a water source associated with the mining and extraction operation is utilized in the generation of boiler feed water of suitable quality for steam generation in order to provide steam for thermal operations in an in-situ bitumen recovery operation.

**[0047]** In accordance with one embodiment, fresh water from a mining operation is utilized to produce boiler feed water that meets the specifications for thermal operations at an in-situ production facility, such as boiler operation at a SAGD facility. The fresh water may be treated at the mine location using conventional water treatment technologies. Conventional water treatment technologies may include, but are not limited to, softening by HLS or WLS optionally followed by afterfilters, and WAC or SAC exchange, membrane technology such as reverse osmosis, nanofiltration and/or ultrafiltration, mechanical vapour compression, or any other suitable hardness removal method. In this embodiment utilizing fresh water, the removal of silica to make boiler feed water is not required owing to its already low residual concentration in the fresh water. The current Once Through Steam Gas (OTSG) specification for silica is about 40-60 ppm, but can be increased if hardness concentrations are reduced to less than about 0.4 ppm.

**[0048]** In another configuration of the embodiment, the removal of hardness ions is facilitated by the addition of caustic (i.e.  $\text{Ca}(\text{OH})_2$ ,  $\text{NaOH}$ ,  $\text{NH}_4\text{OH}$  to raise pH) to the feed stream in a clarification unit or pipeline prior to polishing the stream in a WAC Exchange unit.

**[0049]** The waste solids generated by the overall softening process, which may comprise HLS or WLS sludge solids, membranes or vapour compression concentrate streams, or solids generated from post treatment schemes (i.e. centrifugation of waste streams), among others, may be disposed in the already available tailings pond of the mine, thereby minimizing or eliminating the need for costly sludge lagoons, salt caverns or other disposal options inherent to a typical in-situ operation. Furthermore, the addition of solids generated from the softening process may assist in the settling of the particulate

matter associated with the tailings ponds. If desired, the tailings stream and the sludge streams can be co-mingled in a pipeline to assist with the coagulation and settling of the fine particulate matter.

**[0050]** In another configuration of the embodiment, the water treatment configuration would strictly utilize WAC or SAC units to remove hardness ions. In this simple water processing configuration, the need for capital intensive water treatment facilities can be minimized and waste water streams can be sent to the tailings ponds. Furthermore, no waste solids would be generated.

**[0051]** The softened water could then be used to generate steam, preferably for use in thermal operations at the in-situ facility. The steam may be generated at the mine site or at the in-situ site, for example, using Once Through Steam Generators (OTSG), or Drum Boilers if desired. If OTSGs produce are used to generate and produce wet steam and the in-situ thermal operation is a SAGD application (or derivative thereof), it will typically be desirable to separate the steam and liquid phases to generate a dry steam for injection into a reservoir. Upon separation of the hot liquid phase from the steam, the liquid phase can be sent to the hydrotransport pipeline and used for bitumen extraction, thereby recovering its heat. Alternatively, the hot liquid phase can be used in another process in the mining operation where hot or warm water is required and where the process would not be negatively impacted. Alternatively, the liquid phase can be used for heat recovery and the cooled liquid sent to the tailings pond, hydrotransport or another process requiring water. If steam generation occurs at the mine site, the dry steam is then pipelined to a SAGD well at the SAGD site and injected downhole for bitumen recovery. Upon production, the SAGD produced fluids are preferably subsequently pipelined to the mine operation for separation and processing, thereby minimizing or eliminating the requirement for processing and storage facilities at the SAGD site.

**[0052]** In another embodiment, the SAGD produced fluids are pipelined to the mine site and the produced water is separated and discharged to the tailings pond upon heat recovery. Conventional heat exchangers may be used to recover the heat stored in the produced water. In this particular embodiment, for optimal efficiency, maximum heat recovery from the produced water is desired prior to discharge to the tailings area of the mine site.

[0053] Alternatively, the recovered SAGD produced water is cooled to a processing temperature and added to a processing vessel at the mine site. In one embodiment, the produced water is cooled to a processing temperature and added to a Primary Separation Vessel at the mine site. A typical processing temperature for separation is about 35°C but may vary. Heat is desirably recovered from the produced water during cooling.

