



(22) Date de dépôt/Filing Date: 2007/11/09

(41) Mise à la disp. pub./Open to Public Insp.: 2009/05/09

(45) Date de délivrance/Issue Date: 2012/04/24

(51) Cl.Int./Int.Cl. *E21B 43/24* (2006.01),
C10G 1/04 (2006.01), *E21B 43/34* (2006.01),
E21B 43/241 (2006.01)

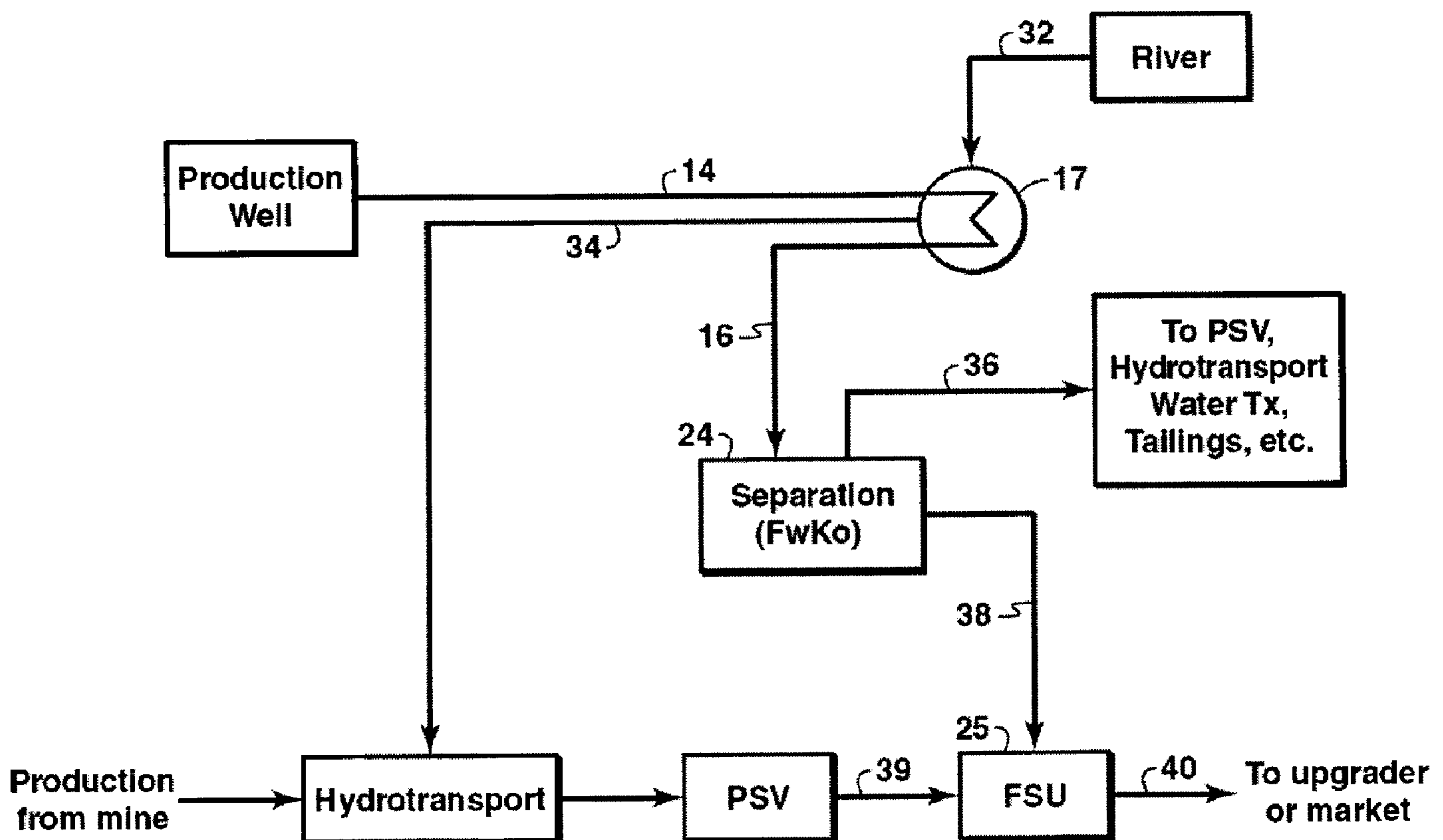
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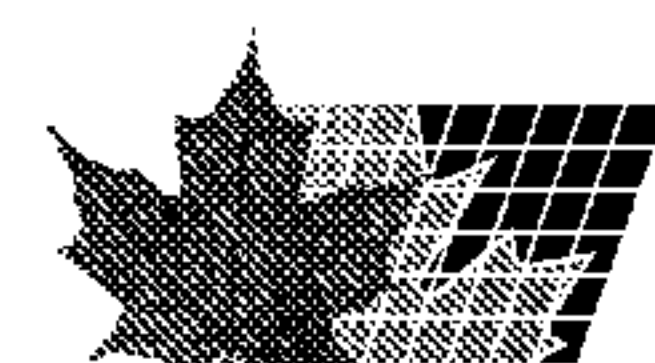
(54) Titre : INTEGRATION D'OPERATION DE RECUPERATION IN SITU AVEC L'EXTRACTION MINIERE

(54) Title: INTEGRATION OF AN IN-SITU RECOVERY OPERATION WITH A MINING OPERATION



(57) Abrégé/Abstract:

There is a general need for improved efficiencies in the bitumen and heavy oil recovery and extraction industry. The present invention is directed to a method and system for integrating an in-situ bitumen recovery operation with a bitumen mining operation



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

for improved efficiencies and synergies therebetween. The method comprises the basic steps of obtaining a production fluid from the in-situ bitumen recovery operation, directing the production fluid to the bitumen mining operation, and incorporating the production fluid into the bitumen mining operation. The basic integrated system comprises a production well for recovering production fluid from the in-situ bitumen recovery operation, a bitumen mining and extraction facility, and a transporter for directing the production fluid from the production well to the bitumen mining and extraction facility for incorporation into the mining and extraction operation. 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. The integrated method and system of the present invention provide the potential to reduce capital investment, operating costs, overall land footprint and fluctuations in mine production, compared with stand-alone in-situ recovery and mining operations. The integrated method and system of the invention also provide the potential for commercial development of smaller scale in-situ recovery operations.

ABSTRACT

There is a general need for improved efficiencies in the bitumen and heavy oil recovery and extraction industry. The present invention is directed to a method and system for integrating an in-situ bitumen recovery operation with a bitumen mining operation for improved efficiencies and synergies therebetween. The method comprises the basic steps of obtaining a production fluid from the in-situ bitumen recovery operation, directing the production fluid to the bitumen mining operation, and incorporating the production fluid into the bitumen mining operation. The basic integrated system comprises a production well for recovering production fluid from the in-situ bitumen recovery operation, a bitumen mining and extraction facility, and a transporter for directing the production fluid from the production well to the bitumen mining and extraction facility for incorporation into the mining and extraction operation. 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. The integrated method and system of the present invention provide the potential to reduce capital investment, operating costs, overall land footprint and fluctuations in mine production, compared with stand-alone in-situ recovery and mining operations. The integrated method and system of the invention also provide the potential for commercial development of smaller scale in-situ recovery operations.

INTEGRATION OF AN IN-SITU RECOVERY OPERATION WITH A MINING OPERATION

FIELD OF THE INVENTION

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

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.

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.

Bitumen comprises large hydrocarbon molecules along with other elements, such as nitrogen, oxygen, vanadium, nickel and sulfur. The structure of oil sand comprises water-wetted sand grains with the viscous bitumen trapped between and around the grains. Bitumen does not flow at normal ambient temperatures and pressures making it difficult and expensive to extract and process.

