



(22) Date de dépôt/Filing Date: 2002/01/24

(41) Mise à la disp. pub./Open to Public Insp.: 2003/07/24

(45) Date de délivrance/Issue Date: 2005/04/26

(51) Cl.Int.⁷/Int.Cl.⁷ C10C 3/00, B01D 53/50, B01D 53/00,
C10L 5/16, C02F 9/04, C02F 1/00

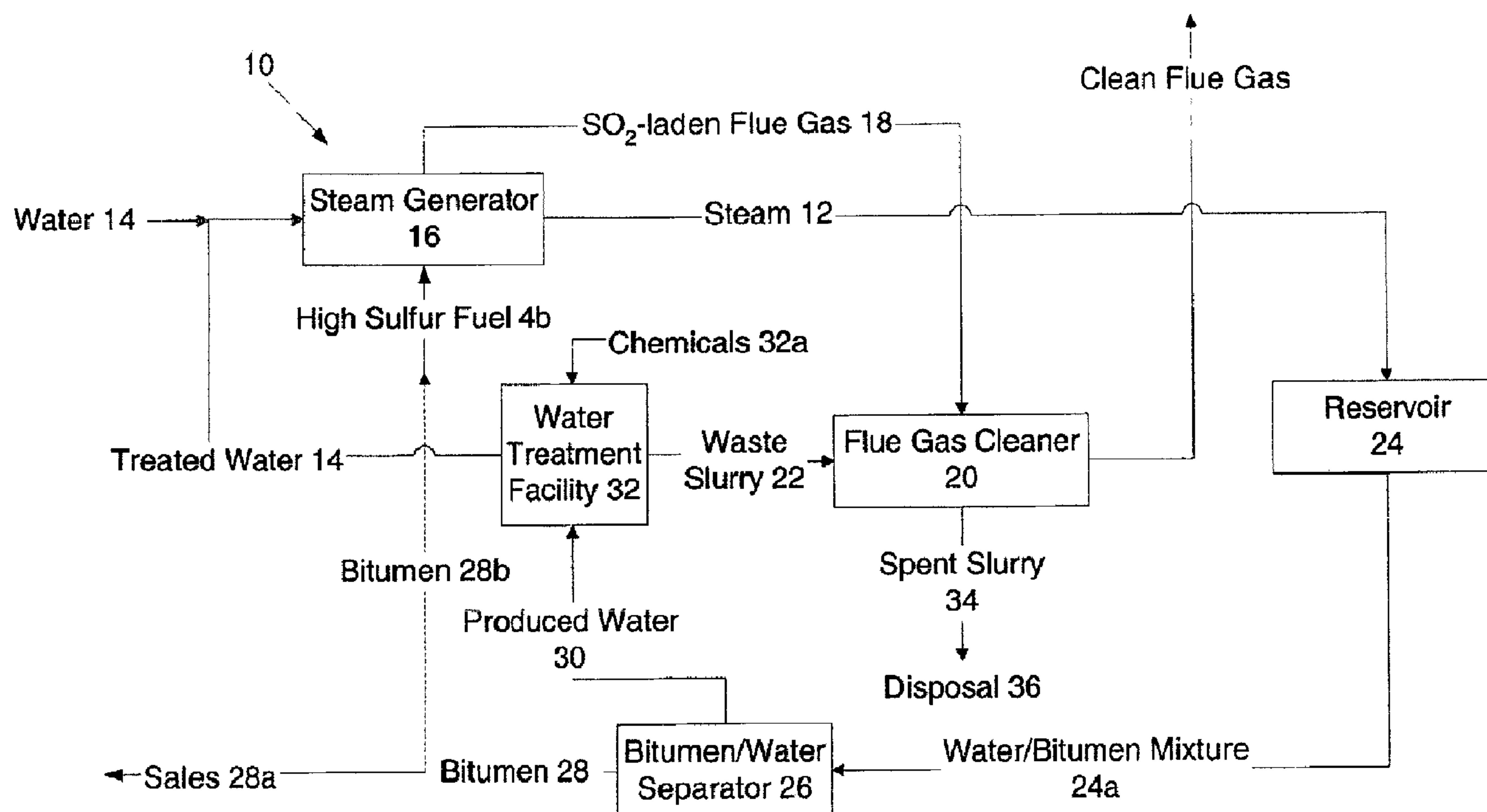
(72) Inventeurs/Inventors:
CHAKRABARTY, TAPANTOSH, CA;
GHOSH, MAINAK, CA

