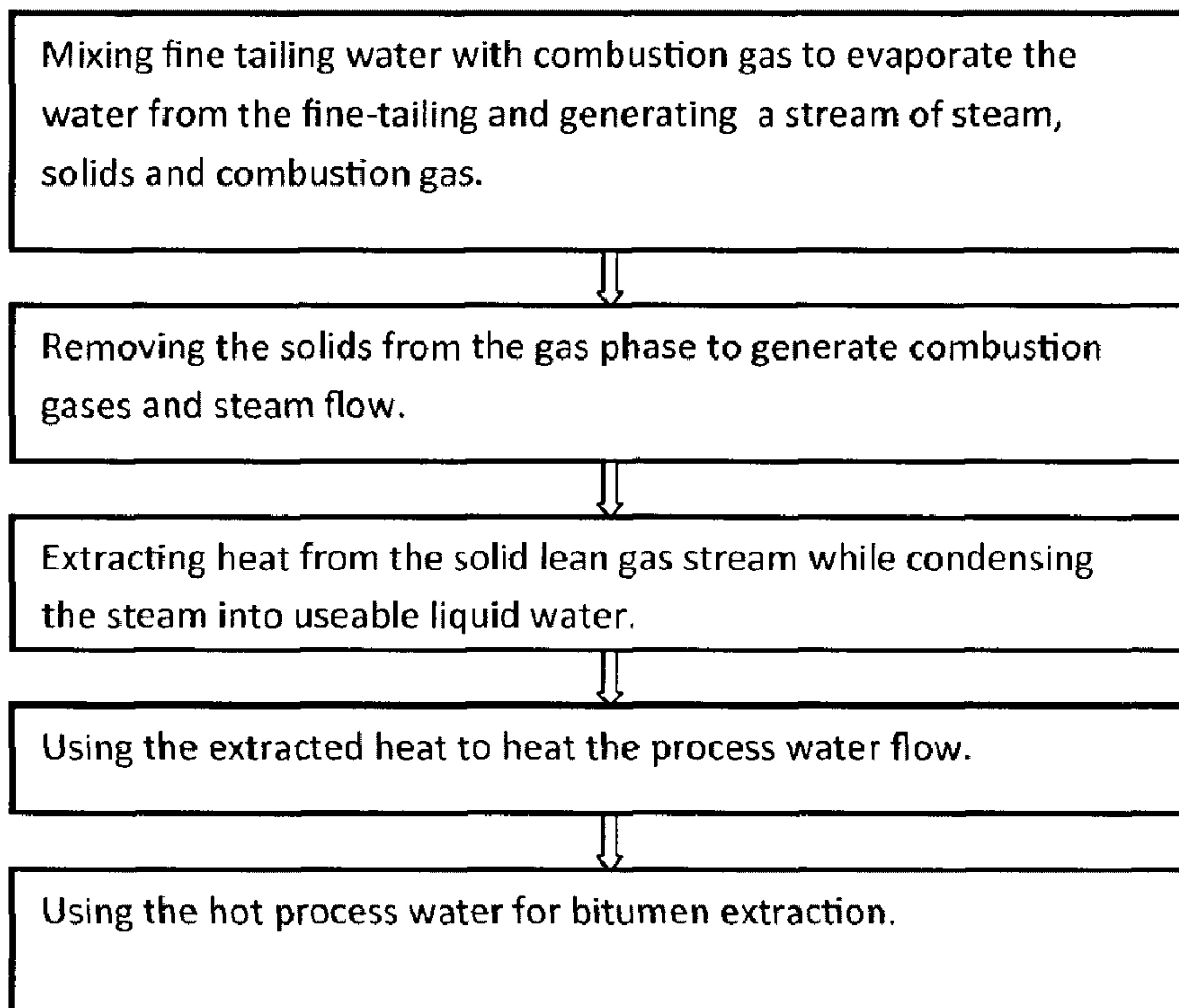




(22) **Date de dépôt/Filing Date:** 2009/11/23
(41) **Mise à la disp. pub./Open to Public Insp.:** 2010/06/12
(45) **Date de délivrance/Issue Date:** 2019/06/25
(30) **Priorités/Priorities:** 2008/12/12 (US61/122,195);
2009/05/12 (CA2,665,751); 2009/05/12 (CA2,665,747)

(51) **Cl.Int./Int.Cl.** *E21B 43/24* (2006.01),
C10G 1/04 (2006.01), *E21B 43/34* (2006.01),
F22B 33/18 (2006.01)
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(54) **Titre : UN SYSTEME ET UNE METHODE DE RECUPERATION DE L'EAU DES RESIDUS**
(54) **Title: A SYSTEM AND METHOD FOR WATER RECOVERY FROM TAILINGS**



(57) **Abrégé/Abstract:**

A method and system for the use of solids-rich water, like fine tailings or lime sludge for extracting bitumen from shallow and deep underground oil sand formations. The method includes the steps of mixing hot combustion gas with solids-rich water under

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

pressure, gasifying the liquid water to gas phase steam and solids, removing the solids from the gas phase to generate solid lean gas phase, mixing the gas with process water to condense the steam and to recover the gas heat, and mixing the generated hot water with oilsands ore for extracting the bitumen. The solid lean gas phase is mixed with saturated water to scrub the remaining solids and acid gases and produce saturated steam. The solids-rich saturated water is recycled and gasified by mixing with the combustion gases, and the saturated steam is condensed to generate heat and to clean condensed water for steam generation for use in enhanced oil recovery.

ABSTRACT OF THE DISCLOSURE

A method and system for the use of solids-rich water, like fine tailings or lime sludge for extracting bitumen from shallow and deep underground oil sand formations. The method includes the steps of mixing hot combustion gas with solids-rich water under pressure, gasifying the liquid water to gas phase steam and solids, removing the solids from the gas phase to generate solid lean gas phase, mixing the gas with process water to condense the steam and to recover the gas heat, and mixing the generated hot water with oilsands ore for extracting the bitumen. The solid lean gas phase is mixed with saturated water to scrub the remaining solids and acid gases and produce saturated steam. The solids-rich saturated water is recycled and gasified by mixing with the combustion gases, and the saturated steam is condensed to generate heat and to clean condensed water for steam generation for use in enhanced oil recovery.

A SYSTEM AND METHOD FOR WATER RECOVERY FROM TAILINGS

FIELD OF THE INVENTION

[01] This application relates to a system and method for water recovery from waste water such as mature fine tailings (MFT) water in the oilsands industry. The recovered water can be used during the bitumen extraction process or for steam generation. The heat is used for thermally efficient heating the process water or for steam generation. The recovered water can be used for steam generation in a commercially – available, non-direct prior art steam generator, as in OTSG (Once Through Steam Generator) and Boiler type facilities or as a process water to generate the oilsands ore slurry.

[02] The present invention minimizes the need for settling fine tailings basins and enables a sustainable tailing practice of “reclaiming as you go”. This means continually reclaiming the excavated oilsands areas and the tailing pond as the mine progresses to a new location. This invention can also minimize the use of natural gas as a heating source for the extraction of heavy oil. Petroleum coke, coal or any other low grade, sulfur-rich carbonic fuel can be used instead of natural gas as the heat source. The sulfur content of the low grade carbonic fuel can be reacted with Lime Stone or Lime Sludge slurry waste from lime softening processes (such as WLS (Warm Lime Softener), widely used for OTSG water treatment in EOR facilities like SAGD or CSS). The reaction generates Calcium Sulfite or Calcium Sulfate, possibly anhydrate, which is extracted with the DCSG solids. The presence of the Calcium Sulfite or Calcium Sulfate can increase the stability of a land-fill in order to support traffic.

[03] The invention also improves thermal efficiency while minimizing the amount of CO₂ generated as compared to the prior-art facilities used in an oilsands mine to generate the hot process water for the bitumen extraction. This is achieved due to the direct contact heat exchange between the combustion gas and the process water.

[04] The steam can be used for Enhanced Oil Recovery (EOR) facilities or for the separation of bitumen from sand and water in open mining oil sand facilities. The water recovery process includes generation and separation of solids in a ZLD (Zero Liquid Discharge), where a dry solid waste or semi-dry slurry that can support traffic is generated for effective

disposal. The heat is recovered and used to heat the processed water, or to pre-heat boiler feed water for steam generation.

BACKGROUND OF THE INVENTION

[05] Tailing pond water is a by-product of the oil, water and sand separation process. These ponds are becoming an increasingly significant environmental problem as the scale of oil sand recovery increases. 1606 ducks died last summer after mistakenly landing in contaminated ponds in northern Alberta. The tailing pond problem is continually escalating, as seen in 1979 when there were tens of millions of cubic meters of fine fluid tailings. Currently in the Fort McMurray area there are close to eight hundred million cubic meters of MFT that covers about 60 square kilometers and require long term containment. Some of the oldest tailing ponds are located (irresponsibly), in close proximity to the Athabasca River. Extensive rainfall in the area can cause these tailing ponds to overflow directly into the river, with devastating effects on the natural environment and on the settlements downriver. The mature tailing water contains suspended fine sediments (less than 40 microns). This sediment can include: clay, heavy metals, hydrocarbons like bitumen, diluent, PAHs (Polycyclic Aromatic Hydrocarbons, which occur in oil and are a byproducts of burning fuels) and Naphthenic Acids, (surfactants found in all heavy oil), sulphate and sodium salinity. The PAHs tend to settle out with the fine sediments. (See the February 2009 PEMBINA report "The waters that bind us", paragraph 2 – "Water and oil sands development" by Peggy Holroyd and Terra Simieritsch.)

[06] In Situ oilsands projects also generate large quantities of disposal water and sludge from their softeners in their facility water treatment plant, steam generation facility and in the oil separation process.

[07] Another basic characteristic of an oil sands project is the use of heat and steam. This is a common characteristic for both surface oil sands mining and In-situ oilsands plants.

[08] In mining, the processed water is heated using steam. Steam is also used to remove NCG and to separate diluent from the sand and the water.

[09] In-Situ EOR facilities use steam for injection underground in order to separate the oil from the sand and move it to the surface. Typical EOR In - Situ facilities use SAGD and CSS (Cyclic Steam Stimulation - "Huff and Puff") technologies.

[10] Most of the work done to resolve the oil sands tailing ponds problem, and especially that of mature fine tailing ponds, is separate from the existence of the oil sand mine and the energy - intensive extraction plant. Using this approach (of separating the cause from the problem) will allow companies to defer the solution to the future, at which time the oil facilities plants will stop operating or have re-located. Such an approach can defer the mature fine tailing reclamation costs to the future, allowing maximization of the Oil Companies present profits while leaving the MFT problem to future generations. It is expected that the ERCB (Energy Resources Conservation Board) will reinforce actions to resolve the MFT problem. In a recent presentation done by the ERCB, it was said that "Fluid tailing volumes are growing steadily.. no fluid tailings pond reclaimed ..and neither the public nor the government is prepared to continue to accept commitments that are not met and increasing liabilities" (See "Oil Sands Tailings: Regulatory Perspective" presentation by Richard Houlihan and Haneef Mian from the ECRB, presented on December 10, 2008 at the International Oil Sands Tailings Conference in Edmonton, Alberta). The strategy currently in use by Alberta regulators is to force oil producers to implement at least a partial solution for the problems associated with oil sand tailing ponds. (See: Tailings Performance Criteria and Requirements for Oil Sands Mining Schemes- Directive 074 issued on February the 3rd 2009 by The Energy Resources Conservation Board (ERCB), a quasi-judicial agency of the government of Alberta. It can be viewed at: <http://www.ercb.ca>)

[11] A basic technical problem and/or disadvantage arises when delaying the resolution of the MFT problem to the future: where the oil is recovered, it would be uneconomic to use an intensive energy method, which uses extensive heat to resolve the fine tailings pond problem. In the present invention, the heat used to resolve the MFT problem is recovered to produce hot water and steam that is used by the oil sand production facility, with minimal energy waste. The overall thermal efficiency of my invention, (which will be reflected in the volume of CO2 emitted) for operation of an oilsands mine plant, is higher than using

steam boilers, as is typically done today. This is true even without considering the other advantages of the current invention compared to the prior-art steam generator; advantages like resolving the MFT problem, reduction of fresh water consumption and the use of low grade fuel (like petcoke) instead of natural gas. In the future, if the heat energy cannot be consumed by a producing oilsand facility, the heat energy will be wasted which will make the implementation of my invention to consume the MFT pond unfeasible. Other methods (like thickening, centrifuge, weather drying and water capping) that do not use intensive heat, can still be used, even when the oilsand mines are not in operation. as the issue outlined above is one disadvantage of my invention as compared to other solutions for the MFT.

[12] However, there is no commercially feasible solution currently in use that completely resolves the oil sand tailing problem in Alberta. There are several activities being carried out by the oil sand producers that are at different R&D stages. (See "Past, Present and Future of Tailing" a presentation by Mark Shaw of Suncor Energy, Alan Fair of Syncrude and Jonathan Matthews of Shell Canada Energy on December 7-10, 2008 at the International Oil Sands Tailings Conference in Edmonton, Alberta). The technologies considered in the presentation which are being tested by the industry include: Evaporation Dry and Freeze Thaw, In-Situ Densification (coke capping), Thickened Tailing, Accelerated Dewatering, Centrifuge MFT, MFT Water Capped lake and Consolidated Tailing (CT).

[13] Currently, there is a large-scale centrifuge pilot project in the works. The tailing ponds require either mechanical or chemical manipulation before subjecting the tailing fine clays to the spin dry cycle. To consolidate its tailings (CT), gypsum, a byproduct of the flue gas system for scrubbing out sulphur, is added, possibly with lime. The theory is that the gypsum interacts electrostatically with the clay and the weight of the added sand squeezes out the water. The thickening process, however, uses flocculants. The flocculants are organic polymers that increase the amount of settling in order to generate non-segregating tailings. The chemical treatment, in which very long molecules stick to different clays and interact mechanically, is enhanced through the addition of sand.