Bitumen can be recovered from oil sand by various methods, the most common of which include surface or strip mining and in-situ recovery methods, including in-situ thermal recovery methods.

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 warm water 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 or higher, 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 more cost effective and efficient than previous modes of transport and it also “conditions” the slurry for bitumen separation, such that less processing is required at the plant prior to extracting the bitumen.

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 material from the hydrotransport process for transport to the extraction plant.

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 process aides 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, and tailings, containing sand and particulate, are pumped off. The middlings and sand tailings may be further processed, for example, to extract more bitumen or recycle water. The waste will eventually be treated or disposed of, for example, in tailings ponds.

The bitumen froth is next treated in a froth separation unit (FSU) to promote separation of the bitumen from other components of the froth, which include water, solvent, other agents, and residual solids. 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.

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.

Currently, on average, between one and a half and two tons of oil sand are processed to produce one 159-liter barrel of synthetic crude oil. Large quantities of oil sand must be mined and processed each day in order to supply the high demand for synthetic crude oil. A significant disadvantage of the bitumen mining operation is that the operation is subject to upset and down time whenever problems occur at either the mining, recovery or processing level. Thus, production volumes can be inconsistent from day to day and there is a need to smooth out fluctuations in production.

The bitumen mining operation requires expensive and elaborate processing facilities and an abundance of water, typically provided from a nearby river or lake or process affected water from a storage pond, as well as energy for heat generation. There is a need for improving efficiencies in the mining industry in general and reducing the energy, resource consumption and environmental impact associated with bitumen mining operations.

In-situ oil recovery methods, such as in-situ thermal 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.

Thermal in-situ recovery processes use heat 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 for enhancing recovery (LASER), as well as water flooding and steam flooding processes.

In typical gravity driven thermal bitumen 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. 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.

The hot production fluids, typically comprising about 70% produced water and about 30% bitumen and produced gases, are recovered at the surface via the production well and are separated into their individual components on site. Production fluids from the wellhead are cooled somewhat and sent to a flow splitter to separate the bitumen, produced water and produced gas into individual streams, which typically each undergo further treatment on site. The process to separate the hot production fluids into their individual components and the subsequent treatment of the separate streams is complex and is prone to operational upsets and down time.

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 water stream is deoiled and the oil free water stream is subsequently treated to provide boiler feed water of quality for steam generation. The produced gas stream can also provide gas for the steam generators. This conventional set up results in numerous waste streams that must be handled appropriately and the residual waste is sent to a disposal well or sludge lagoon.

While it is recognized that in-situ techniques disturb considerably less land than mining operations, and therefore require less land reclamation activity, in-situ techniques are highly capital intensive and require a significant number of vessels for processing, treatment and storage, and disposal areas, that occupy a large land footprint. The commercial development of smaller sized thermal operation plants (e.g. < 20,000 bbl/d bitumen) may not currently be feasible due to high capital investment costs of the existing technologies.

Challenges associated with bitumen mining and in-situ bitumen recovery processes in general include intense capital investment and operating costs, large land footprint due to the equipment and land required for bitumen extraction and processing and waste management and disposal, and vulnerability to fluctuations in production and downtime. 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.

While attempts to improve efficiency by integrating processes within an in-situ thermal bitumen recovery operation or within a mining operation have been made,

advantages to be achieved by integrating production from an in-situ operation with a mining operation have not previously been identified. Combining bitumen end products from in-situ recovery and mining facilities in a single pipeline for transport to market has previously been proposed but this would provide an endpoint transportation benefit only since a complete in-situ processing facility would still be required to separate and process the recovered production fluids and manage the waste associated therewith.

It is desirable to provide new methods and systems for reducing capital investment and operational costs associated with bitumen and heavy oil recovery, to reduce the impact of fluctuations in production associated with bitumen and heavy oil recovery operations, and to reduce the large land footprint of facilities associated therewith.

SUMMARY OF THE INVENTION

The present invention is directed to a novel method and system for integrating an in-situ oil recovery operation with a bitumen mining operation. By integrating the operations, many previously unrecognized efficiencies and synergies may be achieved.

In a first aspect, the present invention provides a method of integrating an in-situ bitumen recovery operation with a bitumen mining operation. The method comprises the basic steps of (a) obtaining a production fluid from the in-situ bitumen recovery operation; (b) directing the production fluid to the bitumen mining operation; and (c) incorporating the production fluid into the bitumen mining operation.

The in-situ bitumen recovery operation may be a thermal in-situ recovery operation, such as steam-assisted gravity drainage (SAGD), cyclic steam stimulation (CSS), or any derivative thereof.

The hot production fluid may be incorporated into any process in the mining operation, such as an extraction, separation or treatment process. The hot production fluid may alternatively be cooled prior to incorporation into a mining process, e.g. via conventional heat exchange, and the captured heat may be used to heat a fluid required for the mining operation.

In a further aspect, the present invention provides an integrated in-situ recovery and bitumen mining system. The system comprises (a) a production well for recovering production fluid from an in-situ bitumen recovery operation; (b) a bitumen mining and extraction facility; and (c) means of directing the production fluid from the production well to the bitumen mining and extraction facility for incorporation into a mining operation.

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

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

Fig. 1 is a schematic exemplifying a typical commercial facilities processing configuration for handling production fluids recovered in an in-situ thermal recovery process;

Fig. 2 is a schematic exemplifying an integrated in-situ recovery operation and mining operation, in accordance with an embodiment of the present invention, wherein hot production fluids are cooled via heat exchange prior to separation at the mining facility, and the captured heat is used to heat a water source, exemplified as river water, for use in bitumen extraction at the mine;

Fig. 3 exemplifies a modification of the embodiment of Fig. 2, wherein the production fluids are cooled and added directly to the Primary Separation Vessel (PSV) at the mining facility, at which point in the operation the in-situ production fluids commingle with hydrotransport effluent;

Fig. 4 exemplifies a modification of the embodiment of Fig. 2, wherein the production fluids are cooled and added directly to the Froth Separation Unit (FSU) at the mining facility;

Fig. 5 exemplifies an optional step in the embodiment of Fig. 4, wherein gas is separated from the production fluids and the degassed fluids are added to the FSU at the mining facility; and

Fig. 6 exemplifies a modification of the embodiment of Fig. 2, wherein the production fluids are cooled and added directly to the hydrotransport line at the mining facility.

DETAILED DESCRIPTION

Generally, the present invention provides a method and system for integrating an in-situ recovery operation with a mining operation to improve energy, resource and/or operational efficiencies. More particularly, the present invention provides a method and system for integrating a production fluid from a thermal recovery operation with a bitumen mining operation for achieving one or more improved efficiencies.

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 an in-situ processing facility with a mining facility. These may include 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 operations and facilities.

Integration of an in-situ recovery operation with a mining facility has the potential to eliminate substantial capital requirements for the thermal in-situ plant as well as smooth out production volumes at the mine, and would allow for more economical development of smaller scale thermal production operations. In one embodiment of the invention, a small scale thermal in-situ facility is integrated with a nearby existing mining facility.

An exemplary prior art commercial facilities processing configuration for processing the production fluids from an in-situ thermal recovery process is depicted in Figure 1. The present invention is not limited in any way to an in-situ bitumen recovery operation having the exemplified configuration so long as production fluids are obtained that can be integrated with a mining operation. The exemplified facilities configuration is described to provide an illustrative example only.

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 exact proportions can vary. The production fluids will generally have an inlet temperature in the range of about 120°C to 220°C, typically about 200°C, and an inlet pressure of about 450 kPa to 2300 kPa, typically about 600 kPa for conventional (bitumen less dense than water) treating. These values may vary considerably however depending on the particular operation.