(73) Propriétaire/Owner:
IMPERIAL OIL RESOURCES LIMITED, CA

(74) Agent: BORDEN LADNER GERVAIS LLP

(54) Titre : METHODE INTEGREE DE PRODUCTION DE BITUME PAR RECUPERATION A LA VAPEUR A L'AIDE D'UN CIRCUIT DE DECHET DE PROCEDE UTILISE POUR EFFECTUER LA DESULFURATION DES GAZ DE COMBUSTION

(54) Title: AN INTEGRATED METHOD FOR STEAM-ENHANCED BITUMEN PRODUCTION USING A PROCESS WASTE STREAM FOR FLUE GAS DESULPHURIZATION



(57) Abrégé/Abstract:

The invention is in the area of thermal recovery of bitumen from an underground reservoir using steam. More specifically, it relates to a method for integrating bitumen production with steam generation by burning a portion of the produced high-sulfur bitumen and then using a waste stream from a boiler feed water treatment process to clean the flue gas.

Abstract

The invention is in the area of thermal recovery of bitumen from an underground reservoir using steam. More specifically, it relates to a method for integrating bitumen production with steam generation by burning a portion of the produced high-sulfur bitumen and then using a waste stream from a boiler feed water treatment process to clean the flue gas.

**AN INTEGRATED METHOD FOR STEAM-ENHANCED BITUMEN
PRODUCTION USING A PROCESS WASTE STREAM FOR FLUE GAS
DESULPHURIZATION**

Field of the Invention

The invention is in the area of thermal recovery of bitumen from an underground reservoir using steam. More specifically, it relates to a method for integrating bitumen production with steam generation by burning a portion of the produced high-sulfur bitumen and then using a waste stream from a boiler feed water treatment process to clean the flue gas.

Background of the Invention

In the thermal recovery of bitumen, natural gas is normally used as a fuel to generate steam. This fuel has little or no sulfur and hence its use does not require SO₂ removal from the flue gas. Fuel cost constitutes the majority share of the bitumen lifting cost at many production sites including places such as Cold Lake and Athabasca in Alberta, Canada. With increasing demand for and a generally upward trend in the price of natural gas, the need for an alternative, less expensive fuel is strong.

Many alternative fuel sources have been considered including coal and bitumen which may include both whole bitumen and/or the heavier fractions of bitumen. Of these, whole bitumen and water emulsions of the whole bitumen and/or the heavier fractions of bitumen are the most promising. However, significant problems exist with the use of bitumen as a fuel because of the high cost associated with removing SO₂ from the flue gas which results from burning bitumen.

Furthermore, in a commercial thermal bitumen recovery operation large volumes of water are needed to make steam. This water becomes contaminated with bitumen and underground minerals during underground injection and subsequent recovery. The produced water from bitumen recovery therefore requires treatment before it can be reused to make steam. That is, it is a requirement that contaminated water from the production of bitumen be treated with chemicals to remove contaminants to enable the water to be re-used in a steam generator and that the contaminants are properly disposed of. Accordingly, past bitumen recovery operations utilize water treatment facilities which introduce treatment chemicals to

the produced water to remove the contaminating hardness ions, silica and/or clay minerals. The treatment chemicals enable most contaminants to be removed as precipitated solids which are subsequently removed from the facility as waste to a slurry pit.

Accordingly, there is a continuing need to improve the operating cost structure at a bitumen production operation of which fuel is a major component. One way this can be achieved is by efficiently combining the bitumen burning, the water treatment and the SO₂ removal processes wherein the waste slurry from treatment of the produced water, containing the precipitated contaminants, is used within the SO₂ scrubbing facilities in order to reduce the SO₂ removal cost.

A review of the prior art reveals that such a solution has not been provided. For example, Canadian Patent No. 1,339,531 discusses a process of producing and burning a natural-emulsified liquid fuel in which the alkali metal level in the liquid fuel is adjusted to reduce SO₂ emissions and Canadian Patent No. 2,105,166 relates to scrubbing SO₂ with mixtures of hydroxides and carbonates of calcium and magnesium in coal-fired boilers; and Canadian Patent Application No. 2,335,771 describes a process that uses hydrovisbreaking in the reservoir, and fractionates the produced visbroken hydrocarbons into a heavier fraction, which is then partially oxidized to generate hydrogen and fuel gas. In this latter patent, the fuel gas is used for steam generation and the steam is then injected with hydrogen for *in situ* hydrovisbreaking.

Summary of the Invention

In accordance with the invention, there is provided an integrated process for producing bitumen and removing sulfur dioxide from a flue gas said process comprising:

- (a) burning whole bitumen or a heavier fraction thereof to generate steam to extract bitumen from a bitumen reservoir in a bitumen and produced water stream, said burning yielding said flue gas;
- (b) removing SO₂ from said flue gas by contacting said flue gas with a waste slurry resulting from treatment of water separated from said bitumen and produced water stream.