[14] Another activity uses CO₂. High purity CO₂ is the by-product of a hydrogen plant. The CO₂ causes a very slight acidification which helps release calcium ions. Most importantly,

it also has an electrostatic effect and reacts chemically with the sediment. Whatever the process, the resulting dry stackable tailings have similar properties. The only commercially operated options are the CT and the MFT Water Capped Lake. Field pilots are currently being done for the Centrifuge MFT, the Accelerated Dewatering and thickened tailings. Most of the methods used by the industry include natural (or accelerated) dewatering. Relying on dry weather in Fort McMurray can be tricky. Project execution personnel are well aware of the challenges involved in reducing the moisture content of the soil (to increase soil compaction) due to unexpected precipitation in that area. There is also a chance that the precipitation in the area will increase in the future due to global warming. It is to be expected that drying the MFT will become even more challenging. The prior-art commercially available thickening tailing process and the MFT centrifuge or thickening process can be incorporated into the invention to increase the total amount of treated tailing and solids removed. The thickened tailing, from flocculants enhanced thickening process or from a centrifuge process, can be used in my invention to produce solid waste, which can be back-fill for supporting traffic, thus increasing the amount of MFT consumed.

[15] The present invention is based on the opportunity of solving the waste sludge or fine tailing water problem through the use of intensive heat processes, while recovering the water and heat. It can then be used for steam generation or for heating the process water in an oilsands extraction mine facility. Through this integrated approach, the tailing pond waste can be treated using energy- intensive processes (like DCSG - Direct Contact Steam Generation), to generate steam and solid wastes that can be disposed of in landfills or as back-fill in the oilsands ore excavation with minimal environmental impacts.

[16] The definition of "Direct Contact Steam Generation" (DCSG) is that the heat is transferred between the liquid water and the combustion gas. This is accomplished through the direct mixing of the two flows (the water and the combustion gases). In the DCSG, the combustion pressure is similar to the produced steam pressure and the combustion gases are mixed with the steam. (See Figure 2A for the schematic of the Direct and Non-Direct steam generation methods)

[17] In a Non-Direct Steam Generator (like a steam boiler with a steam drum and a mud drum) or “Once Through Steam Generator” (OTSG), the heat transfer and combustion gases are not mixed and the heat transfer is done through a wall (typically a metal wall), where the pressure of the generated steam is higher than the pressure of the combustion. This allows for the use of an atmospheric combustion pressure. The product is pure steam (or a steam and water mixture, as in the case of the OTSG) without combustion gases.

[18] Various patents have been issued, that are relevant to this invention. For example, U.S. Patent No. 8,137,566 entitled “Recovery of tailings ponds” (Bozak et al.), describes a method for treating tailing wastes. The method includes the use of jet pumps for agitating the tailing for separation during the carbon phase. The tailings are flocculated and dewatered.

[19] U.S. Patent 4,969,520 Issued on November 13, 1990 to Jan et al., describes a method for treating water for the production of steam for EOR while generating sludge (which is composed mainly of calcium carbonate and magnesium hydroxide). It also describes the separation and recovery of liquids from the sludge using centrifuge, and possibly using a flocculant. The solids are disposed of in a land fill.

[20] U.S. Patent 6,036,748 Issued on March 14, 2000 to Wallace et al., describes a process for reducing the temperature for dissolving gases in black water, which is generated by a gasifier. The process includes flashing the water under low pressure, to release the gas and generate evaporation within the black water. This reduces the water temperature while generating water vapor. Some of the water vapor is later condensed and recycled. The remaining, cooled black water is treated to remove the solids.

[21] U.S. Patent 6,706,199 issued on March 16, 2004 to Winter et al., describes a method and apparatus for withdrawing and dewatering slag from a gasification system, using a sloped conveying lock hopper with rotating auger located in the conveyor of the lockhopper. The solid slag converges upwards while being separated from the water. U.S. Patent 6,027,056 Issued on February 22, 2000 to Maciejewski et al., describes a method for the assembly and slurrying of oil sand containing oversized lumps and water, while removing the oversized lumps and producing slurry suitable for piping to a separation facility.

[22] Canadian patent 1,211,063 Issued on September 9, 1986 to de Calonne, describes a method to treat tailing sludge, as generated in an open oilsands mine. The sludge is mixed with secondary fuel, like petcoke or coal. The water content of the mixture is then reduced to produce a mixture suitable for self-sustaining combustion. The combustion heat is used to produce steam (through a boiler heat exchanger) for use in the extraction process. The combustion process is done in a fluidized bed combustion furnace.

[23] It is a goal of the present invention to provide a system and method for the use of waste water and any type of fuel while recovering the water and producing solid waste, to improve deep tar extraction EOR facilities, like SAGD or CSS.

[24] It is another objective of the present invention to provide a system and method for the use of discharged water and tailing water, while recovering the water and removing solid waste, to improve oil sand extraction facilities like oil sand surface mining and excavating.

[25] These and other objectives and advantages of the present invention will become apparent from a reading of the attached specifications and drawings.

SUMMARY OF THE INVENTION

[26] A method for use of solids-rich water, such as fine tailings or lime sludge for extracting bitumen from shallow and deep underground oilsands formations, the method comprising the steps of mixing hot combustion gas with solids-rich water under pressure; gasifying liquid water to a gas phase steam and solids; removing the solids from the gas phase to generate a solid lean gas phase; mixing the gas with process water to condense the steam and to recover gas heat; and using the generated hot water for extraction of bitumen.

[27] The method may further comprises the steps of using the generated hot water for steam generation and non-direct pre-heating of boiler feed water; and using the steam in an oil sand enhanced oil recovery facility or a mining extraction facility. 13. The method may further comprises generating portion of the process water by recovering the heat and condensing the steam generated from the fine tailings and the combustion gases.

[28] The method may further comprises the steps of combusting low grade fuel, like petcoke or coal with oxygen containing gas, like air to generate said hot combustion

gases; recovering at least portion of said combustion heat for generating high pressure steam from dematerialized water; and using at least part from said high pressure steam for stripping gases or solvents from the extracted bitumen.

[29] The method may further comprises the steps of mixing saturated water with the solid lean gas phase to scrub remaining solids and to produce saturated steam and combustion gases mixture; recycling at least portion of the saturated water with the scrubbed solids and mixing it with said combustion gas; and condensing the saturated steam to generate heat and dematerialized condensed water for steam generation for use in enhanced oil recovery.

[30] The method may further comprises the steps of mixing combusting fuel and oxidizer gas to generate combustion gases; adding alkaline chemical, such as limestone, to the fuel to reduce the amount of generated acids, such as SO₂; mixing the gas phase with saturated water with alkaline chemical to scrub the remaining solids and acid gases, such as SO₂, and produce saturated steam and solid rich saturated water; and recycling at least part from said solid rich saturated water and mixing it with the combustion gases to convert the liquids to gas.

[31] According to another aspect the present invention further comprising the steps of condensing the saturated steam to generate heat and clean condensed water for steam generation; using the hot condensed water for steam generation; and injecting the steam into underground formation through an injection well for enhanced oil recovery.

[32] According to another aspect of the present invention, a method for use of solids-rich water, such as fine tailings water, for extracting bitumen from shallow underground oil sand formations, the method comprising the steps of mixing hot combustion gas with fine tailings water under pressure; gasifying the liquid water to gas phase comprising steam and solids; removing the solids from the gas phase; mixing the gas with process water in direct contact to condense the steam and recover the gas heat; mixing the generated hot water with the oilsands ore to generate a slurry; and extracting bitumen from the slurry.

[33] According to one aspect of the present invention, a method for recover bitumen from minable bitumen formations, such as shallow oilsands formations, comprising the steps of

mining a formation that contains bitumen and inorganic soil, like oilsands; combusting carbon or hydrocarbon fuel with oxygenated gas to generate combustion gas; mixing process water with the combustion gas to generate stream of hot water and Non-Condensing Combustion Gas; mixing the mined formation with hot process -water to generate a slurry; recovering bitumen from said slurry; recovering process water from said slurry; and recycling said process water and mixing it with said combustion gas.

[34] According to another aspect of the present invention further comprising the steps of mixing fine-tailing water with said combustion gas to evaporate the water from the fine-tailing and generate a stream of steam, solids and combustion gas; removing the solids from said gas phase to generate a solids lean gas stream of steam and combustion gas; extracting heat from the solid lean gas stream to condense the steam to water; using the extracted heat to heat the process water flow to generate said stream of hot water; recovering part of said combustion heat to generate high pressure steam from dematerialized water; and using at least part of the generated high pressure steam to remove light hydrocarbons like solvents and Non Condensable Gases from said bitumen.

[35] According to another aspect of the present invention, the invention describes a method for recover bitumen from minable bitumen formations, such as shallow oilsands formations, comprising the steps of mining shallow formation that contains bitumen and inorganic soil, like oilsands, to extract oilsand ore; combusting carbon or hydrocarbon fuel with oxygenated gas in a gasifier to generate syngas and heat; combusting the Syngas with oxidizing gas and mixing non segregating fine- tailings water with the combustion gas to evaporate the water from the fine-tailings and generating a stream of steam, solids and combustion gas; removing the solids from the gas phase to generate a solids lean gas stream of steam and combustion gas; extracting heat and water from the solid lean gas stream; using the extracted heat and water to heat process water flow; mixing the hot process –water with said mined oildans ore to generate a slurry; recovering bitumen from said slurry; disposing of the

slurry course solids; and process water; recovering the non segregating fine- tailings water and process water; recycling said process water for reuse; recycle said non segregating fine-tailings water back to the syngas combustor; and mixing at least portion of said Non Condensable Combustion Gas, after the water and the heat were recovered, with water, like tailings water, to reduce the pH and increase the settling of different components in the water.

[36] According to another aspect of the present invention, the invention describes a system for reuse of solids-rich water for extracting bitumen from shallow and deep underground oilsands formations, the system comprises a combustion boiler, mixing fuel with oxidation gases therein, forming a mixture, combusting the mixture under high pressures and temperatures therein to generate combustion gases, recovering a portion of the combustion heat to generate steam, said fuel being a carbonic fuel; a gas-solid separator unit, the combustion gases being transferred thereto and removing dry form solids from the gas-solid separator unit; a distillation water treatment plant, generating a stream of water using heat from the combustion gas and steam from the separator unit, wherein the distillation water treatment plant is in fluid connection with the combustion boiler; an enhanced oil recovery facility, having a steam injection well, a bitumen and water production well and a separation facility to separate the bitumen from the water in fluid connection to the steam boiler and to the water treatment plant; a direct contact steam generator, mixing said combustion gases generated by the combustion boiler with water containing high levels of solids therein to form a combustion gas mixture, evaporating the water in the combustion gas mixture to leave the solids in a dry form, wherein the direct contact steam generator is in fluid connection to the combustion boiler and to a water treatment facility, wherein the gas-solid separation unit and said distillation water treatment plant are in fluid connection with the direct contact steam generator.

[37] According to another aspect, the present invention further comprises a system for use solids-rich water for extracting bitumen from mineable underground oilsands formations, the system comprising an oilsands open mine facility that excavates oilsands ore; mixing the ore with hot process water; separating the bitumen from the water; discharging the course tailings; generating a flow of process water; and generating a flow of fine tailings; a

pressurized boiler for combusting sulfur rich, carbon fuel, like petroleum coke or coal, possibly with alkaline slurry, like Lime stone slurry, possibly with sludge generated from water Softening process; a Direct Contact Heat Exchanger to wash the boiler combustion gases, recovering the heat and steam while heating the oilsands mine facility process water for extracting bitumen; said oilsands open mine facility is in fluid connection with said Direct Contact Heat Exchanger for the purpose of heating the process water; said pressurized boiler is in fluid connection with said Direct Contact Heat Exchanger for the purpose of extracting heat from said boiler combustion gas; a Direct Contact Steam Generator (DCSG) for mixing Fine Tailings water, possibly with alkaline slurry, with combustion gas to generate a solids, steam and combustion gases mixture with a solids separator to remove solids; said DCSG is in fluid connection with said oilsands open mine facility for the purpose of consuming said fine tailings water for steam generation; said DCSG is in fluid connection with said Direct Contact Heat Exchanger for the purpose of condensing the steam and heating said process water.

[38] The present invention is also comprises from the following steps:

Combusting carbon or hydrocarbon fuel with oxygenated gas to generate combustion gas. Mixing waste water with the combustion gas to evaporate the water from the fine tailing and generating a stream of steam, solids and combustion gas. Removing the solids from the gas phase to generate combustion gases and steam flow. Extracting heat from the solid lean gas stream while condensing the steam into useable liquid water. Using the extracted heat to heat the process water flow. Using the hot process water for oilsands extraction. Mining a formation that contains bitumen and inorganic soil, like oilsands. Mixing the mined formation with hot process -water to generate slurry. Recovering the bitumen. Disposing of the course solids. Separating the process-water from the fine- tailing water. Using the extracted heat to heat the process water flow. Mixing the fine-tailing water with the combustion gas to evaporate the water from the fine-tailing and generating a stream of steam, solids and combustion gas. Removing the solids from the gas phase to generate a solids lean gas stream of steam and combustion gas. Recycling the hot process-water to the first step. Mixing the mined formation with hot process -water to generate a slurry. Combusting carbon or hydrocarbon fuel with

oxygenated gas to generate combustion gas. Extracting heat from gas stream to condense the steam to process-water. Removing the solids from the gas phase to generate a solids lean gas stream of steam and combustion gas. Recycling the hot process-water to the first step. Mixing the mined formation with hot process -water to generate a slurry. Combusting carbon or hydrocarbon fuel with oxygenated gas to generate combustion gas. Extracting heat from the solid lean gas stream to condense the steam to process-water.