[0054] In another embodiment, the warm SAGD produced water containing residual oil is co-mingled with the extraction water in the hydrotransport lines that facilitate the separation of bitumen from the oil sands. It is well known that steam generator scaling in SAGD operations can result from residual oil entrainment in the boiler feed water. By sending the warm produced water to the hydrotransport process in the mining operation, steam generator scaling may be reduced. Moreover, by sending the warm produced water to the hydrotransport process in the mining operation, secondary and even primary de-oiling may optionally be eliminated, thereby reducing the associated capital requirement, and any residual oil comprised in the produced water may be recovered during the extraction process. Furthermore, the energy demand for heat generation for hydrotransport is reduced by the addition of warm produced water.

[0055] In another embodiment, the SAGD produced water can be sent directly to the water treatment facilities at the mine to be processed. The processed water can then be utilized to produce further boiler feed water for steam generation at the SAGD facility or the mining and extraction operation. This approach would be advantageous particularly if there was a need for increased steam production for SAGD, for example, if the SAGD operation expanded its bitumen production. The SAGD produced water would typically require secondary polishing in order to meet the BFW specifications.

[0056] Another embodiment would initially utilize fresh water, which would otherwise be used in the mining and extraction process, as the feed for SAGD steam generation. Upon production, the previously fresh water which is now SAGD produced water, would be subsequently directed for use in the bitumen extraction process. This process proves advantageous over the typical mining and bitumen extraction process configuration, in that the volume of bitumen recovered per unit volume of fresh water would be approximately tripled, assuming a steam-to-oil ratio (SOR) of 3:1 for SAGD, 1m<sup>3</sup> H<sub>2</sub>O:1bbl bitumen and produced water being used for extraction.

[0057] Figure 2 is a schematic illustrating an exemplary water integration configuration using fresh water. Fresh river water, or any other suitable fresh water source, from a mining and extraction site is processed at the mining and extraction facility to provide water suitable for steam generation. Steam is then generated at the mining and extraction site or at the SAGD facility to provide steam for injection into a reservoir for bitumen recovery at the SAGD site. The hot SAGD production fluids are then directed to the mining and extraction site and separated into at least a wet bitumen and a produced water stream. The produced water is subsequently directed to the hydrotransport lines, water treatment facilities, or added to a separation vessel at the mining and extraction facility. Alternatively, the produced water may be directed to the tailings pond, for recycle, preferably following maximum heat recovery from the produced water.

[0058] In another embodiment, recycled tailings water from the mining operation is used to produce boiler feed water for SAGD steam generation. It has surprisingly been found that tailings water exhibits properties amenable to generating boiler feed water. Some typical properties of tailings water are exemplified in Table 2 below, although these properties may vary.

Table 2. Typical Compositions of Tailings Water (top 10m)

Property	OTSG BFW	Extraction Water	Recycled Tailings Water	Tailings Water
pH	9.2 - 9.4	8.1-8.6	6.0-8.5	7.6-8.5
Ca (ppm)	<0.2	50-75	25-50	10-50
Mg (ppm)	<0.2	40-60	30-100	12-40
Total Alkalinity (ppm)	<350	200-300	~900	~900
Silica (ppm)	40-60	<5	<10	10-50
Total Dissolved Solids (ppm)	<10,000	300	<2500	<2500
Residual Oil (%)	ND	N/A	~2	~4
Solids	Nil	>Nil	250ppm (0-3m depth) 18-27% (5-10m depth)	1% (<1m depth) 14-27% (1-10m depth)