Further still, the invention provides a process for producing bitumen from a subsurface reservoir comprising the steps of:

- (a) injecting steam into a reservoir to recover bitumen;
- (b) producing a stream of bitumen and produced water from the reservoir;
- (c) separating the produced water and the bitumen;
- (d) treating the produced water to form a boiler-feed quality water and a waste slurry;
- (e) burning at least a portion of the bitumen and using at least a portion of the boiler-feed quality water to produce steam and a flue gas; and
- (f) contacting the flue gas with the waste slurry to remove sulfur dioxide from the flue gas.

In another embodiment, the invention provides a process for scrubbing sulfur dioxide from a flue gas comprising contacting the flue gas with a waste slurry from a water treatment process, the waste slurry chemically active in removing sulfur dioxide from the flue gas.

In further embodiments, the water treatment process is operatively connected to a bitumen recovery operation and/or the waste slurry comprises at least one of calcium hydroxide, magnesium hydroxide, calcium carbonate and a magnesium silicate mineral and one or more alkaline compounds. It is also preferred that the total solids concentration in the waste slurry is 4-20% by weight and more preferably 5-15% by weight.

In another preferred embodiment, the process is integrated with a bitumen-fired steam generation process and the flue gas originates from the bitumen-fired steam generation process.

Brief Description of the Drawings

Preferred embodiments of the present invention will now be described with reference to the attached figures, wherein:

Figure 1 is a schematic diagram of the presently practiced process of bitumen production in accordance with the prior art;

Figure 2 is a configuration for a high sulfur fuel bitumen production operation; and

Figure 3 is a schematic diagram of an integrated bitumen production, waste-water

treatment and SO₂ scrubbing process in accordance with the invention.

Detailed Description of the Invention

As shown in Figure 1, in a conventional commercial bitumen recovery operation 1, steam 2 is generated from water 3 and treated water 3a by burning a natural gas fuel 4 in a steam generator or boiler 16. The steam 2 is injected into an underground reservoir 6 to reduce the viscosity of the underground bitumen by heat thereby enabling the bitumen to be recovered as a bitumen/water mixture 7. The steam 2 and condensed water also react with the naturally occurring minerals in the reservoir 6 and pick up hardness ions, silica, and clay minerals which contaminate the water portion of the bitumen/water mixture 7. Separation of the mixture in a separator 8 provides product bitumen 9 and produced water 9a. The produced water 9a is treated in a water treatment facility 7a with chemicals 7c which remove the contaminants as a sludge/slurry 7b enabling re-use of the treated water 3 in the production of steam 2. The flue gas 16a does not require scrubbing.

Figure 2 shows a variation 1a of the conventional bitumen recovery operation in which the natural gas fuel can be substituted for by a high sulfur fuel such as bitumen or an emulsion of bitumen or its heavier fractions 4a. Unlike burning natural gas, the burning of a high sulfur fuel produces a high sulfur flue gas 16a which requires scrubbing of SO₂ in a conventional scrubber 5. Scrubber 5, using techniques known in the art, removes SO₂ by reacting the SO₂ with scrubbing chemicals 5a which will produce a scrubber slurry 5b which is disposed in a slurry pit. The cost of the chemicals 5a is such that the process is not always cost-competitive with burning natural gas, depending on the price of natural gas.

In accordance with the invention, an integrated process 10 of water treatment and scrubbing is shown in Figure 3 for a high sulfur fuel fired steam generation and bitumen recovery process. As shown, and as in a conventional bitumen recovery operation described above, steam 12 is generated from water 14 and treated water 14a by burning a fuel (including whole bitumen or heavy fractions thereof) in a steam generator 16 for injection into the reservoir 24. Recovered bitumen and produced water 24a are separated from each other in a bitumen-water separator 26 to produce bitumen 28 and produced water 30. The produced water 30 is treated in a water treatment facility 32 to remove contaminants including hardness ions, silica and clay through the addition of chemicals 32a. A portion of the bitumen 28b is

preferably used as fuel for the steam generator 16 and a portion 28a is directed to sales.

The produced water 30 is treated by techniques known in the art. Within the water treatment facility 32, chemicals including calcium hydroxide, magnesium hydroxide, sodium hydroxide, sodium carbonate, and a flocculant are added to the water, as necessary, to react with or provide adsorption sites for the hardness ions, silica and clay minerals thereby forming a waste slurry 22 which has both a liquid and a precipitated solids component.

The waste slurry 22 generally comprises unreacted chemicals and reacted product. The typical solid concentration range in the waste slurry is 4 to 20% by weight with the corresponding water concentration range as 96 to 80% by weight. A preferred concentration range of the solids is 5 to 15% by weight with the corresponding water concentration range as 95 to 85% by weight.