[39] The method and system of the present invention for steam production for extraction of heavy bitumen by injecting the steam to an underground formation or by using it as part of an above ground oil extraction facility includes the following steps: (1) mixing carbon or hydrocarbon fuel and oxidizing gases like oxygen, enriched air or air; (2) combustion of the mixture under high pressure and temperature; (3) mixing the combustion gas with liquid water that include high levels of solids and organics while transferring the liquid phase to a gas phase; (4) separating the solids from the gas phase; (5) using the gas phase heat to evaporate the de-oil produced water and make-up water at the distillation facility to produce distilled water and concentrated brine; (6) recycling the discharge fluids, like brine from the water treatment facility and blow down from the steam generation facility back to the first step and mix them with the combustion gas; (7) using the produced water (BFW) for steam generation through non-direct heat exchange with combustion gas. This can be done in a separate commercially available steam generation facility or by recovering part from the heat from the DCSG; (8) using the produced steam to recover oil. In another embodiment, to improve the solids removal and possible SO₂ removal, if sulfur rich fuel is used, the produced gas will include these two additional steps after step (4) above: (4A) mixing the produced gas with liquid water, possibly with lime or other alkaline materials for SO₂ removal, at saturated temperature and pressure in order to produce a clean, wet saturate steam and gas mixture, while removing most of the SO₂ and scrubbing any remaining solids from the gas; (4B) recycling at least part of the solid rich water that includes the scrubbed solids, the generated calcium sulfite and calcium sulfate back to step (3) and mixing it with combustion gas to convert the liquid phase water to steam.

[40] Step (3) can be done in a Direct Contact Steam Generator reactor, where most of

the water evaporates as it is converted to steam. There are several feasible designs for the DCSG. The structure can include, but is not limited to: a horizontal rotating reactor, a fluidized bed reactor and an up-flow reactor or any other reactor that can be used to generate a stream of gas and solids. The inventor filed a few patent applications for possible reactors that may be used: US patent no. 7,814,867 entitled "Reaction chamber for a direct contact rotating steam generator" (Betzer), US patent no. 8,468,980 entitled "Direct contact rotating steam generator using low quality water with zero liquid discharge" (Betzer), and US patent no. 8,551,200 entitled "Fluid bed direct contact steam generator system and process" (Betzer). Any other DCSG, like a pressurized spray dryer that can consume the highly contaminated water can be used as well to convert the water to steam and solids.

The common dictionary definition of "dryer" is a machine or device that is used for drying something.

Accordingly, the DCSG (Direct Contact Steam Generator) device used in this invention is part of the general dryers group. The DCSG evaporates liquid containing high levels of solids and organics, (like tailings) by a direct contact (not through a separation metal wall) with the combustion gas. This evaporation generates a mixture of steam, combustion gas, and dry solids. The DCSG dryer operates by a direct contact heat transfer between the generated combustion gas and the liquid water rich stream. The heat energy that is given off by the combustion forces the liquid water to evaporate while generating dry or semi-dry solids.

[41] The discharged NCG is at a relatively low temperature, close to the water condensation temperature. The cooled combustion gases can be discharged to the atmosphere. An additional option, if the recovery of CO₂ for sequestration is required, is to separate the CO₂ from combustion gases using a membrane. Low temperature membrane technology is commercially available. The discharged pressure will be used for the separation process.

[42] Another option is to use an oxygen plant where the combustion gases will be mainly CO₂ that can be directly recovered for sequestration.

[43] According to one aspect of the present invention, a method has been provided for producing a steam and gas mixture for injection into an underground formation to extract heavy bitumen by mixing fuel with oxidation gases to form a mixture; combustion of the mixture under high pressures and temperatures to generate combustion gases; mixing said combustion gases with water having a high level of solids therein to form a combustion gas mixture; evaporating the water in the combustion gas mixture to leave the solids in a dry form; washing the combustion gas mixture with water at a saturated temperature and pressure; scrubbing any remaining solids from the combustion gas mixture to form a clean steam and gas mixture; and injecting the clean steam and gas mixture into the underground formation to extract the heavy bitumen.

[44] According to another aspect of the present invention, a system is provided for producing a clean steam and gas mixture for injection into an underground formation to extract heavy bitumen by mixing fuel with oxidation gases in a combustion boiler to form a mixture, combustion of the mixture under high pressures and temperatures in the combustion boiler to generate combustion gases, mixing said combustion gases with water in the combustion boiler having a high level of solids therein to form a combustion gas mixture, evaporating the water in the combustion gas mixture to leave the solids in a dry form, transferring the combustion gases to a gas-solid separator unit, removing the dry form solids from a gas-solid separator unit, transferring the combustion gases to a steam generation and wash vessel, washing the combustion gas mixture in the steam generation and wash vessel with water at a saturated temperature and pressure, scrubbing any remaining solids from the combustion gas mixture to form the clean steam and gas mixture, and injecting the clean steam and gas mixture into the underground formation to extract the heavy bitumen.

[45] According to another aspect of the present invention, a method is provided for producing a pure steam mixture for injection into an underground formation to extract heavy bitumen by mixing fuel with oxidation gases to form a mixture, combustion of the mixture under high pressures and temperatures to generate combustion gases; mixing said combustion gases with water having a high level of solids therein to form a combustion gas mixture, evaporating the water in the combustion gas mixture to leave the solids in a dry form, removing

the dry form solids; washing the combustion gas mixture with water at a saturated temperature and pressure, scrubbing any remaining solids from the combustion gas mixture to form the clean steam and gas mixture; transferring the clean steam and gas mixture to a heat exchange condenser, using heat from the clean steam and gas mixture to heat water supplied from a distillation facility, combustion of the water from the distillation facility to generate a pure steam mixture that can be used to extract the heavy bitumen, and injecting the pure steam mixture into the underground formation to extract the heavy bitumen.

BRIEF DESCRIPTION OF THE DRAWINGS

[46] FIGURES 1, 1A, 1B, 1C, 1D, 1E, 1F and 1G are a schematic diagrams of the present invention for the generation of hot water for oil-sand mining extraction facilities, with fine tailing water recycling, in order to achieve zero liquid discharge with fine tailing water recycling.

[47] FIGURE 1H is a schematic view of a diagram of the principal of Direct Contact Steam Generation and Non-direct Contact Steam Generation.

[48] FIGURE 2 shows a general block diagram of a prior art steam generation facility used in the oil industry. These facilities are standard and are commercially available.

[49] FIGURE 2A, 2B, 2C and 2D are other schematic views of the present invention with oilsands mine fine tailing water recycling.

[50] FIGURE 3 and 3A are schematic views of an illustration of the current invention for the generation of pre-heated water that can be used at a later time for steam generation in an oil sand EOR facility or mining extraction facility.

[51] FIGURE 4 is a schematic view of an illustration of the current invention without waste water discharge and SO₂ removal.

[52] FIGURE 5 is a schematic view of the current invention with a direct contact steam generator.

[53] FIGURE 6 is a schematic view of the current invention with steam generation and non-direct pre-heating of boiler feed water.

[54] FIGURE 7 is another schematic view of the current invention with steam generation and non-direct pre-heating of boiler feed water.

[55] FIGURE 8 is a schematic of an integrated facility of the present invention with a commercially-available steam generation facility and enhanced oil recovery for heavy oil production.

[56] FIGURE 9 is a schematic of an integrated facility of the present invention with a commercially-available steam generation facility and open-mining oilsand facility.

[57] FIGURE 10 is a schematic of an integrated facility of the present invention with a commercially-available steam generation facility, open-mining oilsand facility, and gasifier for syngas generation.

[58] FIGURE 11 is a schematic view of the present invention with an open mine oilsand extraction facility, where the hot process water for the ore preparation is generated by recovering the heat and condensing the steam generated from the fine tailings steam and the combustion gases.

[59] FIG 11A is a schematic view of integrating pressurized boiler with oilsands mine for heating the ore preparation process water in a direct contact with the combustion gases.

[60] FIGURE 12 is a schematic view of the present invention with an open mine oilsand extraction facility, where the hot process water for the ore preparation is generated from condensing the steam produced from fine tailings. FIGURE 12A is a schematic view of FIGURE 12, incorporating a direct contact steam generator.

[61] FIGURE 13 is a schematic view of a gasifier unit and an open mine oilsand extraction facility, where the hot process water is heated in direct contact with the syngas.

[62] FIGURE 14 is another schematic view of the present invention with an open mine oilsand extraction facility, where the hot process water for the ore preparation is generated from condensing the steam produced from fine tailings.

[63] FIGURE 15 is a schematic view of the present invention with an open mine oilsand extraction facility, where the heat source is a gasifier with maximization of mature fine tailing recovery.

[64] FIGURE 16 is a schematic view of the present invention with an open mine oilsand extraction facility, where the hot processed water for the ore preparation is generated from direct contact heat exchange between the process water, the condensing steam generated from the mature fine tailing, and the combustion gas. FIGURE 16A is a schematic view showing the system of FIGURE 16 with a direct contact steam generator.

[65] FIGURE 17 is a schematic view of the present invention with an open mine oilsand extraction facility, where the hot process water for the ore preparation is generated from condensing the steam generated from the mature fine tailings and from cooling the combustion gas through an indirect heat exchanger.

[66] FIGURE 18 is a schematic view of the present invention with an open mine oilsand extraction facility and a prior art commercial available pressurized fluid bed boiler that was used for combustion coal for power supply.

[67] FIGURE 19 is a schematic view of the present invention with an open mine oilsand extraction facility that include cyclones and thickeners, a tailing pond, a rotating direct contact steam generator and with indirect heat exchange.

[68] FIGURE 20 is a view of the present invention with an open mine oilsand extraction facility with 5 areas where AREA1 is the oilsand mine plant, AREA2 is a steam generation facility, AREA3 is the process water heating area, AREA4 is the tailing pond area with MFT pumping and AREA5 is the pressurized up-flow boiler with MFT injection for steam generation.

[69] FIGURE 21 is a schematic view of a simulator flow chart of one embodiment of the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

[70] FIGURE 1, 1A, 1B, 1C, 1D, 1E, 1F and 1G is self explanatory block diagrams for describing the present invention.

[71] FIGURE 1H is a self explanatory comparison of the principal of Direct Contact Steam Generation and Non-direct Contact Steam Generation.

[72] FIGURE 2 shows a general block diagram of a prior art steam generation facility used in the oil industry. These facilities are standard and are commercially available. They include two basic units – a water treatment unit 1, and a steam generating unit 2 that uses the treated water. The water treatment facility can be any type of commercially available facility- a warm lime softener, an RO (Reverse Osmosis) facility, an evaporation based facility or ion exchange - based facility. Feed water 3 is treated to remove impurities. The particular water treatment facility in use and the level of water purity depends on the water 4 quality required by the steam generation facility, as there is a significant difference between the water requirements of OTSGs and boilers. The water treatment plant 1 generates a stream of rejected water. This reject water is typical of the water treatment process currently being used. It can include sludge from the lime softeners, water from the filters, ion exchangers and polisher back-flashes, RO reject water, evaporator blowdown, etc. The steam generation plant can be an OTSG or Co-Gen facility that generates 80% steam 7. It could also be a steam boiler that generates 100% steam 7. In the heavy oil industry, it is standard to use OTSG for in-situ facilities (like SAGD or CSS) and to use steam boilers producing 100% quality steam for the oil sand open mining facilities, as seen in steam generation facility 2. Most of the water is recycled and used as an in-direct heat transfer medium. Steam generation facility 2 uses carbon based fuel or hydrocarbon fuel 5 and oxidizer gas 6. In most of the current oil sands projects, the fuel in use is natural gas and the oxidizer gas is air. There are also commercial projects in which the fuel is syngas, mainly CO. An additional option for fuel, is to use the produced bitumen, possibly in the form of a slurry mixture. Typically, the oxidation gas 6 is air under atmospheric pressure. Another option is to use enriched air or pure oxygen as the oxidizing gas, (see PCTpatent publication no. WO2006/016042 entitled “Method for generating water vapour adapted to oxycombustion” (Conturie et al.). However, oxycombustion requires the use of an air separation unit to generate an oxygen - rich gas stream. This type of boiler can be used if the high concentration produced CO₂ discharged from boiler 8 can be used as part of the process or for sequestration (to offset the air separation plant costs). Typically, the combustion gas 8 is released to the atmosphere through the steam generator stack at a temperature slightly higher than the dew –point, to prevent corrosion. The steam generation emits a stream of reject

water. The quality and quantity of the reject water depends on the steam generation facility in question. For OTSG, 80% quality steam is generated. The remaining 20% water can be flashed in a few stages to recover water in the form of low-pressure steam. 9. Then, the remaining water is discharged as reject water, preferably to disposal wells (or to a separate ZLD facility, if required by environmental regulators). For boiler - based steam generation, water is constantly being discharged from the boiler mud drums 9. The produced steam 7 is used for injection into the underground formation, (in the case of In-Situ steam generation facilities) or for heating the processed water, the bitumen slurry and the sandy water. The steam is also used for flashing the diluent into the open mine excavation - based oil sand facilities.

[73] FIGURE 2 is a schematic of the present invention for the generation of hot water for oil sand mining extraction facilities, with fine tailing water recycling, in order to achieve zero liquid discharge with fine tailing discharge.

[74] Energy 1 is being injected into reactor 3. The energy should be in the form of a high temperature combustion gas, typically in the range of 1300-400C. Another option is to inject the carbon or hydrocarbon fuel, (like natural gas or petcoke slurry) and the oxidizer gas (like air) into the steam generation reactor 3 and then combust them. The energy is released in the form of heat to generate hot combustion gas. Fine Tailing water 5, possibly with high concentrations of solids like clay, hydrocarbons and other contaminants, is injected into DCSG (Direct Contact Steam Generator) reactor 3, where most of the water evaporates as it is converted to steam. There are several feasible designs for the unit 3. The design can include a horizontal rotating vessel, a fluidized bed reactor, and an up-flow reactor or any other reactor that can be used to generate a stream of gas and solids. The inventor has filed a few patent applications for possible reactors 3. Possibilities for unit 3 include, but are not limited to: US patent no. 7,814,867, Canadian patent application no. 2,626,416 entitled "Direct contact rotating steam generator" (Betzer), US patent no. 8,468,980, Canadian patent application no. 2,655,353 "Direct contact rotating steam generator for steam generation using low quality water with zero liquid discharge" (Betzer), US patent no. 8,551,200, Canadian patent application no. 2,676,717 entitled "Fluid bed direct contact steam generator system and process" (Betzer) and Canadian patent application no. 2,676,720 "Vertical zero liquid discharge

direct contact up-flow steam generator system and method” (Betzer). Any available DCSG unit that can consume Fine Tailings and generate steam and solids can be used as reactor 3. A stream of hot gas 6, possibly with carried-on solids generated in reactor 3, flows into a commercially available solid-gas separator 20. Also, solids 4 can be discharged directly from the reactor 3 (depending on the type of the DCSG reactor used). The separated solids 22 and 4 are disposed of in a landfill. They can be mixed with tailing slurries in order to generate a stable material that can be disposed of into an oilsand mine for reclamation and for supporting traffic. The solid lean gas flow 21, with steam from water flow 5, is mixed with the oilsand mine process water 8 in vertical vessel 7. The processed water is heated due to direct contact with the gas 21. The water carried within the gas condenses and is converted to process water 8. The heated water 9 is typically at temperatures of 70C-90C. It is recycled back to the oil sand mine, where it can be mixed with the excavated oil sand ore after passing through the breaker. The pressure in the system can range from slightly above 1 bar up to 50bar. An increase in pressure augments the efficiency of the water heating and recovery and reduces the needed facility size. The down-side of using high pressure, however, is that higher TIC (Total Installed Cost) and operation costs for the facility will need to be taken into consideration.