[0059] The tailings solids and water mixture may be obtained directly from the tailings line at the processing temperature or drawn from the top of the tailings pond, so as to

minimize the solids content, and may subsequently be sent to a softening vessel such as a clarification unit, eg. HLS, WLS, membrane, ultrafiltration unit or other, and the pH may be raised to a desired target, for example, of about 8.8 to 9.6. The softening method ideally allows for the coagulation of solids and residual oil and the production of boiler feed quality water. The softening process may also serve to assist in the coagulation of the fine particulate matter that is suspended within the tailings. If desired, the hydrocarbon oil may be recovered from the solids via a non-aqueous solvent wash, for example, a C<sub>3</sub>-C<sub>7</sub> hydrocarbon solvent wash, prior to discharge of the solids to disposal. The BFW produced from the tailings is then used for steam generation and the steam is used to recover bitumen from SAGD or other in-situ resources. Upon production, the SAGD production fluids are optimally directed to the mining and extraction site for separation and processing and the produced water can be used in hydrotransport for extraction, sent to a separation vessel, or discharged to the tailings pond. For optimal synergy, the produced water, originally from the tailings, is used for an extraction or separation process rather than being discharged to the tailings pond. Alternatively, the produced water can be sent to the water treatment facilities at the mine site and used to generate more BFW for steam generation.

**[0060]** Figure 3 is a schematic illustrating an exemplary Mining-SAGD water integration configuration using tailings water, as described above. Tailings water from a mining and extraction site is processed at the mining and extraction facility to provide BFW suitable for steam generation. Steam is then generated at the mining and extraction site or at the SAGD facility, for example, to provide steam for injection into a reservoir for bitumen recovery at the SAGD site. The hot SAGD production fluids are then directed back to the mining and extraction site and separated into at least a wet bitumen and a produced water stream. The produced water may be integrated into a process at the mining and extraction facility. For example, the produced water may be directed to the hydrotransport lines or added to a Primary Separation Vessel. Alternatively, the produced water may be directed to the water treatment facilities for softening, to the tailings pond or other disposal area, preferably upon heat recovery.

**[0061]** The use of tailings water to generate BFW suitable for SAGD or other thermal operations proves advantageous in that overall fresh water usage is minimized, since fresh

water at start as well as fresh water at makeup is not required, thereby improving the environmental performance of the overall bitumen recovery operations.

[0062] In yet another embodiment, the tailings stream generated from the froth separation unit (FSU) is sent to a hardness removal vessel in order to generate BFW for a SAGD or other thermal operation. The hardness removal vessel may be any suitable vessel for carrying out a hardness removal method, including but not limited to, HLS, HLS in pipe, WLS, membranes, clarifier, MVR unit or the like, among others. The tailings stream from the FSU will typically be at a processing temperature of about 85°C, although this may vary. In this process configuration, it is expected that the hardness removal process will facilitate the separation of the asphaltenes/solids from the water component of the mixture. The recovered asphaltenes/solids stream can then be subjected to a non-aqueous solvent wash or other suitable treatment to isolate a saleable asphaltene fraction. In addition, the integration of the FSU tailings with a softening process proves advantageous in that the hardness removal process will require little to no additional heat input, since the softening reaction takes place readily at the FSU processing temperature. It should be noted that the FSU water stream and the HLS water stream may be similar and thus some softening may occur in the FSU. For instance, at pH = 8.8 and T = 85-95°C, HLS units have proven to be very effective. Thus, at pH = 8.5 and T = 85°C, softening may occur in the FSU. This would be advantageous where there is adequate flow to the FSU to generate BFW.

[0063] Providing water from a water source at a mining and extraction site for production of BFW and steam for an in-situ bitumen recovery operation would permit in-situ operations to be carried out in locations lacking an abundant water source, i.e. a river or lake, on site, locations which would not generally support a stand-alone in-situ operation. The sources of water that may be used for the generation of steam to support an in-situ recovery operation include but are not limited to, surface, subsurface and process affected water associated with the mining and extraction operation. Such sources may include fresh water from a river or lake, treated water, or tailings water, such as from a tailings pond or froth separation unit. The water may also include produced water from the in-situ operation that has been treated at the mining and extraction facility in order to provide BFW for steam generation to support the in-situ operation. BFW generated may

be used to generate steam for SAGD or other thermal operations at an in-situ facility and may also be used to support operations at the mining and extraction facility.

**[0064]** Production fluids generated at the in-situ site may be separated into individual streams and processed at the in-situ site or may be directed to the mining and extraction facility for separation, processing and even disposal. Preferably, the production fluids are directed to the mining and extraction facility, since this configuration provides for a more economic development of smaller-scale in-situ production facilities.