The hot production fluids 14 from the wellhead are 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. The heat captured may be used to heat a fluid for the operation, such as glycol. The flow splitter may separate the production fluids into two or more separate streams. In Figure 1, the exemplified flow splitter separates the production fluids into a bitumen stream 18, a

produced water stream 20 and a produced gas stream 22. The individual streams each undergo further processing on site.

The bitumen stream 18, which contains residual water, is sent to the treaters, which may contain electrostatic grids. 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 on-site upgrader or transported by pipeline to a refinery or an off-site upgrader. The dilbit is generally stored on site in storage tanks prior to being pipelined to market.

The produced water (PW) stream 20, which comprises some residual bitumen (i.e. <5%), is subsequently deoiled, via resident time in a skim tank, passage through an Induced Gas Floatation (IGF) or another suitable method, such as Induced Static Floatation (ISF), and optionally by passage through 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 treatment. From there, 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. This conventional set up also results in numerous waste streams (energy, water, solids, etc.) that must be handled appropriately, not shown in Figure 1.

Although the complete facilities processing configuration may be required for a stand-alone in-situ thermal oil recovery processing operation, the integration of a thermal oil recovery operation with a nearby oil sand mining facility provides many potential improvements to the process configuration presented in Figure 1, embodiments of which will be discussed in more detail below.

While the method and system of the present invention can be used to integrate any suitable in-situ bitumen recovery operation with a bitumen mining operation, integration of a thermal in-situ operation, such as SAGD, with a bitumen mining operation will be exemplified herein for illustrative purposes. While reference is made to particular exemplary facilities configurations, a skilled person will appreciate that variations, modifications and optional steps can be added or omitted without departing from the scope of the invention.

In a first embodiment of the invention, the production fluids from an in-situ thermal recovery operation are transported from the production well to a mine site for processing. The typical bitumen facilities processing configuration required to separate bitumen and

produced water recovered from an in-situ thermal process is thereby minimized by integrating thermal production fluids and surface facilities with a nearby mining operation.

In this approach, the production fluids 14 are transported, such as by pipeline, from the wellhead at production temperatures and pressures to a desired mine site. Exemplary production temperatures and pressures may be in the range of, for example, $80^{\circ}\text{C} < T < 250^{\circ}\text{C}$, $450 \text{ kPa} < P < 3000 \text{ kPa}$, more typically $120^{\circ}\text{C} < T < 220^{\circ}\text{C}$, $450 \text{ kPa} < P < 2300 \text{ kPa}$. The distance over which the production fluids are transported may range from a few kilometers to a few hundred kilometers depending on the distance between the facilities, and may require the use of pressure boosting stations. Alternatively, the two facilities may be adjacent one another if geological conditions are suitable. A skilled person can determine the tolerable distance and the best mode of transporting the production fluids by taking into account practical considerations, such as heat loss over the distance to be traveled.

The production fluids 14 may subsequently be separated in to their individual components using standard separation vessels and processes for the recovery of bitumen from the oil sands mining operation. In this approach, the requirement for processing facilities at the in-situ location may be significantly reduced.

In one embodiment, exemplified in Figure 2, the first step in the process involves cooling the hot production fluids from a production temperature, typically about 200°C , to a desired temperature, for example, a temperature suitable for processing at the mine. The processing temperature will vary depending on which process the production fluid will enter at the mine. The production fluid can be cooled via conventional heat exchange 17 or by any other suitable means. The medium used to cool the thermal production fluids may be water used in the extraction process at the mine. Extraction water will typically come from a cool water source near the mine site, such as river or lake water, which is typically about 5°C to about 15°C . The water source may also include cooled recycled tailings water, or any other suitable water source. River water is exemplified in the figures to provide a working example. As exemplified in Figure 2, cool river water 32 is heated toward a processing temperature, typically of about 35°C - 45°C for extraction, to provide warm extraction water 34 for recovery of bitumen from oil sand. The increase in temperature of the cool water via this heat exchange will depend on the production temperature and pressure of the production fluids among other factors. For example, if the production fluids (ex. $10,000 \text{ m}^3$) are $120^{\circ}\text{C}/450\text{kPa}$, a 5°C water stream (ex. $100,000 \text{ m}^3$) could reasonably be heated to about 15°C . If the production fluids (ex. $10,000 \text{ m}^3$) are $200^{\circ}\text{C}/2300 \text{ kPa}$, a 5°C water stream (ex. $100,000 \text{ m}^3$) could reasonably

be heated to about 22°C. This integration configuration results in effective heat capture of the production fluids and reduces the amount of fuel/steam required to heat the cool water to the desired processing temperature.

Diluent 24 or condensate is then added to the cooled production fluids 16 in a separation vessel (FWKO) to facilitate primary separation of the bitumen from the produced water. The selection of diluent 24 used to aid in the separation of the SAGD production fluids is selected such that it is compatible with the solvent 25 used in the froth treatment process of the mining operation. By compatible, it is meant that the mixture of the diluent 24 and the solvent 25 will not negatively impact the extraction process or solvent recovery. In one embodiment, the diluent selected is the same as the solvent. For example, a mining operation that employs C₅ solvent for Paraffinic Froth Treatment (PFT) may utilize C₅ solvent to facilitate the separation of bitumen and produced water in the FWKO. Similarly, a process that employs naphtha in the froth treatment process may use naphtha in the FWKO.

The solvent to bitumen volume ratio may be selected such that a desired density difference (between water and diluted bitumen) is achieved. A suitable ratio is selected such that asphaltenes do not precipitate. The ratio selected will depend on the bitumen composition, temperature, pressure, and solvent choice, among other factors, as will be appreciated by the skilled person. Although, in most cases the volume ratio is about 0.5 (1:2) or less, other volume ratios may be selected, for example about 0.25 (1:4) to about 2 (2:1). Higher ratios may also be selected. For example, a ratio higher than 0.5 may be selected while ensuring that the onset of asphaltene precipitation does not occur.

Upon separation, two liquid streams are produced, namely, a deoiled produced water stream 36 and a wet bitumen stream 38. The wet bitumen stream 38 may generally contain about 5% to about 30% water by volume. In one embodiment, the amount of water in the wet bitumen stream 38 is chosen such that the water content approximates the ratio of bitumen to water present in the froth separation unit (FSU) feed stream 39 of the mining operation.

The produced water stream 36 recovered from the FWKO is subsequently sent to water treatment facilities and may be used to prepare boiler feed water of quality for steam generation to support the SAGD operation. Alternatively, the produced water stream 36 can be recycled to the hydrotransport of the mining operation to assist in the liberation of bitumen from the oil sands. If desired, the produced water stream 36 may be discharged to the tailings pond and stored for future use. It is recognized however that

this approach is less advantageous due to wasted heat, via cooling of the stream to ambient temperature or less, and the prevention of immediate water re-use.

The wet bitumen stream 38, comprised of diluted bitumen and produced water, is then sent to FSU wherein makeup solvent 25 is added. The solvent may be any suitable solvent, examples of which include, but are not limited to, C_5 to C_{10} and beyond, including as examples, C_5 , C_6 , C_7 , C_8 , blends of iso C_5 and normal C_5 , mixtures of C_5 and C_6 and mixtures of C_5 - C_8 solvents. The amount of makeup solvent added may be selected based upon the composition of the diluent used in the mining operation. The solvent and the diluent are selected such that they are compatible with one another and are preferably identical. In one example, in the integration of SAGD and a Paraffinic Froth Treatment (PFT) mining operation, the amount of makeup C_5 solvent selected is the amount needed to achieve an overall C_5 :bitumen volume ratio of about 1.8:1. The volume ratio may be selected so as to precipitate about 6% to 10%, or about 6% to 8%, asphaltenes from the bitumen.

The clean de-asphalted upgraded bitumen product 40 is then recovered from the produced water/tailings water and solids stream from the mining operation and can be pipelined to market or sent to an upgrader. The produced water/tailings water and solids stream from the FSU may subsequently be transferred to the tailings pond.