The SO₂-laden flue gas 18 from the generator 16 is directed to a flue gas cleaner or scrubber 20 where, in accordance with the invention, it is contacted with the waste slurry 22 from the water treatment facility 32 thus utilizing both the reacted and unreacted chemicals of the waste slurry 22 within the scrubbing process. In most circumstances, no additional chemicals need to be added. After treatment of the SO₂-laden flue gas 18, the spent slurry 34 is sent to disposal 36.

The precise composition of the chemicals added to the produced water in the water treatment facility may be varied as is known by those skilled in the art for effecting water treatment and will depend on the particular contaminants that may result from a particular reservoir. In order to provide effective scrubbing capabilities, it is preferred that the waste slurry composition include calcium hydroxide, magnesium hydroxide, calcium carbonate and a magnesium silicate mineral, some of which may be present in the water produced from the reservoir before treatment. A representative composition of this slurry is shown in the examples.

Accordingly, the system provides an effective way of combining the use of bitumen as a fuel and scrubbing SO₂ gas from combustion with chemicals contained in the slurry generated by treating the produced water from bitumen extraction.

As a result, an advantage of the invention is that the chemicals for SO₂ scrubbing are continuously generated in the water treatment facility. Moreover, no additional slurry pit is required as per other conventional flue gas desulfurization processes. Further still, the fuel for

the process is generated internally.

In another embodiment where bitumen is used as a fuel, part of the total produced bitumen 28 may be used in the generator 16 and the remainder shipped to market 28a. In one embodiment, further separation of the bitumen 28 is provided to produce heavier and lighter bitumen fractions where the heavier fraction 28b is used as a fuel in the generator 16 and the lighter fraction is shipped to market. As a fuel, the heavier fraction 28b is may be emulsified in water and used as an emulsion fuel in the generator 16.

Moreover, the utilization of the waste stream for SO₂ scrubbing offers a cost-effective method for utilizing sulfur-rich fuel that is cheaper than natural gas. The fuel is also internally generated as whole or a fraction of the produced bitumen; in the latter case also improving the viscosity and gravity of the remaining marketable bitumen.

The invention is illustrated by the following example.

EXAMPLE

Two litres of waste slurry from the Imperial Oil water treatment facility at Cold Lake, Alberta were separated into a water portion and a solids portion for analysis.

The water portion of the waste slurry had the following representative properties and composition as shown in Table 1:

Table 1- Water Composition of Waste Slurry

Properties/Composition	Preferred Range	General Range
pH at 22°C	9.5 to 10	9 to 11
Total Dissolved Solids	10000 to 12000 ppm	8000 to 14000 ppm
Total Hardness	80 to 160 ppm	70 to 180 ppm
Tannin and Lignin	60 to 65 ppm	50 to 80 ppm
Alkalinity Phen. 8.3 as CaCO ₃	300 to 400 ppm	250 to 500 ppm
Alkalinity Total as CaCO ₃	500 to 650 ppm	400 to 800 ppm
Carbonate Ions	200 to 300 ppm	150 to 400 ppm
Hydroxyl Ions	40 to 70 ppm	30 to 100 ppm
Chloride Dissolved	5000 to 7000 ppm	4000 to 10000 ppm
Total Organic Carbon	140 to 160 ppm	120 to 200 ppm
Silica	10 to 50 ppm	5 to 100 ppm
Sulfate	60 to 100 ppm	50 to 120 ppm
Magnesium Ions	10 to 30 ppm	5 to 40 ppm
Calcium Ions	14 to 15 ppm	10 to 40 ppm
Potassium Ions	150 to 180 ppm	130 to 200 ppm

Sodium Ions	3500 to 4500 ppm	3000 to 5000 ppm
Sulfur Dissolved	30 to 40 ppm	25 to 50 ppm

The slurry may also contain a non-ionic flocculating agent, such as NALCO 86070.

The solid portion of the waste slurry contained the following metal ions as shown in Table 2A:

Table 2A- Solids Portion Composition of Waste Slurry

Properties/Composition	Preferred Range	General Range
Mg	10 to 20 wt%	5 to 25 wt%
Ca	20 to 25 wt%	15 to 35 wt%
Si	5 to 6 wt%	4 to 8 wt%
Na	0.45 to 0.80 wt%	0.4 to 1.0 wt%
Al	0.04 to 0.08 wt%	0.03 to 0.10 wt%
K	0.04 to 0.05 wt%	0.03 to 0.06 wt%
Fe	0.15 to 0.25 wt%	0.10 to 0.40 wt%
Sr	1500 to 2400 ppm	1200 to 3000 ppm
Ba	500 to 700 ppm	400 to 1000 ppm

By mineralogical analysis, the solid portion of the waste slurry contains the minerals shown in Table 2B and their typical proportions. These minerals were identified by X-ray diffraction and scanning electron microscope and their relative amounts determined using elemental analysis and mineral quantification software. The adsorbed water in the solid was not measured which explains why the sum of the mineral proportions is less than 100%. Some of these minerals were formed in the water treatment process, while others were either leached out from the reservoir sand or formed in the reservoir following steam injection.