**[0065]** If the production fluids are separated at the in-situ facility, one or more individual streams can then optionally be directed to the mining and extraction facility for further processing, treatment or disposal. For example, the production fluids may be separated into a produced water, produced gas and wet bitumen stream at the in-situ site. The produced water and bitumen streams may subsequently be directed to the mining and extraction facility for processing, treatment or disposal, while the produced gas stream may be sent to the steam generators at the in-situ facility. For optimal synergy however, the production fluids are directed from the wellhead at the in-situ site to the mining and extraction facility for separation, followed by processing, treatment, or disposal. Furthermore, if the production fluids are pipelined from a wellhead to the mine site prior to separation, only one pipeline is required for transporting the production fluids.

**[0066]** If the production fluids are separated at the in-situ facility, the produced water may be partially or fully processed at a water treatment facility at the in-situ site. However, the produced water is preferably directed to the mining and extraction site for treatment, incorporation into an extraction or other process, or disposal. Treatment, processing or disposal at the mine site minimizes or eliminates the need for water treatment facilities and disposal at the in-situ site. This integration configuration also provides an advantage which allows for the development of smaller scale in-situ facilities.

**[0067]** Thus, in accordance with the embodiments described above and variations thereof, water is provided from any suitable water source associated with a mining and bitumen extraction operation and is processed to produce boiler feed water suitable for steam generation. In the integrated configuration, the BFW is then used to generate steam to support or satisfy the demand for steam in an in-situ thermal oil recovery operation. The BFW can be generated from various water sources associated with the mining and extraction operation, including but not limited to surface, subsurface and process affected

waters. The steam is generated at the mining and extraction site or at the in-situ recovery site, all or a portion of which is then used for thermal operations at the in-situ site.

Production fluid from the in-situ site is then preferably directed back to the mine site for separation and the produced water may be added to an extraction process in the mining operation, such as hydrotransport or primary separation, or sent to disposal or water treatment facilities. Treated water can be used to generate BFW for steam generation.

**[0068]** The addition of produced water from a SAGD operation to a hydrotransport line or separation vessel at the mining and extraction facility permits the elimination of the FWKO vessels, and associated electrostatic treaters and water treatment facilities, at the in-situ site if desired, thereby minimizing the land footprint and operating costs of the in-situ facility. The in-situ footprint is further reduced if steam generation is also carried out at the mining and extraction facility. The requirement for disposal areas and other processing equipment may also be reduced or eliminated at the in-situ facility, depending on the level of integration of the production fluids into the mining operation.

**[0069]** Water from the mining and extraction site, for example, fresh river water, tailings or other water, may be used to produce BFW or steam for internal use or at an in-situ bitumen recovery site. Alternatively, water from a water source at the mining and extraction site may be used to provide BFW or steam for multiple in-situ recovery operations. Conversely, multiple mining and extraction facilities may provide BFW or steam to a single in-situ recovery operation.

**[0070]** The production fluids from multiple in-situ facilities may be directed to a single mining and extraction facility for separation, processing or treatment. Alternatively, the production fluids from a single in-situ operation may be divided and directed to multiple mining facilities, although it is recognized that this configuration is less advantageous due to the requirement for multiple pipelines and multiple mining and extraction facilities.

**[0071]** The in-situ operation and the mining facility need not be directly adjacent one another. The tolerable distance between the in-situ recovery operation and the mine site will depend on various factors, such as insulation of the pipeline and weather conditions, and it is within the ability of a skilled person to judge whether the distance between facilities is suitable for integration. Generally speaking, the two facilities may be separated by up to about 200 kms. In one embodiment, the two facilities are separated by up to about 100 kms. In another embodiment, the two facilities are separated by up to about 50 kms. In

another embodiment, the two facilities are separated by up to about 25 kms. If geological conditions are suitable, the in-situ operation and the mining operation may be at the same or adjacent locations.

[0072] The in-situ recovery and mining facilities may be considered two distinct yet integrated facilities or, depending on the level of integration and the distance between the operations, may be considered a single integrated facility or operation having both in-situ recovery and mining and extraction capabilities.