[75] FIGURE 2A is a schematic of the present invention for the generation of hot water for oilsand mining extraction facilities, with Fine Tailing water recycling.

[76] Block 1A includes a Prior Art commercial open mine oilsand plant. The plant consists of mining oilsand ore and mixing it with hot process water, typically in temperature range of 70C-90C, separating the bitumen from the water, sand and fines, and discharging the water mixture to a tailing pond. The cold process water 8 includes recycled process water together with fresh make-up water that is supplied from local sources (like the Athabasca River in the Wood Buffalo area). Another bi-product from the open mine oilsand plant is Fine Tailing (FT) 5 which, after a time, is transferred to a stable Mature Fine Tailings (MFT). Hot pressurized combustion gas or a mixture of fuel and oxidizer 1 is fed to enclosure 3. The hot combustion gases are mixed in enclosure 3 with a flow of FT 5 from Block A1. Most of the liquid water in the FT is converted to steam. The remaining solids 4 are removed from the steam and combustion gas mixture 21. The mixture of pressurized steam and combustion gas is mixed with the cold

process water from Block 1A in a direct contact heat exchanger 7. The cold process water 8 is heated to generate hot process water 9 that is supplied back to operate the Open Mine Oilsand plant 1A. The steam generated from the FT and possibly from the combustion, is condensed and recovered with the hot process water supplied back to Block A1. The pressurized Non Condensable Gases (NCG) from the combustion process are released at 2 or are further used or treated (not shown). The enclosure 3 system pressure can vary from 103kpa to 50000kpa and the temperature at the discharge point 21 can vary from 100C to 600C.

[77] FIGURE 2B is a schematic of the present invention for the generation of hot water for oilsand mining extraction facilities, with Fine Tailing water recycling.

Block 1A includes a Prior Art commercial open mine oilsand plant. The plant consists of mining oilsand ore and mixing it with hot process water, typically at a temperature range of 70C-90C, separating the bitumen from the water, sand and fines, and discharging the water mixture to a tailing pond. The oilsand mine facility 1A generates cold process water 8. The cold process water 8 is heated by direct contact with steam and combustion gas 1. The steam and combustion gas can be supplied from an external source or from an internal fired fuel and oxidizer mixture. Another bi-product from the open mine oilsand plant, the FT or MFT is supplied and mixed at pressurized enclosure 3, where a mixture of steam is generated in a direct contact environment between the FT or MFT and the hot combustion gas. Solids 4 are recovered from the enclosure in a form that is stable enough to support traffic, if used as back-fill. The combustion gas and steam mixture 21 is used to heat the process water 8. The NCG (Non Condensable Gases) 2 are released to the atmosphere or for further treatment.

[78] FIGURE 2C is a schematic of the present invention as described in 2B, where the combustion gases for mixing with the FT / MFT are generated in a separate boiler or gasifier. BLOCK 1A includes a Prior Art commercial open mine oilsand plant. BLOCK 2A include a commercially available pressurized boiler or gasifier where the difference is in the combustion gas composition which, in the case of the gasifier the combustion gas, called syngas, still has caloric value. Fuel 10 and oxidizer gas 11 supplied into a pressurized boiler or gasifier 12 where some of the combustion heat is recovered to generate steam 14 from BFW 13. There are a few commercially available designs that can used for unit 12. PFBC (Pressurized Fluid Bed

Combustion) boiler is one option. There are also few commercial down flow and up-flow gasifiers that can be used, like the down flow GE coal gasifier, for generating hot syngas. Heat is recovered directly from the gasifier for generating steam 14. The pressurized hot syngas 1 is directed to a DCSG where it is mixed with additional oxidizing gas 15 and it is fully combusted to generate additional heat and mixed with FT/MFT 5 to use the heat for transferring the water in the MFT into steam. When a pressurized boiler is used, there is no additional requirement for supplying oxidizer 15. The heat energy source is only the heat of the fully combusted combustion gases from the pressurized boiler 12.

[79] FIGURE 2D is a schematic of the present invention as described in 2B, for generating slightly caustic (pH7.5-9) hot water for mixing with the oilsand ore. Most of the acid gases like the SOX and the NOX can be eliminated with the use of alkali material in the boiler (if a fluid bed boiler is used) and in the DCSG. However, a large percent of CO₂ is an integral part of the combustion gas composition. Some of the CO₂ will dissolve in the extraction process water while generating a weak acidity. One solution is to separate the flows and use a heat exchanger to prevent mixture of the process water with the combustion gas, as described in Figs. 9, 3 and 3A. Another option is to add caustic chemicals, like soda caustic, to react with the acidity. To minimize the amount of NaOH, the hot process water pressure is reduced 9 allowing the CO₂ to bubble out from the water 12. NaOH 17 is added to the hot process water to react with the carbonic acid remains which generates the caustic pH required for the extraction process. The slightly caustic process water is supplied to the oilsand plant for extracting the tar from the sand.

[80] FIGURE 3 is one illustration of the present invention for the generation of pre-heated water that can be used at a later time for steam generation in an oil sand EOR facility or mining extraction facility. The invention has full disposal water recycling, so as to achieve zero liquid discharge.

[81] Energy 1 is introduced to the Direct Contact Steam Generator reactor 3. The energy may be in the form of a high temperature combustion gas, typically in the range of 1300C-400C, or as a mixture of carbon or hydrocarbon fuel, like natural gas or petcoke slurry, and an oxidizing gas, like air. The combustion inside the reactor releases energy in the form of

heat to generate hot combustion gas. Contaminated water 5, like FT or MFT, are injected into reactor 3. There, most of the water is converted to steam, leaving solids with low moisture content. There are several possibilities for the design of reactor 3. The design can be a horizontal rotating reactor, an up-flow reactor, or any other type of reactor that can be used to generate a stream of solids and gas. A stream of hot gas 6, possibly with carried-on solids generated in reactor 3, flows into a commercially available solid-gas separator 20. Solids 4 can also be discharged directly from the reactor 3, depending on the type of reactor used. The separated solids 22 and 4 are disposed of in a landfill. The solids lean flow 21, (rich with steam from flow 5) mixes with condensing water 8 in the direct contact vertical vessel 7. The steam in flow 21 condenses by direct contact with the recycled water 8. The solid remains that previously passed through solid separation unit 20 and were carried on with the gas flow 21, are washed with the heated water 9. They are recycled back to the water treatment facility that originally supplied water for the steam generation facility (not shown). The condensing water 11 is cooled in heat exchanger 10, while transferring the heat energy to water 13 that can be used as a pre-heated water for steam generation or as the hot process water for open mine oilsand facility. The heat extracted from gas flow 21, due to water condensation in vessel 7 and from the NCG (Non Condensable Gas) cooling, is a result of direct heat exchange with the recycled condensed water 8. BFW (boiler Feed Water) 13 from a commercially - available water treatment and steam generation facility (not shown), or process water from a bitumen extraction facility, flows through heat exchanger 10 to collect heat and generate pre-heated BFW or hot process water 12. It is then used in the steam generation facility to generate high-pressure steam for EOR. For example, it may be used in SAGD or for any other function that requires steam in an oilsand bitumen extraction facility. The temperature of the pre-heated water is dependant on the pressure in vessel 7. The pressure in the system can range from slightly above 1 bar up to 100bar. The temperature of the preheated water, as well as the overall thermal efficiency of the system, increases as the pressure increases. However, this advantage comes with added facility costs. The system generates a stream of NCG 2 that can be further treated through a process such as CO₂ separation for CO₂ sequestration. The CO₂ can also be injected into an underground reservoir to recover oil or maintain the reservoir

pressure. The solids free NCG 2 can be used in the oil extraction process for slurry aeration or be released into the atmosphere, possibly after going through an expander in order to recover energy for compressing the process oxidizer gas (not shown).

[82] FIGURE 3A describes another embodiment of the present invention.

[83] Fuel 1 and oxidizer 2 are injected into a pressurized rotating parallel flow DCSG 5 and combusted in the combustion section 5. Fine Tailing water, together with solid rich recycled condensing water 4, are injected into the DCSG. The DCSG includes heat transfer section 6 with internal chains to improve the heat transfer and remove internal solids deposits. The solids are removed from the DCSG in a solid or semi-solid form. Additional MF 8 can be provided to the solids before they discharge. The MF can increase the water content of the solids to prevent dust and to allow the reaction of the calcium sulfite to produce calcium sulfate (gypsum). The amount of FT 8 is such that the solids are dry enough (after mixing with air for oxidizing) to support traffic. If lime stone or possibly softening sludge was used to remove the SO₂ from the combustion, the solids, with some FT 8, will be mixed 63 with air 67 to create an oxidation reaction of the calcium sulfite. This reaction will consume water (that will be supplied by adding additional FT 8 or MFT and through this, increasing the amount of FT that is permanently removed). It will also create a stabilizing effect because of the crystal water affinity with the gypsum (to generate a hydrate molecule). The solids can be trucked 64 using the oilsand ore mine's existing equipment to then be back-fill in the ore excavation. The discharged gas 9 is injected into scrubber and direct contact heat exchanger 54. The hot combustion gas with the steam from the DCSG is mixed with the recycled cool condensing water 65. The steam is condensed to generate a hot water 55, typically in the range of 80C-150C, and any remaining solids from the DCSG are scrubbed by the liquid water. The hot condensate recycled water 55 flows through heat exchanger 58 where the hot condensing water 55 leaving 54 heats the cold process water 59 supplied from the oilsand mine facility to generate the hot process water 57 used in the extraction oilsand mine facility. The cooled condensing water 62 is separated in separator 60. Alkali material like lime stone slurry, possibly with WLS (Warm Lime Softener) sludge 66, is added to recycled condensed water. The solid rich condensed water that includes solids that were carried by flow 9 leaving the DCSG, the alkali

material that reacted with the SO₂ and generated Calcium Sulfite, and possibly other solids (if, for example, Dolomite was present) are separated at separator 60. The solids rich flow 4 is recycled back to the DCSG. The access condensate water 52 is supplied to the Oilsands mine facility, where it can be further treated before being added to the process water or it can be added directly to the cold process water 59.

[84] FIGURE 4 is a schematic of the present invention for the generation of hot water for oil sand mining extraction facilities, with full tailing water recycling to achieve zero liquid discharge with no fine tailing discharge and with SO₂ removal.

[85] Energy 1 is being injected to reactor 3. The energy should be in the form of a high temperature combustion gas, typically in the range of 1300-400C. Another option is to inject fuel and an oxidizer into reactor 3 and combust them inside the reactor. The energy is released in the form of heat, to generate hot combustion gas. Fine Tailing water 5 (possibly with high concentrations of solids like clay, hydrocarbons and other contaminants) is injected into reactor 3, which can be an horizontal counter flow Direct - Contact Steam Generator reactor. Any other reactor design can be used as well. Inside, most of the water evaporates as it is converted to steam. A stream of hot gas 6, possibly with carried-on solids and SO₂ gas generated in reactor 3, flows into a commercially available solid-gas separator 20. Also, solids 4 can be discharged directly from the reactor 3, depending on the type of reactor used. The separated solids 22 and 4 are disposed of in a landfill or mixed with the MFT to generate a stable material that can be disposed of in an oilsand mine for reclamation and to support traffic. The solid lean flow 21, rich with water converted to gas from flow 5, is mixed with saturated water in vessel 12. Alkali chemicals like Lime stone, possibly with slurry from HLS/WLS (Hot Lime Softener / Warm Lime Softener), can be added to the make-up water 14 to react with the SO₂. HLS/WLS are widely used, for example, in the FortMcMurray and Cold Lake area on a large scale to treat water for steam generation in OTSG (Once Through Steam Generation) for deep formation EOR methods (Enhance Oil Recovery) like SAGD or CSS. The saturated water generates saturated NCG and steam 13. The solids rich water, including the generated calcium sulfite and calcium sulfate with the remains of the calcium that didn't react with the sulfur, is recycled back to the DCSG 3, where the calcium remains will continue to react

with the SO₂ and will eventually be removed in solid form 4 or from the solid separator 22. The saturated, clean flow is injected into vessel 7 where it is used to heat the processed water used for ore preparation 9. The processed water is heated due to direct contact with the gas 13. The water carried within the gas condenses and is converted to processed water 8. The heated process water 9 is typically at temperatures of 70C-90C. It is recycled back to the oil sand mine, where it can be mixed with the excavated oil sand after the breaker. The pressure in the system can range from slightly over 1 bar up to 50bar. This increase in pressure augments the efficiency of the water heating and recovery process and reduces the required facility size. The down-side of using high pressure, however, is that higher construction costs for the facility will need to be taken into consideration.