Table 2B- Mineral Analysis of Solid Portion of Waste Slurry

Minerals		
Name	Formula	wt%
Quartz	SiO ₂	4.6 - 6.0 wt%
K-spar	KAlSi ₃ O ₈	0.3 - 0.4 wt%
Albite	NaAlSi ₃ O ₈	0.1 - 0.4 wt%
Calcite	CaCO ₃	55.5 - 59.3 wt%

Magnesite	MgCO_3	1.5 - 3.6 wt%
Siderite	FeCO_3	0.4 - 0.5 wt%
Halite	NaCl	1.2 - 1.9 wt%
Serpentine	$\text{Mg}_6\text{Si}_4\text{O}_{10}(\text{OH})_8$	8.2 - 9.2 wt%
Brucite	$\text{Mg}(\text{OH})_2$	9.8 - 11.5 wt%
Sepiolite	$\text{Mg}_4\text{Si}_6\text{O}_{15}(\text{OH})_2 \cdot 6\text{H}_2\text{O}$	7.6 - 8.2 wt%
Organic Carbon		1.0 - 2.3 wt%
Total		95.8 - 97.9 wt%

Assuming a water concentration of 85-95% by weight, the whole waste slurry would have a composition representative of that shown in Table 3.

Table 3-Whole Waste Slurry Composition

Properties/Composition	Preferred Range	General Range
Solid	5 to 15 wt %	4 to 20 wt%
pH at 22°C	9.5 to 10	9 to 11
Total Dissolved Solids	8500 to 11400 ppm	6400 to 13440 ppm
Total Hardness	68 to 152 ppm	56 to 173 ppm
Tannin and Lignin	51 to 62 ppm	40 to 77 ppm
Alkalinity Phen. 8.3 as CaCO_3	255 to 380 ppm	200 to 480 ppm
Alkalinity Total as CaCO_3	425 to 618 ppm	320 to 768 ppm
Carbonate Ions	170 to 285 ppm	120 to 384 ppm
Hydroxyl Ions	34 to 67 ppm	24 to 96 ppm
Chloride Ions	4250 to 6650 ppm	3200 to 9600 ppm
Total Organic Carbon	119 to 152 ppm	96 to 192 ppm
Dissolved Silica	3 to 5 ppm	0 to 48 ppm
Sulfate Ions	51 to 95 ppm	40 to 115 ppm
Magnesium Ions	9 to 29 ppm	4 to 38 ppm
Calcium Ions	12 to 14 ppm	8 to 38 ppm
Potassium Ions	128 to 171 ppm	104 to 192 ppm
Sodium Ions	3000 to 4275 ppm	2400 to 4800 ppm
Sulfur Dissolved	26 to 38 ppm	20 to 48 ppm
Mg in solid	0.5 to 3 wt%	0.2 to 4 wt%
Ca in solid	1 to 4 wt%	0.6 to 7 wt%
Si in solid	0.3 to 0.9 wt%	0.16 to 1.6 wt %
Al in solid	0.002 to 0.012 wt%	0.0012 to 0.02 wt %
K in solid	0.002 to 0.0075 wt%	0.0012 to 0.012 wt%
Fe in solid	0.0075 to 0.0375 wt %	0.004 to 0.08% wt%
Sr in solid	75 to 360 ppm	48 to 600 ppm
Ba in solid	25 to 105 ppm	16 to 200 ppm

Pure SO₂ from a gas cylinder was bubbled through the waste slurry at room temperature. The SO₂ volume was measured with a Dry Test meter. Using a Drager tube, the SO₂ in the effluent gas was monitored and recorded as a function of the volume of SO₂ bubbled through. As shown in Table 4, the SO₂ concentration in the effluent gas was only 6 ppm after 20 litres of SO₂ at standard temperature and pressure conditions (STP) was bubbled through. At this point, the test was terminated. The pH of the slurry dropped from 9.9 to 4.3 at the end of the test.

Table 4- SO₂ Concentration in Effluent Gas

<u>Volume SO₂ Bubbled (L@STP)</u>	<u>SO₂ Concentration in Effluent Gas (ppm)</u>
8	Trace
16	Trace
18	1
20	6

This test shows that two litres of Cold Lake waste slurry is capable of removing 20 litres of pure SO₂ at STP.