[0073] The produced water from the in-situ operation can be integrated with the mining operation at any point in the operation where a benefit or synergy will be achieved. The benefit or synergy may relate to energy reduction, waste reduction, storage efficiency, manpower reduction, resource conservation or reuse, reduced land footprint or reduced capital or operating costs. For example, the produced water may be directed to a hydrotransport line, primary separation vessel, water treatment facility, or tailings disposal site.

[0074] The in-situ operation is preferably a thermal in-situ operation, however, it is recognized that other in-situ recovery operations, such as vapour extraction (VAPEX) operations, could also be integrated with a mining operation, and the production fluids, including produced water, transported to the mining operation for processing or disposal at the mining and extraction site. The produced water may be used to make BFW for use at a thermal in-situ facility.

[0075] A mining operation or facility is generally understood to include mining, extraction, processing and treatment facilities and operations. Some mining facilities may also include upgrading or partial upgrading facilities.

[0076] Integration of water between an in-situ oil recovery operation and a mining operation offers many potential capital cost reductions over individual stand-alone operations. Integration of the two plants permits the omission of redundant equipment, reduction in fresh water consumption, potential for reuse and recycling of water between the operations, minimized land footprint for an in-situ operation since the production fluids can be separated and processed at the mining facility, and omission of costly waste storage and sludge lagoons typically associated with in-situ operations. Furthermore, energy, waste, and even manpower may be reduced by integrating the operations.

[0077] The integration of the two processes offers the potential to lower capital and operating costs due to synergies between the mining and in-situ recovery operations and facilities and advantageously allows for the economic development of smaller scale in-situ production operations.

[0078] In the preceding description, for purposes of explanation, numerous details are set forth in order to provide a thorough understanding of the embodiments of the invention. However, it will be apparent to one skilled in the art that these specific details are not required in order to practice the invention.

[0079] The above-described embodiments of the invention are intended to be examples only. Alterations, modifications and variations can be effected to the particular embodiments by those of skill in the art without departing from the scope of the invention, which is defined solely by the claims appended hereto.

**CLAIMS:**

1. A method of integrating water between a bitumen mining and extraction operation and an in-situ bitumen recovery operation, comprising:
  - (a) providing water from a water source associated with the bitumen mining and extraction operation; and
  - (b) directing all or a portion of the water, or all or a portion of boiler feed water or steam generated therefrom, to the in-situ bitumen recovery operation for use therein.
  
2. A method of integrating water between a bitumen mining and extraction operation and an in-situ bitumen recovery operation, comprising:
  - (a) providing water from a water source associated with the bitumen mining and extraction operation;
  - (b) processing the water to provide boiler feed water suitable for steam generation;
  - (c) generating steam from the boiler feed water; and
  - (d) utilizing all or a portion of the steam generated to support the in-situ bitumen recovery operation.
  
3. The method of claim 2, wherein the in-situ bitumen recovery operation is a thermal in-situ bitumen recovery operation.
  
4. The method of claim 3, wherein the thermal in-situ bitumen recovery operation comprises steam-assisted gravity drainage (SAGD), cyclic steam stimulation (CSS), or a derivative thereof.
  
5. The method of claim 4, wherein the derivative thereof is solvent-assisted SAGD (SA-SAGD), steam and gas push (SAGP), combined vapor and steam extraction (SAVEX), expanding solvent SAGD (ES-SAGD), constant steam drainage (CSD), liquid addition to steam enhancing recovery (LASER), water flooding or steam flooding.
  