[86] FIGURE 5 is an illustration of the invention, shown in combination with a commercially available steam generation facility 30- a prior art steam generation facility 30 including a water treatment unit 1 and a steam generation unit 2. The water discharged from water treatment plant 10 and the water discharged from the steam generation facility 9 is injected into a Direct Contact Steam Generator facility 15, where the discharged water is subjected to a hot pressurized combustion gas. The pressure can vary from 1bar up to 70bar. Hot gases are generated from the combustion of carbon-based fuel 14 and oxidizer gas 13. The fuel 14 can be in the form of a gas (like natural gas), liquid (like slurry or liquid hydrocarbon) or solid (like pet-coke or coal). Dry solids or semi-dry solids 16 in a non-pumpable slurry form are removed from the produced gas flow 17. The discharged solids 16 can be disposed of efficiently in a landfill. Gas flow 17 contains non-condensable gas and steam from water 12 in the form of gas, possibly with some solid remnants. The gas 17 is washed in vessel 20 through direct contact with saturated water 21. During this stage, additional steam can be generated. Make-up water 22 is continually added. The water can include lime and additional alkalis to remove gas contaminants, such as SO₂. Solids rich contaminated saturated liquid - phase water 18 is recycled back to the direct contact steam generator 15. There, it will be converted to mainly gas 17 and solids 16 for disposal. A saturated, solids free steam and non-condensed gas mixture 23 is generated. Steam 23 is mixed in pressurized vessel 25 with the boiler feed water 19 from water treatment plant 1. The steam is condensed into water 24. The temperature and pressure

in vessel 25 is different in comparison to vessel 20, as the purpose of vessel 25 is to recover the saturated steam flow generated in vessel 20. Water 24, is at a lower temperature due to being saturated at the partial pressure level inside vessel 25. The heat from the non - condensable gas and from the condensed water vapor in gas flow 23 is recovered in direct contact with BFD 19; this is done to generate heated boiler feed water 26. The heated BFW can be at a temperature in the range of 50-200C. Based on the pressure inside vessel 25, the percentage of NCG will vary as will the volume of BFW 19 that was injected into vessel 25 from the water treatment plant. This is done in order to collect the heat and the water. The generated heated BFW 26 is pumped from the bottom of vessel 25 to the boiler 2, and is then pressurized and converted to steam at steam generation facility 2. The system may include pre-treatment of the BFW to remove dissolved gases that have negative impacts on the steam generation facility, like traces of CO₂ or SO₂ (not shown). The steam generation unit 2 used for this process should be a common, commercially available, direct facility unit. This may include an OTSG or steam boiler (possibly with economizer), air pre-heater, flue gas recycler, or any other commercially available improvement. Fuel 5 and air are used in the steam generation facility 2 for steam generation, while generating flue gases 8. The steam generation facility generates high-pressure steam 7 and some reject water 9. The reject water is recycled back, along with the water treatment facility reject water 10, to the direct contact steam generation unit 15. The high-pressure steam 7 can be used for EOR and is injected into an underground formation, as in SAGD, or is used as the heat source in an oilsand mining plant operation.

[87] FIGURE 6 is a schematic of the present invention that includes commercially available steam generation facilities, with non-direct pre-heating of the BFW. Figure 6 is similar to figure 5, with a few differences: the prior art facility in figure 6 shows steam generation that requires high quality BFW, as in the case of a package boiler. In the boiler, condensed water from the direct contact mixture of BFW with the saturated steam and NCG (non condensable Gas) flow cannot be used without complicated treatment before using the water in the steam boiler 2. A prior art steam generation facility 30 includes a water treatment unit 1 and a steam generation unit 2. The discharged water from both the water treatment plant and the steam generation facility 10, is injected directly to a Direct Contact Steam Generator facility 15. There,

the discharged water is subjected to a pressurized hot combustion gas. The hot gases are generated from the combustion of carbon-based fuel 14 and oxidizing gas 13. Dry solids or semi-dry solids 16 in non-pumpable slurry form are removed from the produced gas flow 17. The discharged solids 16 can be disposed of efficiently in a landfill or in an excavation site, where they can be covered and re-claimed back into the environment. Gas flow 17 contains hot combustion non-condensable gas and steam from the water that was converted to steam, possibly with some carried-on solid remnants. The gas 17 is washed in vessel 20 through direct contact with saturated water 21. During this stage, additional steam is generated. Make-up water 22 is continually added. The water can include lime and additional alkalis to remove gas contaminants like SO₂. A saturated, solids free steam and non-condensed gas mixture 18 is generated. Heat and water from stream 18 is recovered in heat exchanger 22 with BFW 19 from the steam generation facility. The heated BFW 23 is used in the steam generation facility for steam generation. The recovered condensed liquid water 26 is recycled back to the water treatment facility 1 for further treatment, before it can be fed into steam generation facility 2. The remaining non Condensable Gas, with some carry-on water vapor 27, can be released to the atmosphere, or sent for further treatment (like CO₂ sequestration). The produced steam 7 from the steam generation facility 2 can be used for many purposes. It can be used for underground injection (as in EOR), or to heat water, or to separate bitumen from oilsand slurry. As well, it can be used to flash out diluent in open oil sand mine extraction.

[88] FIGURE 7 is a schematic of the present invention for the integration of the present invention with a commercially available steam generation facility and with non-direct pre-heating of the BFW. Figure 7 is similar to figure 6 with a few notable differences. The prior art facility in figure 7 includes steam generation that requires high quality BFW. A prior art steam generation facility 30 includes a water treatment unit 1 and steam generation unit 2. The discharged water from the water treatment plant and from the steam generation facility 10 are injected directly into a Direct Contact Steam Generator facility 15, where the discharged water is subjected to a pressurized hot combustion gas. The hot gases are generated from the combustion of carbon-based fuel 14 and oxidizing gas 13. Dry solids, or semi-dry solids 16, in slurry form are removed from the produced gas flow 17. The discharged solids 16 can be

disposed of efficiently in a landfill or at the excavation site where the solids can be covered and re-claimed by nature. Gas flow 17 contains hot combustion, non-condensable gas and steam from the water that was converted to steam, possibly with some carried-on solid remnants. The gas 17 is washed in vessel 20 through direct contact with saturated water 21. During this stage, additional steam is generated. Make-up water 22 is continually added. The water can include lime and additional alkalis to remove gas contaminants like SO₂. A saturated, solids free steam, non-condensed gas mixture 18 is generated. The heat and water from stream 18 is recovered in vessel 23 with direct heat exchange with recycled water 23. The recycled water 26 flows through liquid-liquid heat exchanger 25, with the BFW 19 from the steam generation facility; the heated BFW 32 is used in the steam generation facility. The recovered condensed liquid water 31 is recycled back to the water treatment facility 1, for further treatment before it can be fed into the steam generation facility 2 and heated in heat exchanger 25. The remaining Non Condensable Gas, with some carry-on water vapor 24, can be released to the atmosphere. Or it can be sent to undergo further treatment, like CO₂ sequestration. The produced steam 7, from the steam generation facility 2, can be used for underground injection as in EOR, to heat water and separate bitumen from oilsand slurry.

[89] FIGURE 8 is a schematic of an integrated facility of the present invention with a commercially available steam generation facility and EOR for heavy oil production. The steam for EOR is generated using a lime softener based water treatment plant and OTSG (Once Through Steam Generator) steam generation facility. This type of configuration is most common in EOR done in Alberta. It is obtained from deep oil sand formations using SAGD or CSS. Produced water 3, is broken down inside a separator facility to oil 4 and water 5. There are many methods of separating the bitumen from the water- the most common one uses gravity. Light hydrocarbons can be added to the product to improve the separation process. The water, with some oil remnants, flows to a produced water de-oiling facility 6. In this facility, de-oiling polymers are added. Waste water, with oil and solids, is rejected from the de-oiling facility 6. In a traditional system, the waste water would be recycled or disposed of in deep injection wells. The de-oiled water 10 is injected into warm lime softener 12, where lime, magnesium oxide and other softening chemicals are added 8. The softener generates sludge 13. In a standard facility,

the sludge is disposed of in a landfill. The sludge is semi-wet and hard to stabilize. The softened water 14 flows to a filter 15, where filter waste is generated 16. The waste is sent to an ion-exchange package 19, where regeneration chemicals 18 are continually used and rejected with carry-on water as waste 20. In a standard system, the treated water 21, flows to an OTSG where approximately 80% quality steam is generated 27. The OTSG typically uses natural gas 25 and air 26 to generate steam. The flue gas is released to the atmosphere through stack 24. Its saturated steam pressure is around 100bar and the temperature is slightly greater than 300C. The steam is separated in separator 28, to generate 100% steam 29 for EOR and blow-down water 30. The blow down water can be used as a heat source and also to generate low pressure steam. The steam 29, is delivered to pads, where it is processed and injected into the ground through injection well 53. The production well 54 produces an emulsion of water and bitumen 3. In some EOR facilities, injection and production occur in the same well, where the steam is 80% quality steam 27. The steam is then injected into the well with the water. This is typical of the CSS pads. The reject streams includes the blow down water from OTSG 33, as well as the oily waste water, solids and polymer remnants from the produced water de-oiling unit. This also includes sludge 13 from the lime softener, filtrate waste 16 from the filters and regeneration waste from the Ion-Exchange system 20. The reject streams are collected 33 and injected into Direct Contact Steam Generation 34. Additional water 32, from any available water source, can be added. The energy source can be a gas, liquid, solid, carbon or hydrocarbon - based fuel 36 and oxidizing gas, (like air) 35. The DCSG can be vertical, stationary, horizontal or rotating, as seen in scheme 34. Dry solids 37 are discharged from the DCSG, after most of the liquid water is converted to steam. The combustion gas and steam 38 temperature can vary between 120C to 300C. The pressure can vary between 1bar and 50 bar. The solid lean gas is injected into vessel 41, where the gas is washed with saturated water 42 to remove the solids remnants. The water can include lime for removal of sulfur gas. Make-up water 47 can be added to the vessel 47. Solid rich water, possibly with gypsum (generated from the reaction between the sulfur and the lime), is continually removed from the bottom of vessel 41. It is recycled back to the DCSG, where the solids are removed in a dry or semi-dry form 37. The liquid water is converted back to steam 38. The solids - free saturated steam and combustion

gases 43 flow to a second vessel 45. In this vessel, the steam condensates to liquid water 44. Then, it is cooled due to direct contact heat exchange with the BFW (Boiler Feed Water). Water 21 is generated by the water treatment facility 1 and partially generated by the ion-exchange system 19. The heated water, 22 can be sent back as pre-heated BFW to the OTSG, to generate 80% quality steam, or it can be recycled back to water treatment facility 40, where it is added to de-oiled produced water 10.

[90] FIGURE 9 is a schematic of an integrated facility with a commercially available steam generation facility 1, for open mining oilsand facility 60. The steam for the bitumen extraction is generated with commercially available boilers 17 that include steam and mud drums. The water for steam generation is produced using a standard, commercially available water treatment facility that is based on ion exchange and polishers. Raw water 3 flows to the de-mineralized water clarifier and filter 2. The filtered water 6 flows to a cation reactor and de-gasifier 7. The water then flows to anion reactor 11. From the anion reactor, it goes to a mixed bed polisher 14, to generate de-mineralized BFW quality water 16. Chemicals are continually supplied during the process, to remove minerals. In the process, reject and backwash water is continually generated 5, 9, 12, 15. The reject water contains minerals and water treatment chemicals. The reject water is collected and injected into the vertical up-flow, cold fluid bed, direct contact steam generator 30. Fuel 27 and oxidizer are injected to the bottom of fluidized bed steam generator 30. The water 26 is sprayed into the steam generator 30, above the combustion zone. The sprayed water is composed of: water treatment facility 1 reject water, boiler blow-down water 22, and reject water 47 from oilsand mine extraction facility 60. The reject water includes tailing water and possibly hydrocarbon contaminants. The liquid water is converted to steam and carries most of the solids upwards, where they are discharged at the top of the vessel as a solid - rich stream of gas 31. Some of the cooler discharged gas, at a temperature range of 150C-400C, is recycled back to the bottom of the vertical steam generator 30 to maintain the cold fluid bed below the combustion zone. This reduces the temperature and increases the up-flow stream in vessel 30. Solids 36 are removed in dry form from the solid - rich gas flow 33. The solid lean gas flow 35 is washed in tower 38 with saturated water to remove any solid remnants. Sulfur gas can be removed as well with the use of lime.

After most of the solids have been removed, the solid rich water is recycled back to steam generator 30. Make-up water, possibly with alkali material like lime stone, is added to vessel 38 to maintain saturated liquid water level. The saturated stream of steam and NCG 40 flows to vessel 42, where heat is recovered using direct - contact cold water circulation 43. The recovered heat goes in through liquid heat exchanger 44. The heat increases the temperature of the treated BFW (Boiler Feed Water) in steam generation facility 1. The heated BFW temperature can be in the range of 70C-200C, depending on the partial steam pressure of vessel 42. The heated BFW 23 is fed to the boiler steam generator 17 to generate high pressure steam for the oil sand mine and bitumen extraction facility 60. The condensate 45 can also be used directly as process water in facility 60.