The above-described embodiments of the invention are intended to be examples of the present invention. Alterations, modifications and variations may 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.

WE CLAIM:

1. A process for producing bitumen and removing sulfur dioxide from a flue gas said process comprising:
 - (a) burning whole bitumen or a heavier fraction thereof to generate steam to extract bitumen from a bitumen reservoir in a bitumen and produced water stream, said burning yielding said flue gas; and
 - (b) removing SO₂ from said flue gas by contacting said flue gas with a waste slurry resulting from a water treatment process for treatment of water separated from said bitumen and produced water stream.
2. A process for producing bitumen from a subsurface reservoir comprising the steps of:
 - (a) injecting steam into a reservoir to recover bitumen;
 - (b) producing a stream of bitumen and produced water from the reservoir;
 - (c) separating the produced water and the bitumen;
 - (d) treating the produced water in a water treatment process to form a boiler-feed quality water and a waste slurry;
 - (e) burning at least a portion of the bitumen and using at least a portion of the boiler-feed quality water to produce steam and a flue gas; and
 - (f) contacting the flue gas with the waste slurry to remove sulfur dioxide from the flue gas.
3. A process for scrubbing sulfur dioxide from a flue gas generated in the bitumen recovery process comprising contacting the said flue gas with a waste slurry from a water treatment process, wherein the waste slurry results from treatment of produced water in the said water treatment process within the said bitumen recovery process using steam to recover bitumen from an underground reservoir.
4. A process as in claim 3 wherein the process is integrated with a bitumen-fired steam generation process and the flue gas originates from the bitumen-fired steam generation process.

5. A process as in any one of claims 1-4 wherein said waste slurry comprises at least one of calcium hydroxide, magnesium hydroxide, calcium carbonate and magnesium silicate.
6. A process as in any one of claims 1-5 wherein said waste slurry comprises one or more alkaline compounds.
7. A process as in any one of claims 1-6 wherein the total solids concentration in the waste slurry is 4-20% by weight.
8. A process as in any one of claims 1-7 wherein the total solids concentration in the waste slurry is 5-15% by weight.
9. A process as in any one of claims 1-8 wherein the water treatment process includes the addition of chemicals for the precipitation of contaminants dissolved within water extracted from the reservoir.
10. A process as in any one of claims 1-9 wherein the waste slurry has a solids component having a metal ions composition including 5 to 25% by weight Mg, 15 to 35% by weight Ca, 4 to 8% by weight Si, 0.4 to 1.0% by weight Na, 0.03 to 0.10% by weight Al, 0.03 to 0.06% by weight K, 0.1 to 0.4% by weight Fe, 1200 to 3000 ppm, Sr, and 400 to 1000 ppm Ba.
11. A process as in any one of claims 1-9 wherein the waste slurry has a solids component having a metal ions composition including 10 to 20% by weight Mg, 20 to 25% by weight Ca, 5 to 6% by weight Si, 0.45 to 0.8% by weight Na, 0.04 to 0.08% by weight Al, 0.04 to 0.05% by weight K, 0.15 to 0.25% by weight Fe, 1500 to 2400 ppm Sr and 500 to 700 ppm Ba.
12. A process as in any one of claims 1-9 wherein the waste slurry has a liquid component including the following properties:

pH at 22°C	9 to 11
Total Dissolved Solids	8000 to 14000 ppm
Total Hardness	70 to 180 ppm

Tannin and Lignin	50 to 80 ppm
Alkalinity Phen. 8.3 as CaCO ₃	250 to 500 ppm
Alkalinity Total as CaCO ₃	400 to 800 ppm
Carbonate Ions	150 to 400 ppm
Hydroxyl Ions	30 to 100 ppm
Dissolved Chloride	4000 to 10000 ppm
Total Organic Carbon	120 to 200 ppm
Silica	5 to 100 ppm
Sulfate	50 to 120 ppm
Magnesium Ions	5 to 40 ppm
Calcium Ions	10 to 40 ppm
Potassium Ions	130 to 200 ppm
Sodium Ions	3000 to 5000 ppm
Sulfur Dissolved	25 to 50 ppm.

13. A process as in any one of claims 1-9 wherein the waste slurry has a liquid component including the following properties:

pH at 22°C	9.5 to 10
Total Dissolved Solids	10000 to 12000 ppm
Total Hardness	80 to 160 ppm
Tannin and Lignin	60 to 65 ppm
Alkalinity Phen. 8.3 as CaCO ₃	300 to 400 ppm
Alkalinity Total as CaCO ₃	500 to 650 ppm
Carbonate Ions	200 to 300 ppm
Hydroxyl Ions	40 to 70 ppm
Chloride Dissolved	5000 to 7000 ppm
Total Organic Carbon	140 to 160 ppm
Silica	10 to 50 ppm
Sulfate	60 to 100 ppm
Magnesium Ions	10 to 30 ppm
Calcium Ions	14 to 15 ppm
Potassium Ions	150 to 180 ppm
Sodium Ions	3500 to 4500 ppm
Sulfur Dissolved	30 to 40 ppm.