6. The method of claim 4, wherein the thermal in-situ recovery operation is SAGD.

7. The method of any one of claims 2 to 6, wherein the water comprises surface water, subsurface water or process affected water associated with the bitumen mining and extraction operation.
8. The method of any one of claims 2 to 6, wherein the water is fresh water or tailings or recycled tailings water associated with the bitumen mining and extraction operation.
9. The method of claim 8, wherein the water is tailings or recycled tailings water from a tailings pond, primary separation unit or froth separation unit.
10. The method of any one of claims 2 to 9, wherein the water processing takes place at a mining and extraction facility, an in-situ bitumen recovery facility, or a combination thereof.
11. The method of any one of claims 2 to 10, wherein the steam is generated at a mining and extraction facility, an in-situ bitumen recovery facility, or a combination thereof.
12. The method of claim 10, wherein the water processing comprises primary hardness removal and optionally secondary hardness removal at a mining and extraction facility.
13. The method of claim 10, wherein the water processing comprises generating boiler feed water in a single processing step.
14. The method of any one of claims 2 to 13, wherein the steam is generated at a mining and extraction facility and is subsequently transported to an in-situ bitumen recovery facility.
15. The method of any one of claims 2 to 13, wherein the water processing takes place at a mining and extraction facility and the processed water is subsequently transported to an in-situ bitumen recovery facility for steam generation.

16. The method of any one of claims 2 to 15, wherein the steam generated is injected into a reservoir to assist in bitumen recovery in the in-situ bitumen recovery operation.
17. The method of any one of claims 2 to 16, further comprising the step of removing residual water from the steam prior to utilizing the steam in the in-situ recovery operation.
18. The method of claim 2, further comprising the steps of:
- (e) obtaining a production fluid from the in-situ recovery operation;
  - (f) obtaining produced water from the production fluid; and
  - (g) directing the produced water to the mining and extraction operation.
19. The method of claim 18, wherein the production fluid is transported from the in-situ recovery operation to the mining and extraction operation and wherein step f) is carried out at a mining and extraction facility.
20. The method of claim 18 or 19, wherein in step (g) the mining and extraction operation comprises hydrotransport, primary separation, water treatment, tailings management or tailings disposal.
21. The method of any one of claims 18 to 20, wherein the produced water is directed to a tailings pond following recovery of heat from the produced water.
22. The method of claim 21, wherein the heat is recovered using conventional heat exchange.
23. A method of integrating water between a mining and bitumen extraction operation and a thermal in-situ bitumen recovery operation, comprising:
- providing water from a water source at the bitumen mining and extraction operation; and
  - processing the water to produce steam for use in the thermal in-situ bitumen recovery operation.

24. The method of claim 23, further comprising:  
obtaining produced water from the in-situ bitumen recovery operation; and  
directing the produced water to the bitumen mining and extraction operation for  
processing, treatment or disposal.
25. A system for integrating water between a bitumen mining and extraction operation  
and an in-situ bitumen recovery operation, comprising:  
(a) a bitumen mining and extraction facility having a water source associated  
therewith;  
(b) an in-situ bitumen recovery facility; and  
(c) a transporter for transporting water from the water source, or all or a  
portion of boiler feed water or steam generated therefrom, to the in-situ bitumen recovery  
facility for use in an in-situ bitumen recovery operation.
26. The system of claim 25, wherein the in-situ bitumen recovery operation is a  
thermal in-situ recovery operation.
27. The system of claim 26, wherein the thermal in-situ recovery operation comprises  
steam-assisted gravity drainage (SAGD), cyclic steam stimulation (CSS), or a derivative  
thereof.
28. The system of claim 27, wherein the derivative thereof is selected from solvent-  
assisted SAGD (SA-SAGD), steam and gas push (SAGP), combined vapor and steam  
extraction (SAVEX), expanding solvent SAGD (ES-SAGD), constant steam drainage  
(CSD), liquid addition to steam enhancing recovery (LASER), water flooding or steam  
flooding.
29. The system of claim 27, wherein the thermal in-situ recovery operation is SAGD.
30. The system of any one of claim 25 to 28, wherein the water source comprises  
surface water, subsurface water or process affected water.

31. The system any one of claim 25 to 28, wherein the water source comprises fresh water or tailings or recycled tailings water.
32. The system of claim 31, wherein the water source comprises tailings or recycled tailings water from a tailings pond, primary separation vessel or froth separation unit.
33. The system of any one of claims 25 to 32, wherein the mining and extraction facility comprises water treatment facilities.
34. The system of claim 33, wherein the mining and extraction facility further comprises steam generating facilities.
35. The system of any one of claims 34, wherein the transporter is a pipeline for transporting steam generated at the steam generating facilities to the in-situ bitumen recovery operation for use in bitumen recovery.
36. The system of claim 22, further comprising a production fluid transporter for transporting production fluid from the in-situ bitumen facility to the bitumen mining and extraction facility.
37. The system of claim 36, wherein the production fluid transporter is a pipeline.