The integration of an in-situ production facility with a mining operation utilizing PFT is exemplified in Figure 2. This process allows for the generation of a dry and solids free upgraded bitumen product 40 from in-situ production that can be pipelined to market or transferred to an upgrader either on-site or off-site.

In the above-described embodiment, the elimination of various equipment, such as electrostatic treaters to separate bitumen from water, as well elimination of additional diluent tankage and storage, encountered in typical SAGD operations may be realized. Moreover, integration of production from the SAGD operation would smooth out the daily fluctuations in production volumes from the mining operation.

If desired, volume ratios of solvent may be intentionally selected to encourage the precipitation of asphaltenes. In an extension of the above-described embodiment, for example, if softening of the produced water stream 36 isolated from the FWKO vessel is required and conventional softening (e.g. HLS or WLS) is utilized, higher volume ratios of C_5 solvent may be intentionally added to the bitumen/produced water production fluid in the FWKO vessel for precipitation of asphaltenes. An exemplary ratio would be about 1.8:1 C_5 solvent to bitumen. In the setup, de-asphalting could be carried out in the FWKO vessel. The precipitated asphaltenes would then flow with the produced water

stream, optionally with the addition of a flocculant, from the FWKO to the water treatment facilities (e.g. HLS). In the softening vessels, the asphaltenes would coagulate with precipitated hardness solids to form a hydrocarbon-inorganic solids mixture that would be discharged to the tailings pond upon cooling, preferably utilizing heat exchange. The de-asphalted bitumen product formed in the FWKO vessel could then be added to the FSU, if residual precipitation is required, or directly combined with the PFT production from the mining operation and pipelined to the desired market.

In another embodiment of an integrated thermal bitumen recovery operation and bitumen mining operation, exemplified in Figure 3, using SAGD as an example, the SAGD production fluids 14 are transported to the mine site, preferably via pipeline, and are added directly to the Primary Separation Vessel (PSV) at or near processing temperature, typically about 35°C. In this embodiment, the bitumen present in the production fluids is recovered at the mine site after combining the production fluids with the production from the mining and extraction facilities, permitting elimination of the FWKO vessels and electrostatic treaters in the thermal operation. FWKO vessels and/or treaters could of course be utilized with any of the embodiments, if desired or required. Heat recovered from the thermal production fluids can be used to heat a fluid for use at the mine to a desired temperature, such as via conventional heat exchange 17. For example, heat from the production fluids 14 may be used to heat cold extraction water, exemplified as river water 32, to provide warm extraction water, exemplified as river water 34, for use in bitumen extraction and the cooled production fluids 16 are then added to the PSV.

Alternatively, hot production fluids 14 may be added to the PSV at or near production temperature. The introduction of hot production fluids 14 into the PSV could provide deaeration of froth, thereby reducing the requirement for designated steam use.

In yet another embodiment of an integrated thermal recovery operation and bitumen mining operation, using SAGD as an example, the hot production fluids 14 are transported to the mining site and added directly to the Froth Separation Unit (FSU) at or near production temperature, typically about 200°C, thereby eliminating the requirement for FWKO and electrostatic treaters in the thermal operation.

Diluent, for example, naphtha or paraffinic solvent, may be added upstream of the FSU, to the SAGD production fluids, or directly to the FSU, to facilitate the separation of the bitumen from the water and solids. Heat from the production fluids is used to warm the FSU to the desired processing temperature to enhance separation. Water and solids recovered from the process can be stored in tailings ponds for further use. The diluted

bitumen may be further processed or sent to an on site upgrader or pipelined to a desired market. The diluent may be recycled for reuse.

In one embodiment, the in-situ production fluids are combined with a mining operation that utilizes a process to remove asphaltenes, such as PFT. This results in a partially deasphalted product recovered from an in-situ recovery operation.

Figure 4 exemplifies an embodiment wherein the hot production fluids 14 are cooled, to at or near processing temperature, typically about 45°C to 90°C, via heat exchange 17, before being directed to the FSU. In the embodiment shown, PFT is carried out. The heat recovered from the hot production fluids 14 is used for the mining and extraction operation. In the exemplified embodiment, the captured heat is used to heat cool river water 32 to provide warm river water 34 for use in the extraction process. Of course, any other suitable water source could also be used.

In a modification of this embodiment, a slip stream of the SAGD production fluids is added to the FSU to maintain the proper bitumen to water to solids balance and ensure effective operation of the unit.

The production stream coming from the thermal operation can optionally be tailored to match the fluid going into the FSU from the mining operation. For a PFT process, the composition of fluids at the inlet of the FSU is approximately 60% bitumen, 30% water and 10% solids, although these proportions may vary. Diluent (i.e. paraffinic solvent) is then added to this composition to facilitate the partial removal of asphaltenes and solids. The production fluids from the in-situ operation comprise approximately 70% water and 30% bitumen and gas.

In an optional step, the SAGD production fluids 16 may be directed to a de-gas vessel for gas separation, as exemplified in Figure 5, prior to reaching the FSU, such that gas free production fluids 19 are then added to the FSU. The gas stream 22 produced may be directed to the mine processing facilities. The production fluid may further undergo an optional dewatering step prior to reaching the FSU to adjust the water content.

In a further embodiment of an integrated thermal recovery operation and bitumen mining operation, exemplified in Figure 6, using SAGD as an example, the hot production fluids 14 are transported, preferably via pipeline, to the mining and extraction site and are subsequently added to a hydrotransport line to facilitate the extraction of bitumen from the mined oil sands. In the embodiment shown, the production fluids 14 are cooled to processing temperature, typically about 35°C, via heat exchange 17, and the cooled production fluids 16 are added to the hydrotransport line. The captured heat may be used

to heat cool river water 32 to provide warm river water 34 for various mining operations, such as bitumen extraction.

In an alternate embodiment, the production fluids are added to the hydrotransport line at or near production temperature, typically about 200°C. The hot production fluids 14 assist with the extraction process by providing heat to facilitate separation of the bitumen. The addition of hot production fluids 14 to the hydrotransport line decreases the demand for water and heat for hydrotransport at the mine. SAGD produced water composition is not expected to differ in comparison to typical extraction water sources currently used and will therefore have a negligible impact on extraction efficiency.

The production from the hydrotransport line is subsequently directed to the froth separation facilities and the bitumen or partially upgraded bitumen can then be recovered and sent to the desired market. Water and solids generated in the process may be stored in the tailings area of the mine.

The SAGD production fluids may optionally be directed to a de-gas vessel for gas separation prior to being added to the hydrotransport line. The gas may then be directed to the mine processing facilities or used to generate steam to support the SAGD operation. The optional step of degassing the production fluids prior to integration into the mining operation could be applied to any of the described embodiments.

The addition of production fluids to a hydrotransport line at the mine eliminates the requirement for the FWKO vessels and associated electrostatic treaters and water treatment facilities, and thereby minimizes the land footprint and operating costs of the thermal facility. The requirement for disposal areas and other processing equipment may also be eliminated at the thermal facility depending on the level of integration of the production fluids into the mining operation.

The production fluids from an in-situ operation can be partially treated at an in-situ facility prior to being integrated into the mining operation. However, for optimal synergy, the production fluids are transported from the wellhead to the mining facility to be processed. This enhances the development potential of small scale in-situ bitumen recovery operations.

The production fluids from multiple in-situ operations may be integrated with a single mining operation. Alternatively, the production fluids from a single in-situ operation may be divided and processed in multiple mining facilities, although this scenario may be less advantageous due to the requirement for multiple pipelines from the in-situ operation.

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 or less. For instance the two facilities may be separated by up to about 100 kms, up to about 50 kms, or 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.

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 having both in-situ oil recovery and mining and extraction capabilities. Furthermore, it is understood that the mine site and extraction facility may not be directly adjacent one another.