[91] FIGURE 10 is a schematic of the integrated facility of the present invention for open mine oilsand extraction plant 60, using commercially available steam generation facilities, and a gasifier for syngas generation. The steam for bitumen extraction can be generated using a commercially available boiler 12, an OTSG 20, or a gasifier 54. The steam boiler 12 and the gasifier 54 generate steam from BFW water 9. The steam is used for heating purposes, through heat exchangers in a closed cycle. This minimizes the size of the heat treatment facility 1 required for generating high quality BFW, as it will have to produce only start-up and make-up water. The water treatment plant 1 for the generation of BFW is a commercially available package. The water 2, for production of BFW in the water treatment package is fresh water (not processed water from bitumen extraction 60). For example, river water without oil traces can be used. The BFW 16 is fed to the steam boiler 12 facility. Some of the BFW 11 is fed to the gasifier unit 54. The produced steam 15 from the steam boiler 12 and from the gasifier 55 is fed to oil extraction plant 60 to heat the processed water. The condensed water 17 is recycled back from oilsand plant 60, as a BFW to be re-used in the boiler 12 and the gasifier 54. The oilsand extraction facility requires processed steam as well. The processed steam is used in direct contact with the process flow; for example, it is used for froth de-aeration or for flashing out light carbons and diluent. The steam generated through OTSG can use a much lower quality water than boiler 12 and gasifier 54. The generated 80% steam 29 is separated in separator 30 to generate 100% steam 31 and blow-down water 18. The 100% steam and the blow-down

water 18 are both used in the oilsand open mine facility 60. The blow-down water 18 is mixed with process water from facility 60, with the pressure dropping, to generate processed hot water at 80-90C for tar separation. Some processed water 19 from facility 60 can be sent to water treatment plant 24. The use of fresh water, 27 instead of the processed water 19, is preferable so as to reduce the water treatment plant 24 requirements as it eliminates the oil removal stage. The water treatment plant is tailor - made to the quality of the source water. If fresh river water is used, the plant, 24 would be very simple, as the OTSG can use this type of water with minimum treatment (I.e.- treatments like filtering, oxygen removal and adding anti-scaling additives). If the water used by the water treatment plant is processed water, then the water treatment system 24, will be similar to a typical water treatment plant used in EOR facilities, like SAGD, as described in Fig. 8. The gasifier 54 can be any type that is commercially - available. The use of a gasifier with a water quenching bath is preferable. That is because the integration of gasifier 54 with DCSG (Direct Contact Steam Generation) 46 eliminates the problem of treating the "black" and "grey" water 45. This, in turn, is because the gasifier quenching water 45 is converted to steam and the solids are discharged in a dry form and are ready for the landfill. Water - quenching gasifiers have been developed by Texaco from the 1950's. Currently, they are available from GE. The gasifier 54 uses oxygen enriched gas 56 and carbon fuel 57. The carbon fuel can be petcoke or coal slurry. In the gasifier, the exothermic reaction heat generates high pressure steam 55 from BFW 11. The gasifier can replace the industrial boiler 12 as the high quality steam producer where all the treated BFW 9 will be consumed 11 by the gasifier and the steam 55 will replace the High quality steam 15. The pressurized hot discharged syngas 47 flows to DCSG 46, where it is mixed with solid rich water to generate a stream of gas 44 with dry solid discharge 48. The water injected to the DCSG 46 may be the solid rich quenching water from gasifier 54, the concentrated fine tailing water 43 from the oilsand bitumen extraction facility 60, or the recycled saturated water 42. The solids are discharged from the DCSG through pressure chambers 50 and 51, in order to reduce the pressure to atmospheric. Heat exchanger 49 can be used to recover heat from the discharged solids. The solid lean gas flow 44 is treated in vessel 40, where the solid remnants are scrubbed from the gas flow. The liquid water in vessel 40 is saturated so that additional steam is

continually generated. Make-up water 41 is added to vessel 40 to generate a saturated stream of solid - free syngas and steam 39. The make-up water can include the HLS (Hot Lime Softening) sludge from the OTSG water treatment 24. The heat and water is fully recovered from the saturated stream 39 in vessel 37. This is done through direct contact between the treated water 25 and the up-flow saturated gas 39 in vessel 37. The steam is converted to water and washed from the syngas, generating cooler and dryer syngas 36 and hot water 28 that is used in the OTSG 20 to generate 80% steam. To avoid direct use of the water that recovers the heat from the syngas in the OTSG, a heat exchanger can be added (not shown). The syngas is treated using various commercially - available methods in facility 35. Sulfur, mainly H₂S, can be removed from the syngas. Hydrogen can be generated, for use in sweetening the produced oil. The sweet syngas 34, composed mainly of CO, may be used to replace natural gas as the fuel source in the OTSG 20 and steam boiler 12. It can also be used to generate electricity and steam in a co-generation facility (not shown).

[92] FIGURE 11 is a schematic of the invention with an open mine oilsand extraction facility, where the hot process water for the ore preparation is generated by recovering the heat and condensing the steam generated from the fine tailings and the combustion gases. A typical mine and extraction facility is briefly described in block diagram 1 (See "Past, Present and Future Tailings, Tailing Experience at Albion Sands Energy" presentation by Jonathan Matthews from Shell Canada Energy on December 8, 2008 at the International Oil Sands Tailings Conference in Edmonton, Alberta). Mined Oil sand feed is transferred in trucks to an ore preparation facility, where it is crushed in a semi-mobile crusher 3. It is also mixed with hot water 57 in a rotary breaker 5. Oversized particles are rejected and removed to landfill. The ore mix goes through slurry conditioning, where it is pumped through a special pipeline 7. Chemicals and air are added to the ore slurry 8. In the invention, the NCGs (Non Condensed Gas) 58 that are released under pressure from tower 56 can replace the injected air at 8 to generate aerated slurry flow, or its compression energy can be recovered (by an expander) to compress air that can be used at 8. The conditioned aerated slurry flow is fed into the bitumen extraction facility, where it is injected into a Primary Separation Cell 9. To improve the separation, the slurry is recycled through floatation cells 10. Oversized particles are removed

through a screen 12 in the bottom of the separation cell. From the flotation cells, the coarse and fine tailings are separated in separator 13. The fine tailings flow to thickener 18. To improve the separation in the thickener, flocculant is added 17. Recycled water 16 is recovered from the thickener and fine tailings are removed from the bottom of thickener 18. The froth is removed from the Primary Separation Cell 9 to vessel 21. In this vessel, steam 14 is injected to remove air and gas from the froth. The recovered froth is maintained in a Froth Storage Tank 23. The steam can be produced in a standard high pressure steam boiler 40, in OTSG, or by a COGEN, using the temperature in a gas turbine tail (not shown). The boiler consumes fuel gas 38 and air 39. The coarse tailings 15 and the fine tailings 19 are removed and sent to tailing processing area 60. The fine and coarse tailings can be combined or removed and sent separately (not shown) to the tailing process area 60. In unit 60, the sand and other large solid particles are removed and then put back into the mine, or stored in stock-piles. Liquid flow is separated into 3 different flows, mostly differing in their solid concentration. A relatively solids - free flow 62 is heated. This flow is used as heated process water 57 in the ore preparation facility, for generation of the oilsand slurry 6. The fine tailings stream can be separated into two sub streams. The most concentrated fine tailings 51 are mixed with dry solids, generated by the DCSG, to generate a solid and stable substrate material that can be put back into the mine and used to support traffic. The medium concentrated fine tailing stream 61 flows to DCSG facility 50. Fuel 46 and oxidizing gas 47 are used in the facility to generate a hot combustion gas. The combustion can be at full or partial combustion (like in a gasifier). Some of the combustion energy in facility 50 can be used to generate "standard" steam in a heat exchanger (like in a boiler or gasifier with a radiation heat exchange section). The discharged combustion gas energy is used to convert the fine tailing 61 water into a dry or semi dry solid and gas stream. The temperature of the discharged solid - rich gas can vary from 150C to 400C. The solids are separated from the gas stream in any commercially available facility 45 which can include: cyclone separators, centrifugal separators, mesh separators, electrostatic separators or other combination technologies. The solids lean gas 52 flows into tower 56. The gas flows up into the tower, possibly through a set of trays, while the solid carried-on remnants are scrubbed from the up flowing gas through direct contact with liquid water. The water vapor that was

generated from heating the fine tailing in the DCSG is condensed and is added to the down-flowing extraction water process 57. The presence of small amounts of remaining solids in the hot process water can be acceptable. That is because the hot water is mixed with the crushed oilsand 3 in the breaker during ore preparation. The temperature of the discharged hot water 57 is between 70C and 95C, typically in the 80C-90C range. The hot water is supplied to the ore preparation facility. The separated dry solids from the DCSG are mixed with the concentrated slurry flow from the tailing water separation facility 60. They are used to generate a stable solid waste that can be returned to the oilsand mine. Any commercially available mixing method can be used in the process: a rotating mixer, a Z type mixer, a screw mixer, an extruder or any other commercially available mixer. The slurry 51 can be pumped to the mixing location, while the dry solids can be transported pneumatically to the mixing location. The NCG (Non Condensed Gases) 58 that were not condensed by the process water, are discharged from the top of the tower 56. It replaces the air and can be injected into the slurry at 8 for aeration. It can also be expanded on a turbo expander to recover excess energy. Furthermore, it can be treated to remove gas fractions (for example, recover CO₂ for EOR or sequestration). Otherwise it can just be released to the atmosphere. The described arrangement, where the fine tailings are separated into two streams 61 and 51, is intended to maximize the potential of the process to recover MFT. It is meant to maximize the conversion of fine tailings into solid waste for each weight unit of the supplied fuel source. The system can work in the manner described for tailing pond water recovery. The tailing pond water is condensed into hot water generation 57, without the combination of the dry solids 53 and tailing slurry 51. The generated dry solids 53 are a "water starving" dry material. As such, they are effective in the process of drying MFT (Mature Fine Tailing), to generate trafficable solid material without relying on weather conditions to dry excess water. The water affinity of the dry solid composite released from the DCSG 50 is dependent on its composition and particle size. The most effective water affinity material is a solid that, with the presence of water, creates crystals with water molecules. Gypsum belongs to this group of materials. If highly sulfurous material fuel is used in the DCSG (like petcoke), lime can be added to remove the SO₂ and generate gypsum. The gypsum will lose its crystal water when it is subjected to the high temperatures inside the DCSG, as its water

will be converted to steam. This will improve the ability of the dry discharged solids to solidify a MFT slurry to a stage where it can carry traffic. (See U.S. Patent No. 6,960,308 called "Endothermic Heat Shield Composition And Method For The Preparation Thereof" , issued to the inventor on November 1, 2005).

[93] FIGURE 11A describes a system and method for generating hot process water through a direct contact heat transfer without the use of a DCSG. The use of a DCSG is required if FT removal in solid form is advantageous. If there is no requirement to remove the FT / MFT (like in the case where other reclamation methods to resolve the MFT problem will prove to be effective, cost-effective and accepted by the regulators), then a simplified method and system, without the use of DCSG, as described in FIG.11A, can be used with a few significant advantages. The main advantage of such a facility, compared to prior art methods for production of hot water for oilsand bitumen extraction are: The overall thermal efficiency in the system described in FIG.11A is higher in comparison to the prior art used in the oilsand mine facilities (that includes boiler systems generating steam to heat the process water). The high efficiency will result in a reduction in the amount of CO₂ generated. Another advantage is the use of a solid low grade fuel like petcoke and coal, instead of clean valuable natural gas. Another advantage is the simplification of the scrubbing system. This is an advantage as compared to boiler systems that operate on a sulfur rich solid fuel like petcoke and coal for generate steam with in-direct heat exchangers, as used in power plants, for example. The discharged combustion gas should be treated to remove SO₂ remains and solid particles (fling ash) before releasing it to the atmosphere. In power plants, this is done using lime stone, possibly with the fuel or after the combustion as a means to scrub the SO₂ and with bag filters and electric static precipitators after the cyclone separators in order to remove the dust to bring it to acceptable levels. In the present facility, there will be no need to use extensive scrubbers and filters beyond, maybe a basic cyclone separator, as the process water used for the oilsand extraction will wash the combustion from the tracers of SO₂ gas and the small solids particles. The small amount of solids, like fly ash, will not have any significant negative impact on the process water. The pH might be affected by small traces of acid gas and can be adjusted as part of the extraction process with additional alkaline material. Because the process waters

are much less sensitive to contamination than the environment (as they are mixed with dirty oilsand ore) the scrubbing system will be minimal, if it exists at all, with an associated low cost compared to a scrubbing system for releasing combustion gases to the environment. The process includes crushing fuel 60, like petcoke, together with lime stone 61 and water 62 to generate a pumpable slurry 59; mixing the fuel slurry together with compressed air 57; combusting the mixture under pressure to generate pressurized combustion gas 1 and heat (the combustion can be performed in a fluidized bed where the compressed air 57 is supplied from the bottom as described in FIG. 11A); recovering at least a portion from the combustion heat through a heat exchanger inside the boiler 55 to generate steam 51; directing a stream of a cool process water 30, possibly from the upper layer of a tailing pond 47 or from any other available water source 16 and mixing the process water with the pressurized combustion gas 1 to recover the combustion gas heat while heating the process water 33; directing the hot process water 33 to the oilsand extraction facility (AREA 1) and mixing it with oilsand ore 3 to generate slurry 6; and separating the water and solids (16 and 19) from the bitumen 23. The solids generated by the pressurized boiler resulting from the supplied fuel and the lime stone (or dolomite) supplied to the combustor, can be removed and mixed with MFT to accelerate its stabilization (as shown in FIG. 13). If required, an additional solid separation unit can be added to separate solids from the pressurized combustion gas 1 (not shown). The facility in AREA 2 can be any commercially available Pressurized Boiler that generates high pressure steam and pressurized combustion gases (see Handbook of Fluidization and Fluid-Particle Systems by Wen-Ching Yang, Chapter 15- Applications for Gasifiers and Combustors by Richard A. Newby; paragraph 3.3.3 Coal Fueled PFBC). Examples for pressurized boilers are the Pressurized Internally Circulating Fluidized-bed Boiler (PICFB) developed by Ebara, and the Pressurized-Fluid-Bed-Combustion-Boiler (PFBC) developed by Babcock-Hitachi. Any other pressurized combustion boiler that can combust petcoke or coal can be used as well. The oilsand mine and extraction facility in AREA 1 is a prior art facility described in FIG. 11. AREA 3 includes a tailing pond (see FIG.12). Some small amounts of MFT (in comparison to the MFT amounts that are consumed by the DCSG, as described in the other examples) can be dried and stabilized with the use of the combustion solids (not shown). The cold process water is heated by direct

contact with up-flow combustion gas in a pressurized vertical vessel 31, which can include internal trays. These types of vessels are widely commercially available. The pressurized cold and clean pressurized combustion gas 32 (after it was scrubbed by the process water) can be released to the atmosphere, or used in the extraction process, or for generating energy through a turbo expander, or to recover the CO₂ with a commercially available membrane gas separation facility (not shown).