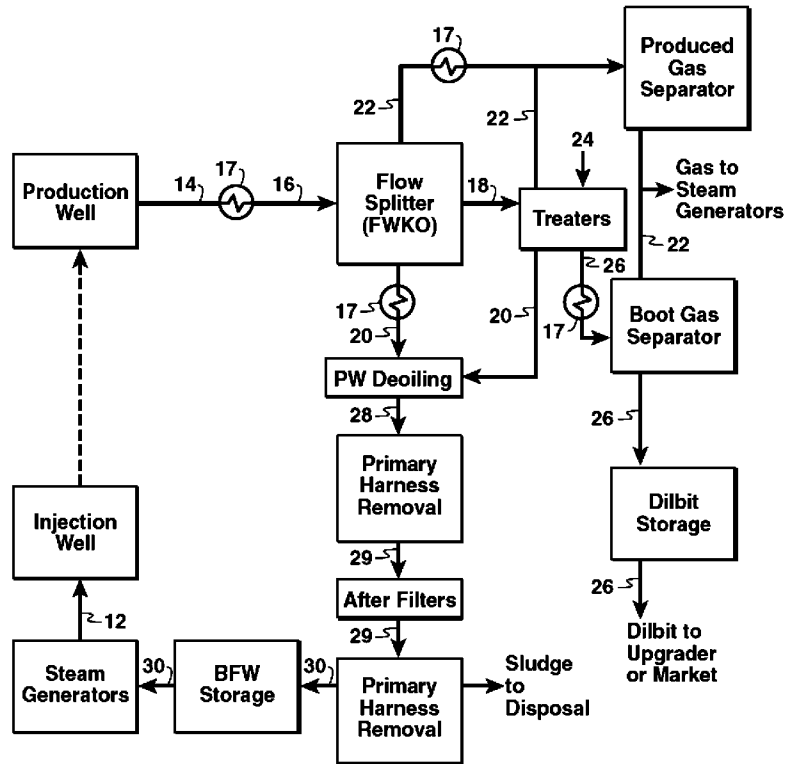


Fig. 1

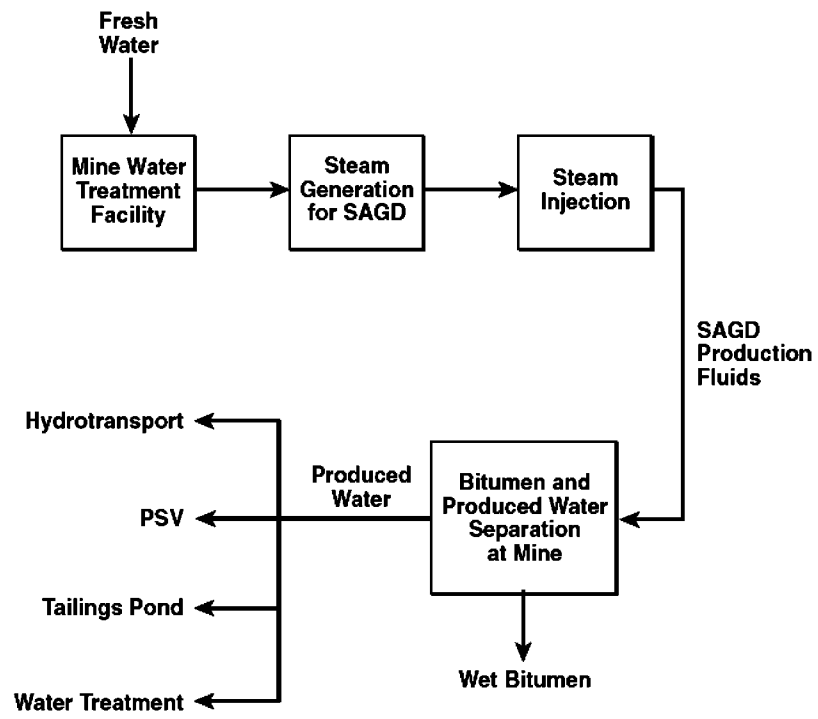


Fig. 2

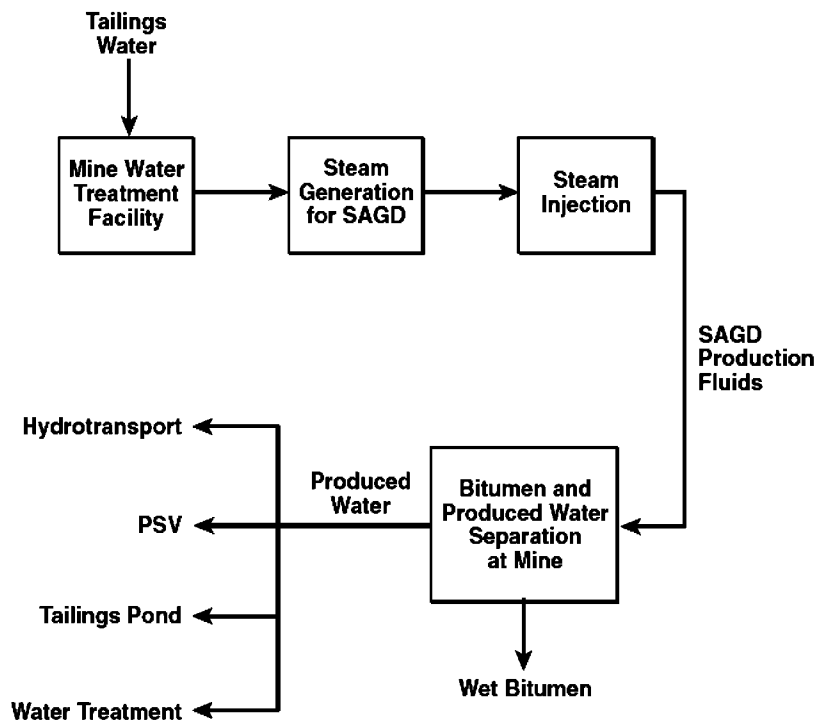


Fig. 3

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 08/79578

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - E21B 43/24 (2008.04)

USPC - 299/7, 166/272.3

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

USPC - 299/7, 166/272.3

IPC(8) - E21B 43/24 (2008.04)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

USPC - 299/7, 166/272.3 and all USPC classes - see keywords below

IPC(8) - E21B 43/24 (2008.04) - see keywords below

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PubWEST(USPT, PGPB, EPAB, JPAB); Google, Google Scholar

Search Terms: bitumen, mining, operation, BFW, boiler feed water, tar sands, oil sands, water, in-situ, SAGD, integrate, recycle, reuse, recover, consume, integrate, combine, associate, coordinate, unite, unify, tailing, extractor, heat exchanger.

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4,499,949 A (AUDEH) 19 February 1985 (19.02.1985), col 3, ln 38-41, 50-52 - col 4, ln 1-3, 12.	1-9, 18-20, 23-32
Y	US 2003/0127400 A1 (KRESNYAK) 10 July 2003 (10.07.2003), para[0003], [0072], [0088], [0089], [0091], [0092], figure 1.	1-9, 18-20, 23-32
Y	US 4,240,897 A (CLARKE) 23 December 1980 (23.12.1980), col 2, ln 18-20, 30-31, 33-35 - col 3, ln 18-21.	9, 19-20, 24, 32

Further documents are listed in the continuation of Box C.

\* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&amp;" document member of the same patent family

Date of the actual completion of the international search

02 December 2008 (02.12.2008)

Date of mailing of the international search report

15 DEC 2008

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents

P.O. Box 1450, Alexandria, Virginia 22313-1450

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PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 08/79578

**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.  Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
  
2.  Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
  
3.  Claims Nos.: 10-17, 21-22, 33-37  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

1.  As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2.  As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3.  As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
  
4.  No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

**Remark on Protest**

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.