14. A process as in any one of claims 1-10 wherein the waste slurry has a solids component including the following properties:

Quartz	SiO ₂	4.6 - 6.0 % (wt%)
K-spar	KAlSi ₃ O ₈	0.3 - 0.4 % (wt%)
Albite	NaAlSi ₃ O ₈	0.1 - 0.4 % (wt%)

Calcite	CaCO_3	55.5 - 59.3 % (wt%)
Magnesite	MgCO_3	1.5 - 3.6 % (wt%)
Siderite	FeCO_3	0.4 - 0.5 % (wt%)
Halite	NaCl	1.2 - 1.9 % (wt%)
Serpentine	$\text{Mg}_6\text{Si}_4\text{O}_{10}(\text{OH})_8$	8.2 - 9.2 % (wt%)
Brucite	$\text{Mg}(\text{OH})_2$	9.8 - 11.5 % (wt%)
Sepiolite	$\text{Mg}_4\text{Si}_6\text{O}_{15}(\text{OH})_2 \cdot 6\text{H}_2\text{O}$	7.6 - 8.2 % (wt%)
Organic Carbon		1.0 - 2.3 % (wt%).

Figure 1
Prior Art

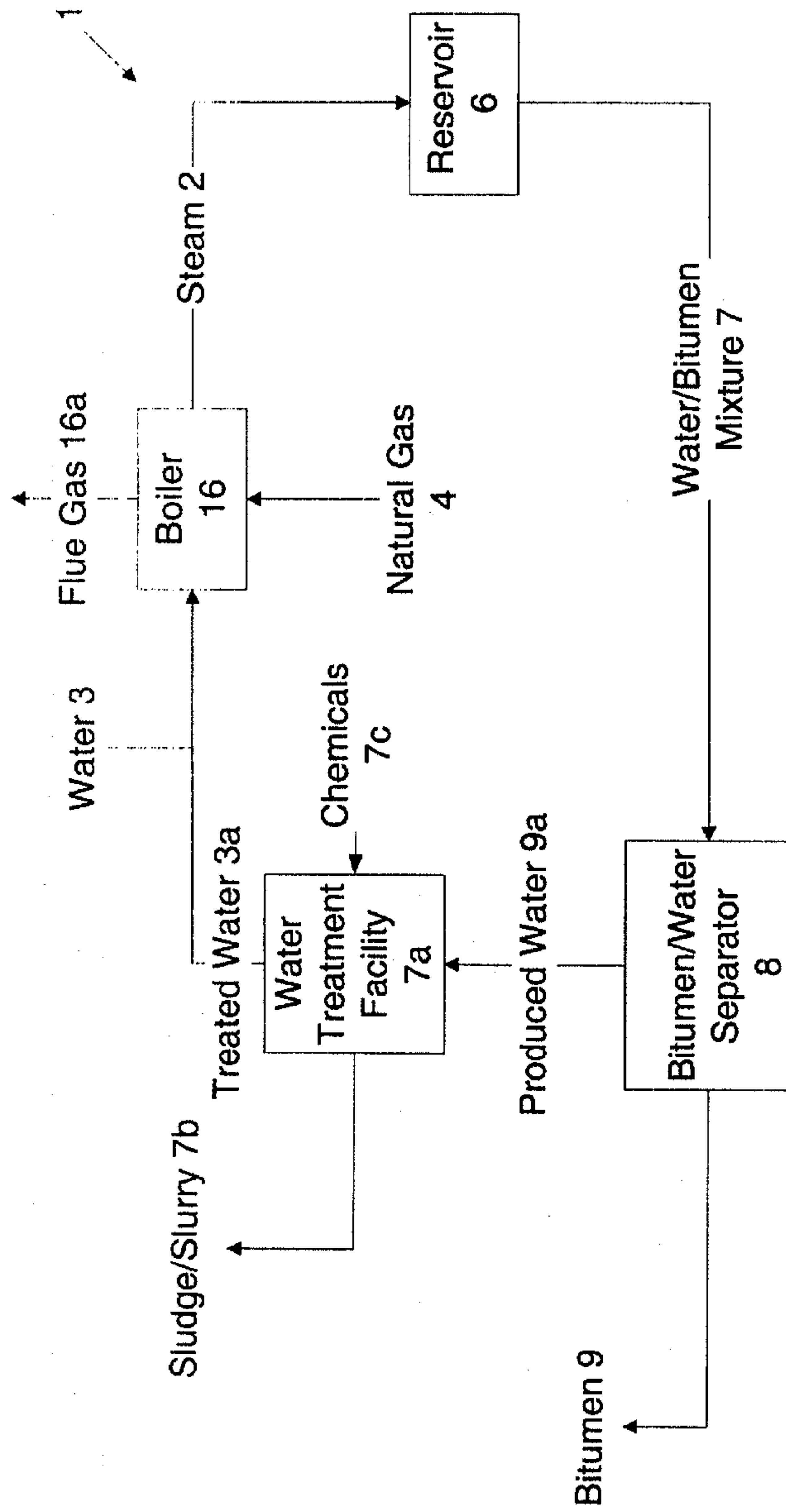


Figure 2

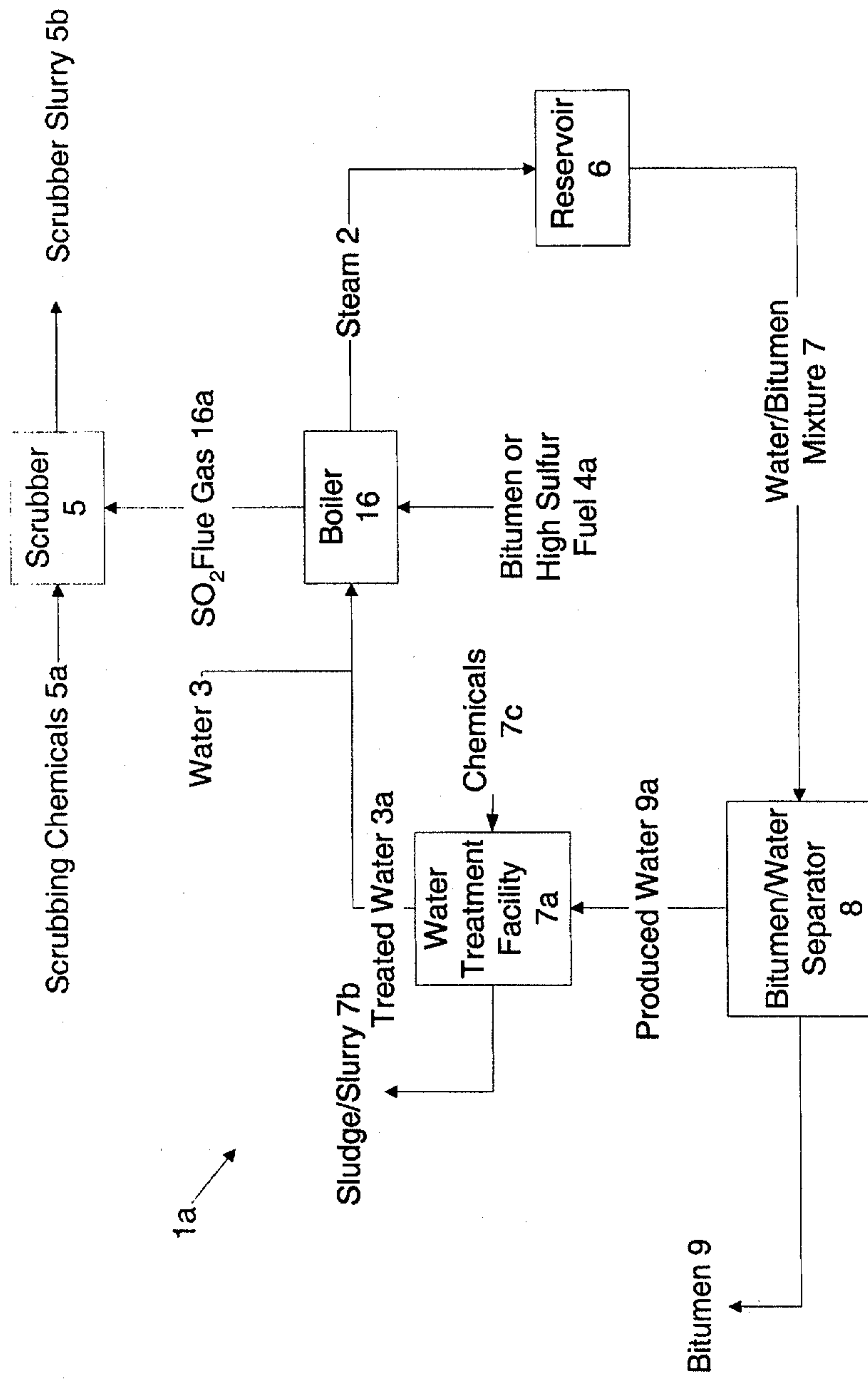


Figure 3