[94] FIGURE 12 is a schematic of the invention with an open mine oilsand extraction facility, where the hot process water for the ore preparation is generated from condensing the steam produced from the fine tailings. As in Fig. 11, a typical mine and extraction facility is briefly described in block diagram 1. The tailing water from the oilsand mine facility 1 is disposed of in a tailing pond. The tailing ponds are built in such a way that the sand tailings are used to build the containment areas for the fine tailings. The tailing sources come from Extraction Process. They include the cyclone underflow tailings 13, mainly coarse tailings and the fine tailings from the thickener 18, where flocculants are added to enhance the solid settling and recycling of warm water. Another source of fine tailings is the Froth Treatment Tailings, where the tailings are discarded by the solvent recovery process- characterized by high fines content, relatively high asphaltene content, and residual solvent. (See "Past, Present and Future Tailings, Tailing Experience at Albion Sands Energy" a presentation by Jonathan Matthews from Shell Canada Energy on December 8, 2008 at the International Oil Sands Tailings Conference in Edmonton, Alberta). A sand dyke 55 contains a tailing pond. The sand separates from the tailings and generates a sand beach 56. Fine tailings 57 are put above the sand beach at the middle-low section of the tailing pond. Some fine tailings are trapped in the sand beach 56. On top of the fine tailing is the recycled water layer 58. The tailing concentration increases with depth. Close to the bottom of the tailing layer are the MFT (Mature Fine Tailings). (See "The Chemistry of Oil Sands Tailings: Production to Treatment" presentation by R.J. Mikula, V.A. Munoz, O.E. Omotoso, and K.L. Kasperski of CanmetENERGY, Devon, Alberta, Natural Resources Canada on December 8, 2008 at the International Oil Sands Tailings Conference in Edmonton, Alberta). The recycled water 41 is pumped from a location close to the surface of the tailing pond (typically from a floating barge). The fine tailings that are

used for generating steam and solid waste in my invention are the MFT. They are pumped from the deep areas of the fine tailings 43. Fuel 48 and oxidizing gas 49 are injected into a DCSG. MFT 43 is pumped from the lower section of the tailing pond and is then directed to the DCSG 50. The DCSG described in figure 12 is a horizontal, counter flow rotating DCSG. However, any available DCSG that can generate gas and solids from the MFT can be used as well. Due to the heat and pressure inside the DCSG, the MFT turns into gas and solids as the water is converted to steam. The solids are recovered in a dry form or in a semi-dry, semi-solid slurry form 51. The semi-dry slurry form is stable enough to be sent back into the oilsand mine without the need for further drying to support traffic. The produced steam 14, needed for extraction and froth treatment, is generated by a standard steam generation facility 36 from BFW 37, fuel gas 38 and air 39. The blow-down water 20 can be recycled into the process water 20. By continually consuming the fine tailing water 43, the oil sand mine facility can use a much smaller tailing pond as a means of separating the recycled water from the fine tailings. This smaller recyclable tailing pond is cost effective, and it is the simplest way to do so as it does not involve any moving parts (in contrast to the centrifuge or to thickening facilities). This solution will allow for the creation of a sustainable, fully recyclable water solution for the open mine oilsand facilities.

[95] FIGURE 12A shows the integration of a parallel flow DCSG with a direct contact process water heater and with solid discharge force oxidation. Fuel 76, like petcoke that includes high levels of sulfur, is injected with oxidizing air 75 into a parallel flow DCSG. Low quality water that can include large percentage of organics 77 is injected into the DCSG. MFT 43 is also injected to the DCSG. The DCSG includes Direct Contact heat transfer section, with chains that improve the heat transfer and break solid deposits inside the reactor. The DCSG pressure is in the range of 103kpa-5,000kpa. The solids are discharged by a screw as a semi-solid, concentrated material. Lime Stone is added to the DCSG water feed (77 and 43) to react with the generated SO₂. The generated Calcium Sulfite will be forced to oxidize with air 78 and water to generate gypsum at mixer 710. Possible mixers types that can be used were mentioned in Fig.11. Screw conveyor 710 with air supply 78 can be used as well. If required, more water can be added in the form of MFT 43. The discharged solids will be stable enough to support traffic. The combustion gas and steam 717 will be mixed in direct contact heat exchange

with the process water, which can be supplied from the tailing pond 41 or from the operating oilsand facility 50. The hot process water, that includes the condensed water from the MFT, is supplied to the oilsand plant for mixing with the oilsand ore.

[96] FIGURE 13 is a schematic of gasifier unit and an open mine oilsand extraction facility, where the hot process water is heated in direct contact with the syngas. In this figure, the MFT 33 is not converted into steam and solids, but is mixed with the dry solids generated by the system 15. Gasifier 5, with a water quenching bath at its bottom, generates HP (High Pressure) steam 3 from BFW 4 that is supplied from water treatment plant (not shown). The gasifier generates syngas from partial combustion of low grade fuel, like petcoke or coal 1. The hot syngas is mixed with water in an up-flow direct contact steam generator 10. (Refer to U.S. provisional patent application 61/092,668, filed by the inventor on August 28, 2008 and Canada patent application 2,676,720 filed by the inventor on August 28, 2009). The dry solid particles are removed from the gas flow with a cyclone and electrostatic separator or with any commercial separation package 16. The solid lean syngas stream flows to vessel 23, where it is mixed in direct contact with cold extraction water 27 to heat the water to 80C-90C. The hot process water 24 is used in the ore preparation facility 40. The dry solids 15, generated by gasifier 5, are mixed with MFT 33 which is then pumped. It is removed from the tailing pond to generate a stable material that can be used to support traffic. In the process, water from the MFT is not recovered, or used to generate steam or hot process water. This arrangement is less effective in recovering MFT, but easier to implement. It can only be implemented if removal and reclamation of MFT will be done using other methods, and not with DCSG.

[97] FIGURE 14 is a schematic of the invention with open mine oilsand extraction facility, where the hot process water for the ore preparation is generated from condensing the steam generated from the fine tailings. The tailing water from the oilsand mine facility 43 (not shown) is disposed of in a tailing pond. Fuel 3, possibly petcoke, coal or asphaltin slurry, and oxidizer 4 (possibly air) are fed into and then combusted inside a horizontal parallel flow DCSG 1. Concentrated MFT 2 is injected into the DCSG as well. The MFT is converted to gas, steam, and solids. The solids are removed in a solid gas separator 7 where the solid lean stream is washed in tower 10 by saturated water. In the tower, the solids are washed out and then

removed. SO₂ can be removed from the saturated water using lime. The solid rich discharge flow 13 can be recycled back to the DCSG or to the tailing pond. The amount of heat recovery is limited in order to maintain heat exchanger 17 at a reasonable size. Heat is recovered from saturated gas 16. Steam is condensed to water 20. The recovered heat can be used for pre-heating the BFW (not shown) or for use in any other process. The condensed water 20 can be used as hot process water and can be added to the flow 24. The remaining heat is recovered and the water vapor is washed. It condenses to liquid water in vessel 21 because of direct contact with cold process water 25. The NCG 36 can be used as part of the process for slurry aeration or for reducing the pH in the tailing water (not shown). The fine tailings 32 are pumped from the tailing pond and separated into two flows by a centrifugal process 14. This unit separates the fine tailings into two components: solid rich 30 and solid lean 33 flow. The centrifuge unit is commercially available and was tested successfully in two field pilots (See “The Past, Present and Future of Tailings at Syncrude” presentation by Alan Fair from Syncrude on December 7-10, 2008 at the International Oil Sands Tailings Conference in Edmonton, Alberta). Other processes, like thickening the MFT with chemical polymer flocculent, can be used as well instead of the centrifuge. The solid lean flow can contain less than 1% solids. The solid rich flow is a thick slurry (“cake”) that contains more than 60% solids. The solid lean flow is recycled back to a settling basin (not shown) and eventually used as process water 35. The solid concentration is not dry enough to be disposed of efficiently and to support traffic. This can be solved (shown in my invention) by mixing it with the “water starving” material (virtually dry solids generated by the DCSG) possibly with calcium sulfite and calcium sulfate. Mixing of the dry solids and the thick slurry can be achieved through many commercially available methods, as mentioned in Fig. 11. In this particular figure, the mixture is done by a screw conveyer 29 where the slurry 30 and the dry material 8 are added to the bottom of a screw conveyor, mixed by the screw, and then the stable solids are loaded on a truck 28 for disposal. The produced solid material 27 can be backfilled into the oilsand mine excavation site and then used to support traffic. In this particular figure, there are two options for supplying the fine tailing water to the DCSG: one is to supply the solid rich thick slurry 30 from the centrifuge or thickening unit 31. The other is to provide the “conventional” MFT, typically with 30% solids,

pumped from the settlement pond. Feeding the MFT "as is" to the DCSG eliminates the TIC, operation, and maintenance costs for a centrifuge or thickening facility. For option 1, the overall amount of recovered MFT will be larger, while the heat efficiency and the amount of heat recovered from each ton of fuel will be smaller (and vice versa for option 2).

[98] FIGURE 15 is a schematic of the invention with an open mine oilsand extraction facility, where the heat source is a gasifier with maximization of the MFT recovery (in comparison to Fig. 13). The partial combustion takes place inside the gasifier. The hot syngas 5 flows to the horizontal parallel flow DCSG 1. Concentrated MFT 2 is also injected into the DCSG. The MFT is converted to gas, mainly steam, and solids 6. The solids 8 are removed in a solid gas separator 7. The solid lean stream flows through heat exchanger 11, where it heats the process water or any other process flow 12, indirectly through a heat exchanger. Sour condensing water 13 is removed from the bottom for further treatment. The syngas 17 is also treated further. This treatment can include the removal of the H₂S in an amine plant. It can also include generating a hydrogen and CO based gas to replace the natural gas (not shown). The fine tailings 14 are pumped from the tailing pond and can then be separated into two flows through a specific separation process. Separation 15 is one option to increase the amount of MFT removal. The process can use natural MFT both at flows 2 and 16. This separation can be based on a centrifuge or on a thickener (like a High Compression Thickener or Chemical Polymer Flocculent based thickener). This unit separates the fine tailings into solid rich 16 and solid lean 2 flows. The solid lean flow is fed into the DCSG 1 where dry solids are generated and removed from the gas-solid separator. The solid rich flow 16 is mixed with the dry solids 8 in a screw conveyor to generate a stable material 27.

[99] FIGURE 16 is a schematic of the invention with an open mine oilsand extraction facility, where the hot processed water for the ore preparation is generated from direct contact heat exchange between the process water, the condensing steam generated from the MFT, and the combustion gas. The tailing water from the oilsand mine facility 43 disposed of in a tailing pond. Fuel 5 (possibly petcoke, coal, or asphaltin slurry) and air 6 is injected into and then combusted inside a horizontal counter flow DCSG 7. MFT flow 9 is injected into the DCSG. The MFT is converted to gas, mainly steam, and solids. The solids are directly removed from the

DCSG. The solid lean discharge stream 10 is washed in tower 13 by saturated water. In the tower, the solids are washed out and removed. SO₂ is removed using lime. The solid - rich discharge flow 11, with the generated calcium sulfite and calcium sulfate, is recycled back to the DCSG 7. The steam saturated gas 15 flows to vessel 20, where it is mixed with the cold process water 22 recycled from the tailing pond. The generated hot water is used in ore preparation unit 40. The pressurized NCG from vessel 20 can be used in the process (not shown) or expanded on a turbo expander 18 to recover part of the energy used for compressing the oxidizing air 18. The fine tailings 25 are pumped from the tailing pond. They can be separated into two flows by a centrifuge or thickening process or used in their natural form without any treatment 23. This centrifuge or thickening unit separates the fine tailings into a solid rich flow 9 and a solid lean flow. The centrifuge and thickening units are commercially available. The solid lean flow is recycled back to process water 22. The solid concentrated flow 9 is mixed with the dry solids 4 to generate a stable disposal material.

[100] FIGURE 16A is a schematic of the present invention with a parallel flow DCSG. A typical oilsands mine and extraction facility is briefly described in block diagrams 1 and 2 (see Fig. 11)

[101] The oilsand plant generates a flow of tailings 50 and cold process water 40. For its operation, the plant mainly consumes the process water after it has been heated-up to 70C-90C. The tailing 50 includes a portion of stable FT (Fine Tailings) that will be pumped from the deep locations of the tailing pond. Fuel 76 and oxidation gas 75 are injected into a vertical parallel flow DCSG 71. FT 77 is injected into the DCSG. Chains are used to improve the heat transfer and to remove solids deposits. FT can be injected into the DCSG near the discharge side. FT flow 723 is injected in order to control the discharge temperature, for dust control, and to exactly control the moisture content of the solids discharge. The solids 718 can be removed from the system using a single or double extruder type design or any other controlled way that can mobilize the stable solids. The removed solids are trucked out to be used as re-fill and to support traffic. The DCSG can also include a solid removal cyclone on the steam and combustion gas discharge 717. The discharged gas is washed in vessel 51 to remove SO_x, NO_x, and any solid remains. Make-up water 54 is continually added to vessel 51, possibly with an

alkali chemical like Lime stone slurry to remove the SO₂. The generated solids, with the lime stone remains that didn't react with the SO₂, are recycled back to the DCSG together with the FT, where they can complete their reaction with the SO₂. The make-up water is taken from the hot process water 57. The solids free and SO₂ free (traces levels of sulfur oxides will remain even after the two stages of SO₂ removal in the DCSG 71 and in the scrubber 51) saturated gas flow 52 will flow to vessel 56 (a counter flow direct contact heat exchanger between the cold process water 40 that is spread at the top of the vessel and the up-flow saturated steam and combustion gas 52). The saturated steam (from the FT) condenses with the process water. The hot process water 57 supplied back to the oilsand extraction plant.