The production fluids 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, manpower reduction, resource conservation or reuse, reduced land footprint or reduced capital or operating costs.

The in-situ operation is preferably a thermal in-situ bitumen recovery 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, so long as the production fluids are suitable for transport to and integration with the mining operation. A mining operation generally includes mining, extraction, processing and treatment facilities and operations. Some mining operations may also include upgrading or partial upgrading facilities.

Integration of production fluids from an in-situ oil recovery operation with a mining operation offers many potential capital cost reductions over individual stand-alone operations. Integration of the two plants also has the potential to: permit omission of redundant equipment, share one expensive diluent pipeline to transport product to market, produce a higher quality in-situ production product, minimize land footprint required for an in-situ operation since the production fluids can be processed at the mining facility, and omit costly waste storage and sludge lagoons typically associated with thermal in-situ bitumen recovery operations. Furthermore, energy, waste, resource consumption, and even manpower may be reduced by integrating the operations. The integration of the two processes offers the potential to lower capital and operating costs

due to synergies between the mining and thermal recovery operations facilities and allow for the economic development of smaller scale in-situ production operations.

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. For instance, temperature and pressure ranges are provided for exemplary purposes and not to limit the scope of the invention.

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 an *in-situ* bitumen recovery operation with a bitumen mining and extraction operation comprising:
 - (a) obtaining a production fluid from the *in-situ* bitumen recovery operation;
 - (b) directing the production fluid to the bitumen mining and extraction operation; and
 - (c) incorporating the production fluid into the bitumen mining and extraction operation.
2. The method of claim 1, wherein the *in-situ* bitumen recovery operation is a thermal *in-situ* recovery operation.
3. The method of claim 2, wherein the thermal *in-situ* recovery operation comprises steam-assisted gravity drainage, cyclic steam stimulation, or a derivative thereof.
4. The method of claim 3, wherein the derivative thereof is selected from solvent-assisted steam-assisted gravity drainage, steam and gas push steam-assisted gravity drainage, combined vapor and steam extraction, expanding solvent steam-assisted gravity drainage, constant steam drainage, liquid addition to steam enhancing recovery, water flooding or steam flooding.
5. The method of claim 3, wherein the thermal *in-situ* recovery operation is steam-assisted gravity drainage.
6. The method of claim 1, wherein the *in-situ* recovery operation comprises vapour extraction.
7. The method of claim 2, wherein the production fluid is incorporated into a process in the bitumen mining and extraction operation.
8. The method of claim 7, wherein the process is an extraction, separation or treatment process.

9. The method of claim 8, wherein the process is an extraction process comprising hydrotransport.
10. The method of claim 8, wherein the process is a separation process comprising primary separation or froth separation.
11. The method of claim 10, wherein the separation process is froth separation comprising paraffinic froth treatment.
12. The method of claim 10, wherein the separation process is froth separation comprising naphthenic froth treatment.
13. The method of claim 1, wherein solvents or diluents are used in the integrated method and are selected such that they are compatible with one another in that they do not negatively impact bitumen production operations and the production thereof.
14. The method of claim 8, wherein the production fluid is incorporated into the process at or near a production temperature or a processing temperature.
15. The method of claim 14, wherein the production fluid is incorporated into the process at a production temperature.
16. The method of claim 15, wherein the production temperature is about 120°C to about 220°C.
17. The method of claim 16, wherein the production temperature is about 150°C to about 210°C.
18. The method of claim 17, wherein the production temperature is about 200°C.
19. The method of claim 8, wherein the production fluid is directed to the bitumen mining and extraction operation via transportation by pipeline.
20. The method of claim 8, wherein the production fluid is directed to the bitumen mining and extraction operation at a production temperature and is cooled to a desired processing temperature prior to being incorporated into the process.

21. The method of claim 20, wherein the production fluid is cooled via conventional heat exchange.
22. The method of claim 21, wherein heat captured when the production fluid is cooled is used to heat a fluid for use in the bitumen mining and extraction operation.
23. The method of claim 22, wherein the fluid is for use in an extraction, separation or treatment process.
24. The method of claim 23, wherein the fluid is river water, lake water, pond water, or process affected water for use in an extraction process.
25. The method of claim 20, wherein a diluent is added to the cooled production fluid to facilitate separation of bitumen and water from the thermal *in-situ* recovery operation in a primary separation process in the mining and extraction operation.
26. The method of claim 25, wherein the diluent selected is compatible with a solvent used in a froth treatment process prior to entering the mining and extraction operation.
27. The method of claim 26, wherein the solvent is selected from C₅, C₆, C₇, C₈, C₉, C₁₀, blends of iso C₅ and normal C₅, mixtures of C₅ and C₆ or mixtures of C₅-C₁₀ solvents.
28. The method of claim 26, wherein the diluent and the solvent are each C₅ or naphtha.
29. The method of claim 26, wherein after the primary separation process, a wet bitumen stream is obtained which is incorporated into the froth treatment process.
30. The method of claim 29, wherein the froth treatment process involves precipitation of asphaltenes from the bitumen.
31. The method of claim 26, wherein the solvent: bitumen volume ratio is selected such that about 6% to about 10% asphaltenes are precipitated from the bitumen.

32. The method of claim 26, wherein the solvent is C₅ and the C₅: bitumen volume ratio is about 1.8:1.
33. The method of claim 26, wherein a partially deasphalted and upgraded bitumen product is recovered and sent to an upgrader or pipelined to a desired market.
34. The method of claim 7, further comprising a degassing step wherein gas is separated from the production fluid prior to incorporating a degassed production fluid into the process.
35. A system for integrating an *in-situ* bitumen recovery operation with a bitumen mining operation, the system comprising:
- (a) a production well for recovering production fluid from the *in-situ* bitumen recovery operation;
 - (b) a bitumen mining and extraction facility; and
 - (c) a transporter for directing the production fluid from the production well to the bitumen mining and extraction facility for incorporation into the mining and extraction operation.
36. The system of claim 35, wherein the *in-situ* recovery operation is a thermal *in-situ* recovery operation.
37. The system of claim 36, wherein the thermal *in-situ* recovery operation comprises steam-assisted gravity drainage, cyclic steam stimulation, or a derivative thereof.
38. The system of claim 37, wherein the thermal *in-situ* recovery operation is steam-assisted gravity drainage.
39. The system of claim 37, wherein the derivative thereof comprises solvent-assisted steam-assisted gravity drainage, steam and gas push, combined vapor and steam extraction, expanding solvent steam-assisted gravity drainage, constant steam drainage, liquid addition to steam enhancing recovery, water flooding or steam flooding.

40. The system of claim 35, wherein the *in-situ* recovery operation comprises vapour extraction.
41. The system of claim 35, further comprising a heat exchange module for capturing heat from the production fluid and transferring said heat to a fluid requiring heating.
42. The system of claim 41, wherein the fluid requiring heating is water from a surface, subsurface or treatment process affected water source.
43. The method of claim 41, wherein the fluid requiring heating is river water.
44. The system of claim 35, wherein the transporter is a pipeline.
45. The system of claim 35, wherein the production well and the bitumen mining and extraction facility are located up to about 200 kilometers apart.
46. The system of claim 45, wherein the production well and the bitumen mining facility are located up to about 100 kilometers apart.
47. The system of claim 46, wherein the production well and the bitumen mining facility are located up to about 50 kilometers apart.
48. The system of claim 47, wherein the production well and the bitumen mining facility are located up to about 25 kilometers apart
49. The system of claim 35, further comprising an upgrader for upgrading or partially upgrading recovered bitumen.
50. The system of claim 35, further comprising an end product pipeline for directing recovered bitumen to a desired market.
51. A method of integrating a steam-assisted gravity drainage bitumen recovery operation with a bitumen mining and extraction operation comprising:

- (a) obtaining a production fluid from the steam-assisted gravity drainage operation;
- (b) pipelining the production fluid to the bitumen mining and extraction operation; and
- (c) incorporating the production fluid into a process in the bitumen mining and extraction operation.

52. The method of claim 51, wherein the production fluid or a fluid stream separated therefrom is incorporated into an extraction, separation or treatment process in the bitumen mining and extraction operation.

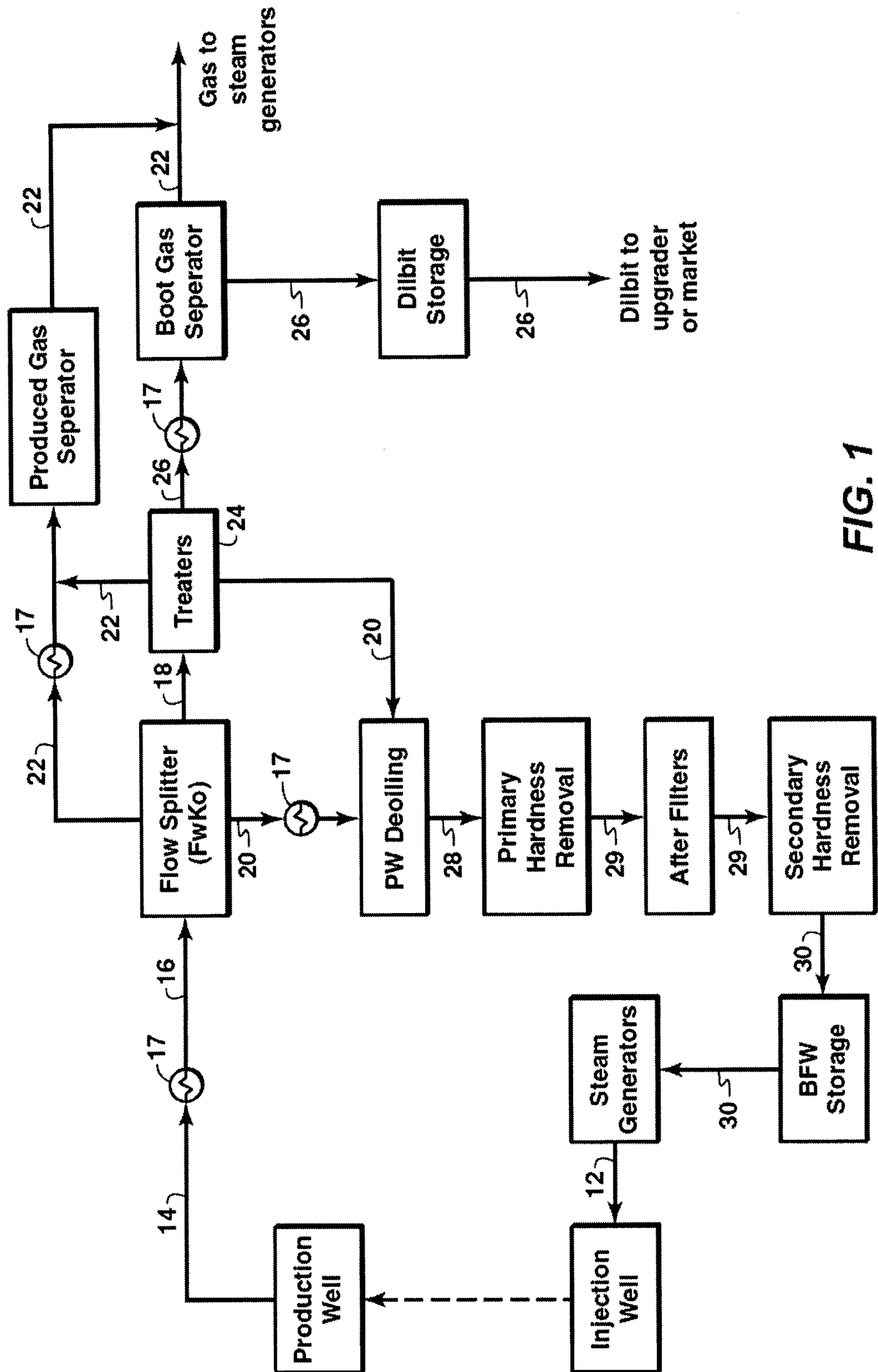


FIG. 1

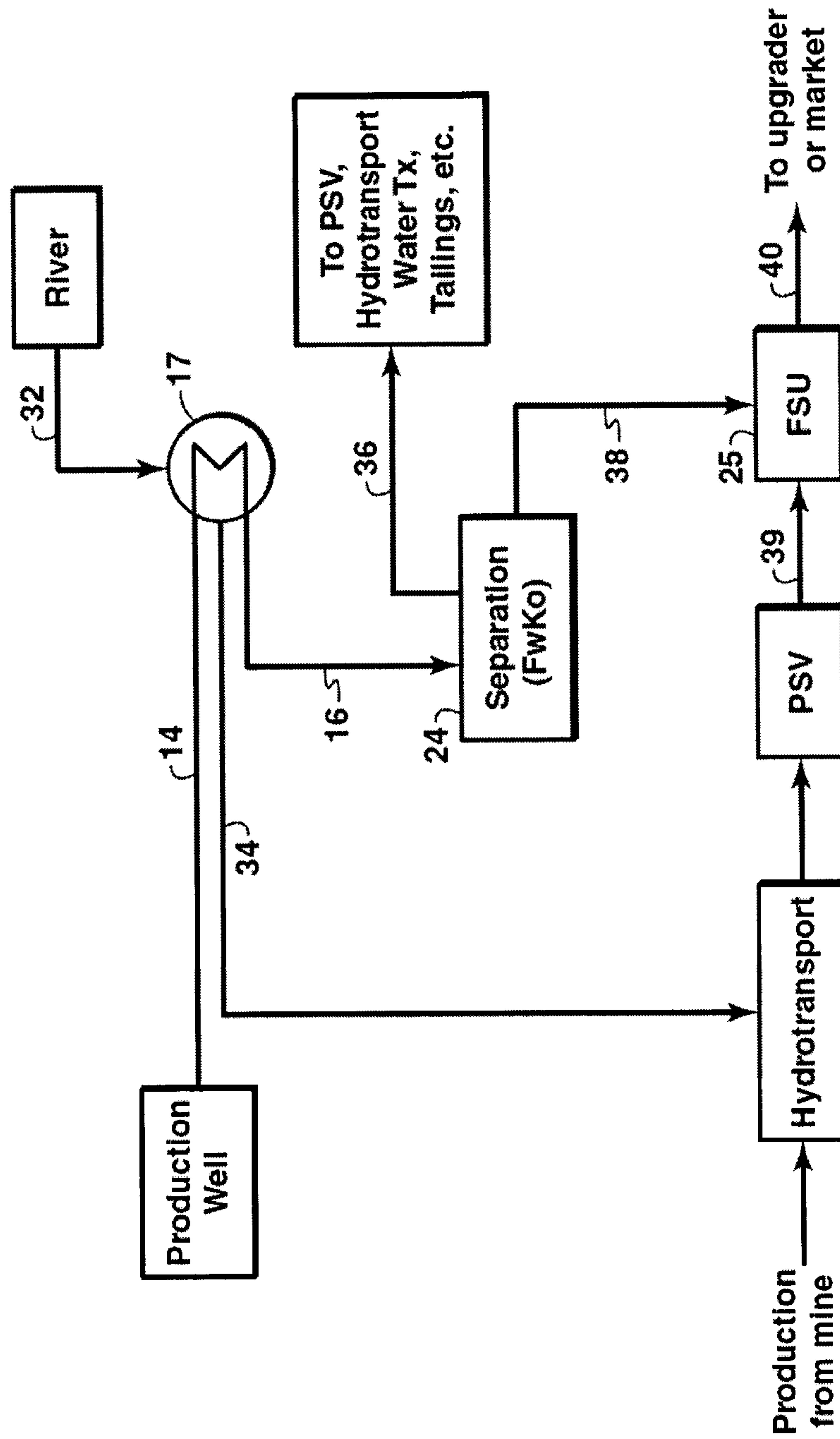


FIG. 2

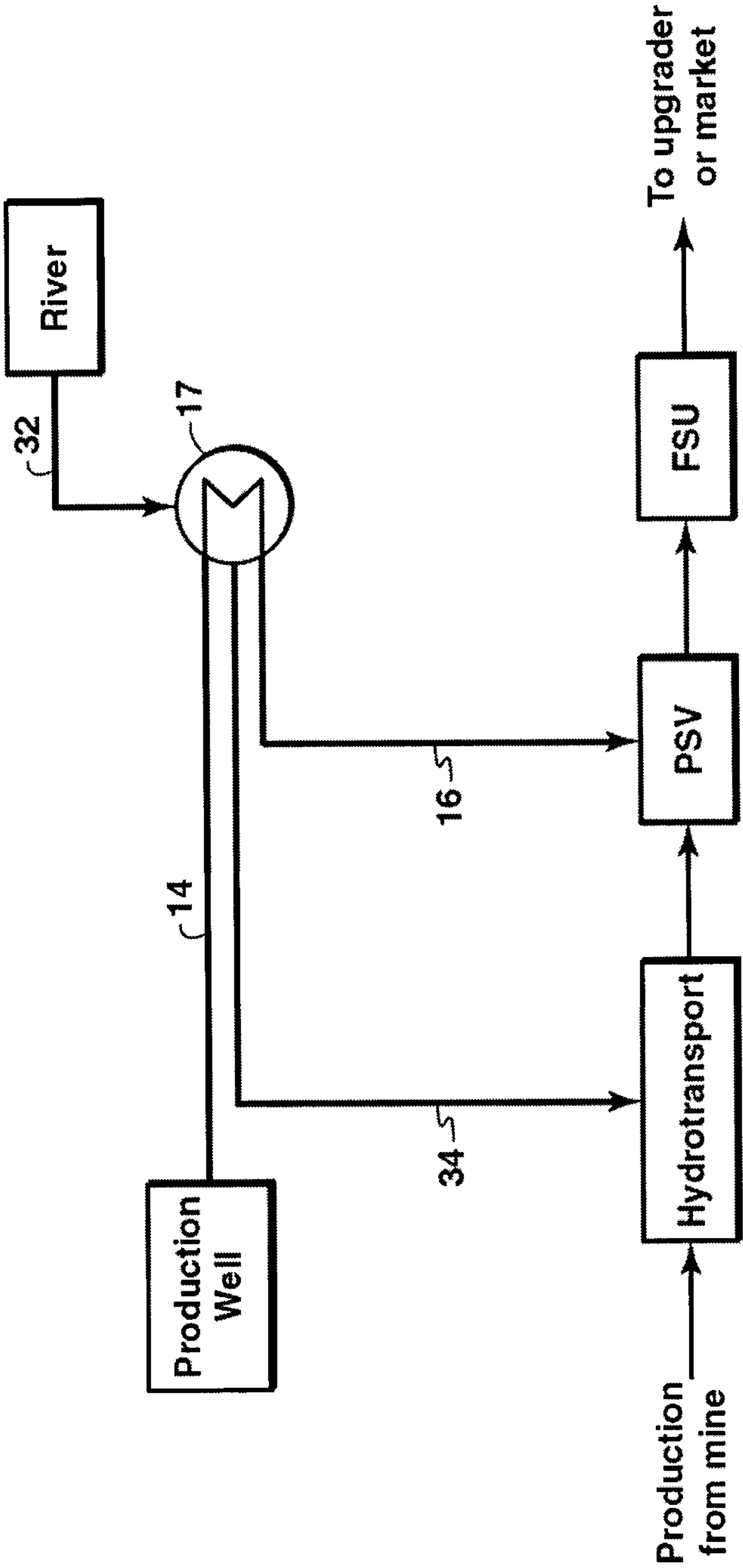


FIG. 3

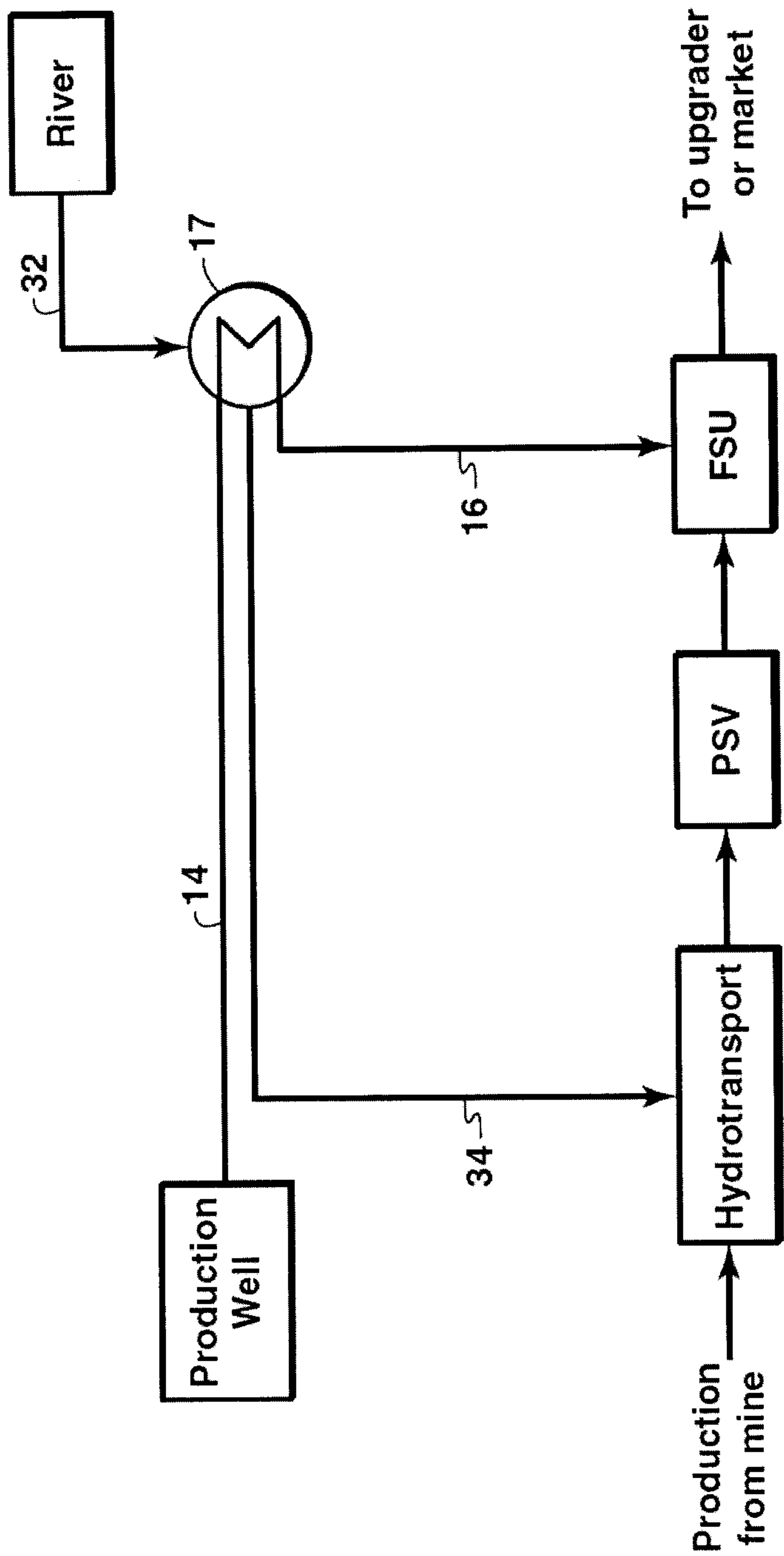


FIG. 4

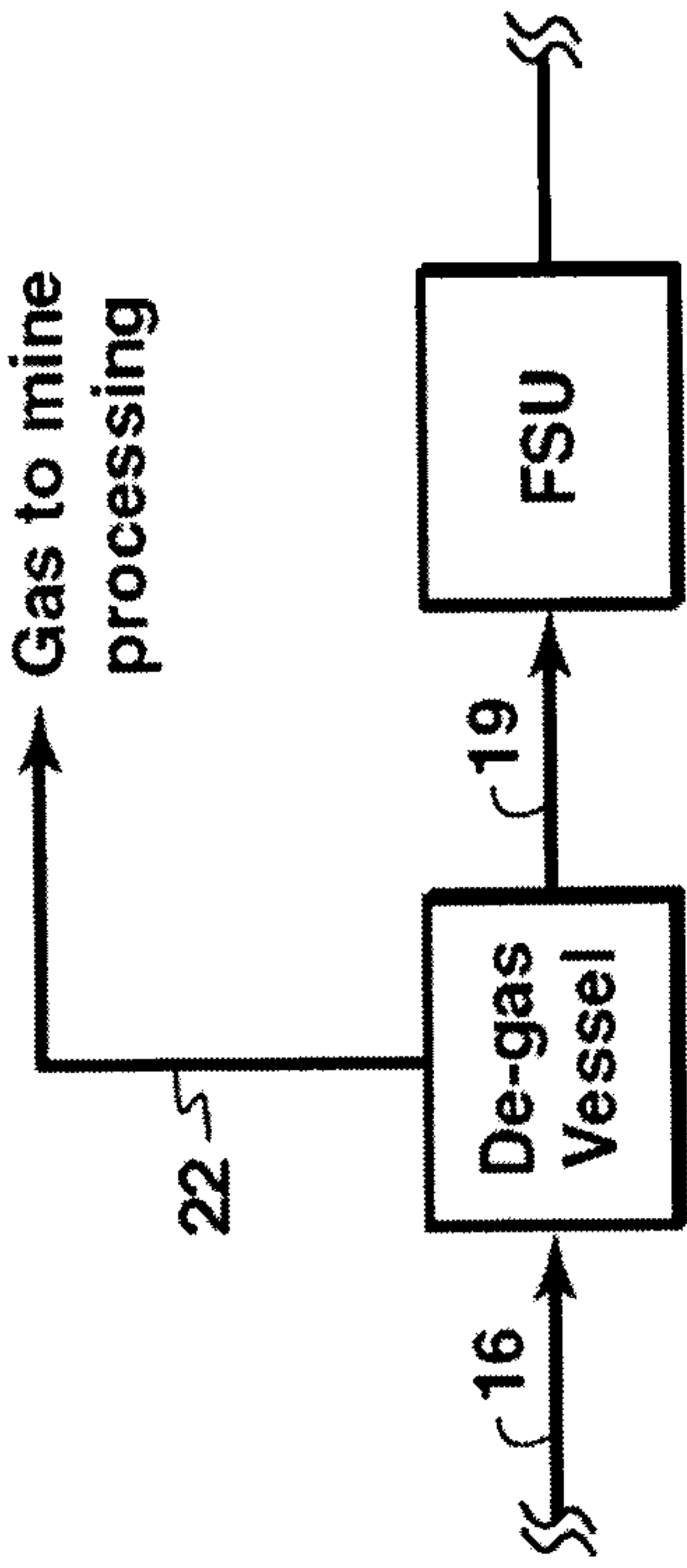


FIG. 5

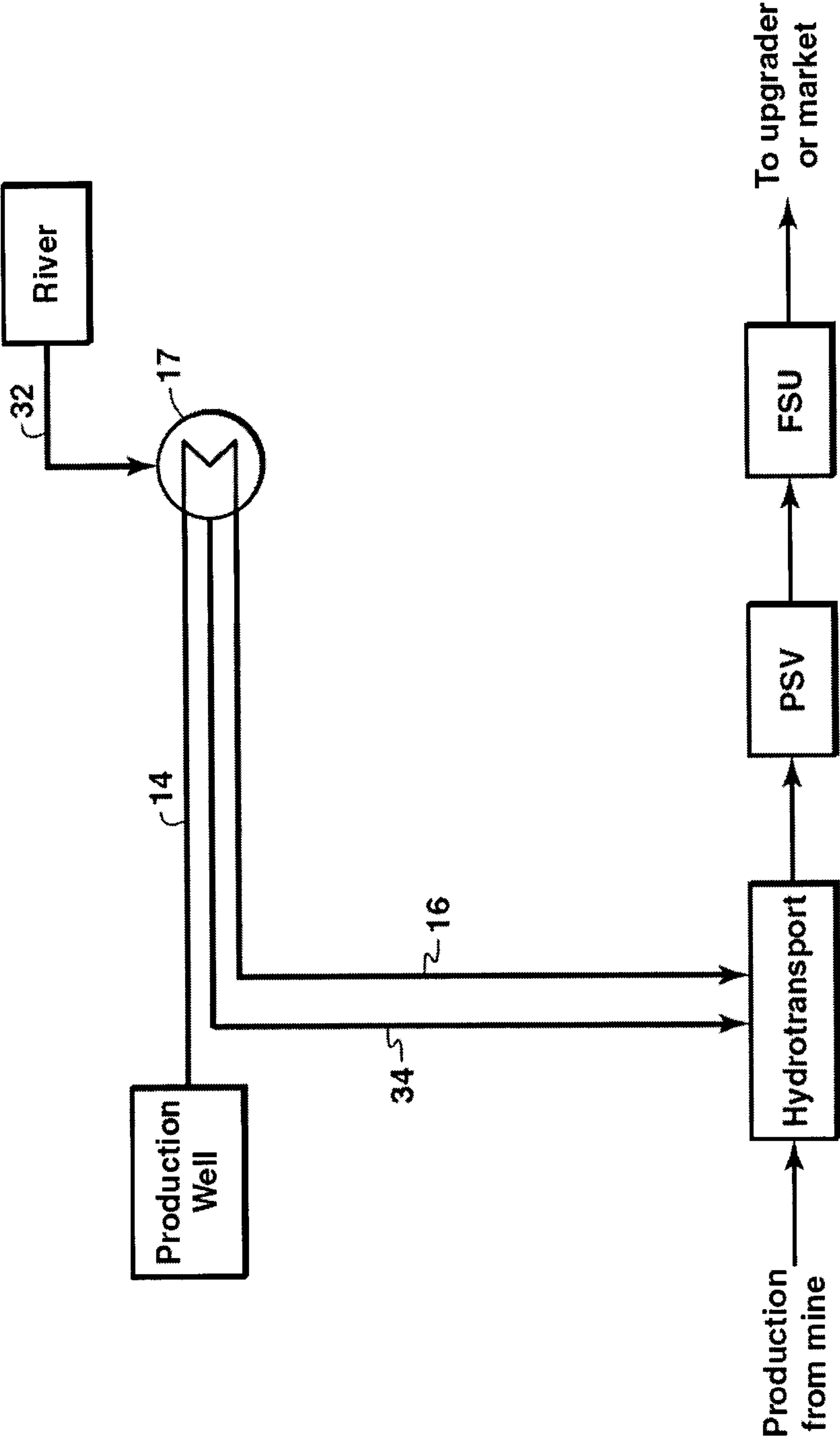


FIG. 6