[102] FIGURE 17 is a schematic of the invention with an open mine oilsand extraction facility, where the hot process water for the ore preparation is generated from condensing the steam generated from the MFT and from cooling the combustion gas through an indirect heat exchanger. Fuel 3 and oxidizer 4 are mixed and combusted inside a horizontal parallel flow DCSG 1. MFT 2 is also injected into the DCSG. The MFT is converted to gas, mainly steam, and solids. The injected MFT can include lime stone or HLS sludge from OTSG facilities, like SAGD. The calcium will react with the SO₂ to reduce the amount of SO₂ in the DCSG discharge. The solids are removed in a solid gas separation 7. The solid lean stream is washed in tower 10 by discharged tailing water from the oilsand extraction facility. This tailing water collects the heat from the up-flow gas and the condensed saturated water 17. The hot tailing water 13 exchanges heat in heat exchanger 12- where the water heats the cold process water while cooling the tailing water. The cooled tailing water 15 is directed to the tailing pond where its acidity (especially due to the SO₂ gas remains from the fuel combustion) might accelerate the steeling time for the fine tailings, thus decreasing the tailing pond size. The hot process water is used for the ore preparation. The pressurized NCG 17 can be used for aerating the slurry or for expansion on a turbo expander for producing energy, as described in previously figures. The amount of SO₂ in the discharged gas 9, even with the use of lime stone slurry with the MFT, will be higher than in, for example, in Figs. 3A and 4 where the SO₂ it is removed in two stages (the calcium that didn't react in the wet scrubber flows backwards to the DCSG). This option, for increasing the acidity of the tailing pond using SO₂ (and to a much smaller extent, with the high

level of CO₂ presence in the DCSG combustion gases) can be used with the previous Figures. However, even if the acidity will accelerate the FT separation, it will be required to remove the acidity from the recycled process water before it is reused (to bring it to a pH that is only slightly caustic) and to investigate the environmental impacts of acid tailing ponds.

[103] FIGURE 18 is a schematic view of the invention with an open mine oilsand extraction facility and a prior art commercially available pressurized fluid bed boiler that used combustion coal for power supply. Examples of pressurized boilers are the Pressurized Internally Circulating Fluidized-bed Boiler (PICFB) developed and tested by Ebara, and the Pressurized-Fluid –Bed-Combustion-Boiler (PFBC) developed by Babcock-Hitachi. Any other pressurized combustion boiler that can combust petcoke or coal can be used as well. AREA #1 is a prior art Pressurized Boiler. Air 64 is compressed 57 and supplied to the bottom of the fluid bed combustor to support the combustion. Fuel 60, like petcoke is crushed and grinded, possibly with lime stone 61 and water 62, to generate pumpable slurry 59. The boiler includes internal heat exchanger 63 to generate high pressure steam 51. Dry fuel 54 can be fed to the pressurized boiler through dry feeding system 53 which includes a set of pressurized chambers. The steam 51 is generated from steam boiler drum 52 with boiler water circulation pump 58. The boiler heat exchanger 63 recovers energy from the combustion. BFW 65 is fed to the boiler to generate steam 51. The steam can be used in the bitumen plant for various uses like flashing solvent and traditional heating of the produced water. The boiler generates pressurized combustion gas 1 at a pressure of 103kpa and up to 1.5mpa and temperatures of 600C-900C. The discharge flow can include a cyclone (not shown) to recycle unburned fuel back to the fluid bed. The cyclone will be simple compared to the solid separation required in the prior art (see Handbook of Fluidization and Fluid-Particle Systems by Wen-Ching Yang, Chapter 15-Applications for Gasifiers and Combustors by Richard A. Newby; paragraph 3.3.3 Coal Fueled PFBC). The reason is that in the prior art, the hot combustion gas from the PFBC expands on a gas turbine to recover energy and after that it is released to the atmosphere. The gas turbine is sensitive to solid particles (both for abrasive particles and for particles that intend to be deposited on the turbine stators and rotors). The discharge to the atmosphere is even more stringed and will required filter bags or electrostatic separators, together with gas scrubbers, to

remove the SO_xs and the NO_xs to the specified level. In my application there is no need to remove solids from the combustion gas 1 because this gas is fed to the DCSG 3 where additional solids are created (due to the conversion of MFT to solids and gas). Solids from the fluid bed of the PFBC 55 can be recovered to maintain the fluid bed solids level. (This is a common practice in FBC (Fluid Bed Combustion) and PFBC). The solids are directed and added (not shown in FIG. 18) to the solids discharged from the DCSG in lines 4 and 23. The fluid bed solids can be mixed with the DCSG solids and discharged as a stable solid waste 27 that can be back-filled and used to support traffic. The pressurized combustion gases leaving AREA#1 are mixed with MFT 48 and possibly with other low quality waste water and slurry sources, like HLS/WLS sludge produced by SAGD/CSS water treatment plant. Additional lime stone can be added to the DCSG. There are a few designs that can be used as the DCSG 3. The solids in dry form, possibly with small amount of water content to reduce dust problems, are discharged from the DCSG. Another option is to add a solids separator 20 at the DCSG discharge flow line 6. This might not be required if the solids are removed effectively from the DCSG lower section, and especially if they contain a high enough water humidity to control the generated dust. The amount of water required with the discharged solids 27 will be according to the back-fill specification. The maximum amount of humidity in the discharged solids should be allowed as long the solids are stable enough to be transported by standard oilsands mine equipment and support traffic. This will maximize the amount of MFT consumed in the process and minimize possible dust problems. The heat from the combustion NCG and the steam leaving the DCSG 21 is recovered by direct contact heat exchange and condensation with liquid water 13. The hot water from tower 7, with the condensing steam from flow 21, is used by non-direct heat exchange to heat the process water 15 which is used in the oilsand mine ore preparation facility 40 for mixture with the mined oilsand ore. The condensate (that was originally generated from the MFT in the DCSG), that possibly contains low levels of sulfur and nitrogen acids and some solid remains as well, is directed to a tailing pond. The water recovery and thermal efficiency in this scheme is lower than in, for example, the heat and water recovery described in FIG. 12 or FIG. 3A. However, this configuration can be simpler to implement and less sensitive to solids, acids and other contaminations in the generated gas. If the levels of contamination in the heated

scrubbing water 9 are acceptable for use in the ore preparation facility, the heated scrubbed water can be directed there 49, as described in FIG. 12. The NCG 12 from direct contact heat exchanger and scrubber 7 can be used in the extraction facility for froth aeration. One possible problem with using it will be the change in pH from caustic to light acidity due to the high percentage of CO₂ in the combustion gas. The impact of that on the extraction and separation process should be further examined and tested. The MFT 46 is supplied to the DCSG 48. Some MFT can be directed and mixed with the extracted solids to increase their humidity content as previously described.

[104] FIGURE 19 is a schematic of the invention. AREA 1 include a prior art extraction facility. (See "Non Segregating Tailings at the Horizon Oil Sands Project" presented by Canadian Natural Resources Limited on December 2008 at the International Oil Sands Tailings Conference in Edmonton, Alberta). Hot water 57 is mixed with oilsand ore (not shown) and hydro transported 11 to PSC (Primary Separation cell) 12. Bitumen Froth is separated from the PSC and after deaeration 14, is supplied to Froth treatment facility (not shown). The water, solids, and bitumen remains are pumped from the bottom of the PSC and directed to the first stage cyclones 17. The water and solids are discharged from the cyclone bottom and directed to NST (Non Segregating Tailing) pump box 24. The water, with some bitumen, flows to the second stage cyclone feed pump box 19 and from there to the second stage cyclones 21. The water and solids from the second stage cyclones are directed to the NST pump box. Water, with bitumen recovered from the second cyclone top 22, together with water, bitumen and solids recovered from the middle of the PSC 26, is directed to a flotation feed pump box and into flotation cells 28. From the flotation cells the bitumen is recovered and recycled back to the PSC and the tailings are recovered and directed to a thickener 34. Process water is recovered from the thickener for reuse. The recovered process water 59, possibly with make-up water from other sources, and recycled water from the tailing pond (not shown) are directed to a heat exchanger where it heats the water using the heat recovered from the DCSG gas discharge. The system is described in FIG. 3A, however, any other configuration, as described in FIG. 2A-D, with internal fired DCSG or external PFBC connected to DCSG, can be used as well. The condensate 52 from the MFT and gasified in the DCSG 4, is recovered and directed to the thickener 34. Any acidity

or solids are diluted and removed in the thickener, and eventually recovered and recycled back as process water. The cold NCG combustion gas, after the steam and the water are recovered, is mixed with the NST (Non Segregating Tailings) to reduce the pH occurring due to the high content of CO₂.

[105] FIGURE 20 is a schematic of an oilsand mine plant of the present invention divided into a few areas. AREA 1 describes a schematic view of an oilsand plant that includes elements from the plant described in FIG. 11 (See "Past, Present and Future Tailings, Tailing Experience at Albion Sands Energy" presentation by Jonathan Matthews from Shell Canada Energy on December 8, 2008 at the International Oil Sands Tailings Conference in Edmonton, Alberta) and the Extraction described in FIG.19 (See "Non Segregating Tailings at the Horizon Oil Sands Project" presented by Canadian Natural Resources Limited on December 2008 at the International Oil Sands Tailings Conference in Edmonton, Alberta). AREA 2 includes a steam generation facility, where water 87 is treated in water treatment facility 81, as described in FIG.9, to generate BFW. The generated steam used in the extraction and bitumen treatment plant for stripping gas, solvent etc. and the fuel used for the steam production in AREA 2 is typically natural gas, to eliminate expensive scrubbing facilities. AREA 4 includes the tailing pond. MFT are recovered from the tailing pond in order to be gasified in direct contact with combustion gases. Some additional MFT can be removed by mixing with the dry solids generated from the combustion and from the evaporation of the MFT when it is exposed to high temperatures. AREA3 is used for transferring the heat from the generated steam rich gas stream 53 to generate the hot process water 57 for mixing it with the oilsands ore. AREA 5 includes a fluidized bed up-flow DCSG. Fuel 31, like petcoke, and oxidizing gas 31, like air, is combusted to generate an up-flow stream of combustion gas. MFT 40 is spread into the upflow combustion gas stream. The solids are supported by circulating up-flow combustion gases 36. Solids 49 and 45 are removed in a dry form where they are further mixed with MFT to prevent dust problems and to remove additional MFT from the tailing pond. There are a few systems and designs that can be used in AREA5, some of them described in other figures of the present invention, like the fired DCSG in FIG. 12A or the PFBCB of FIG. 18. The PFBCB can replace the

steam generation facility in AREA2, as some of the combustion heat can be used for generating the steam for the extraction and bitumen processing facility of AREA1.

[106] FIGURE 21 is a schematic view of a simulator flow chart of one embodiment of the present invention. The simulation was performed using VMG Sim simulation program and further described in EXAMPLE 1 below.

EXAMPLES

[107] EXAMPLE 1: The following flow table is a simulation of the present invention that was done using a VMG Sim simulation program. Coal feed with high sulfur content in a slurry form, together with compressed air was fed into a Plasma gasifier PG1. The system pressure is 10 bar. The coal flow burned in the process is 1.08 mt/hour. The amount of sulfur in the coal was increased in the simulation to 13.8%, which is more than four times the amount of sulfur in low grade coal, to check the process sensitivity. Some air by-passes the gasifier and is mixed with the syngas to generate additional heat and for full combustion. "Dirty water", composed of pond water and make-up water, is supplied with the lime stone to SX-01 and mixed with the combusted syngas to generate a stream of gases and solids. The "dirty water" flow includes the pond water (MFT) together with the recycled water that includes the solids that by-pass the solid separator and the lime stone solids. The "dirty water" flow is 11.7 mt/hour at a temperature of 81C and has a 24% solids content by weight. The discharge from CRx1, called "Tail Gas", is the discharge from the DCSG, before the removal of the solids (it is different from the DCSG where the solids are removed with some water content to prevent dust as was described in FIG. 3A, for example). Pond water with 23% solids are supplied to the process at rate of 6.9 mt/hour and at a temperature of 25C. "Process water" and lime stone is supplied to SX-01. The "process water" is different from the process water used, after heating, for mixture with the oilsand ore. It can include fine tailings as long they will stay in a liquid form, even after adding the lime stone and the by-pass solids. In another example, the whole stage of SX-01 was eliminated and replaced directly with the "Water Recovery Tower" as described in FIG. 2A, FIG. 12 etc. where the solid remains are scrubbed by the oilsands plant hot process water and the

lime stone is supplied with the petcoke fuel or with the “Pond water” (MFT water that will replace the “Dirty Water” in the present simulation). The dry solids from separator CX-01 are supplied to mixer M1 where they are mixed with additional MFT (and therefore removing additional MFT from the tailing pond) with low pressure air to oxidize the generated CaSO_3 to gypsum and increase the water content in the solids to reduce potential dust while still having a stable solid material that can be used as back-fill and to support traffic. The saturated steam and combustion gas mixture from multi feed separator SX-01, named “Hot Steam Product”, is at temperature of 167C, has a mass flow of 21 mt/hour and includes 52% steam, and the rest is the combustion NCG. The “Hot Steam Product” is directed to the “Water Recovery Tower” where it is washed with “Cold Water”- which is the water supplied from the oilsand mine plant and used, after heated, for the extraction process for mixing with the oilsands ore. The “Cold Water” flow is at a temperature of 20C and has a mass flow of 93.4 mt/hour. The cold “Non Condensable” gases expand on turbo-expander EX1 with an efficiency of 48% and generates 240hp. The “Hot Water” temperature is 90C with a mass flow of 104.3 mt/hour. The additional water in the heated process water is due to the steam condensation from the “Hot Steam Product”, which includes 52% steam. The “Hot Water” is directed to the oilsand plant, where it is mixed with the oilsands ore for extracting the tar. The CO_2 product ratio (defined as the amount of product hot water at 90C) generated per 1 kg of generated CO_2 is 40 [kg $\text{H}_2\text{O}/\text{kgCO}_2$], (without considering the air compression electrical consumption).

/Tail_Gas (Material Stream)				
Prop Pkg: Gasification				
Connections				
Material Inlets				
	Connection	Up Stream Unit Op		
In	CRx1	----		
Material Outlets				
	Connection	Down Stream Unit Op		
Out	CX-01	----		
External Signal Connections				
	Connection	Value		
T [C]	/CN_Reactor_Outlet_T.In	250.1		
Equilibrium Results				
PropName	Bulk	Vapour	Liquid0	
Phase Fract	1.00	0.95	0.05	
T [C]	250.1	250.1	250.1	
P [kPa]	1061.93	1061.93	1061.93	
MoleFlow [kgmole/h]	936.07	885.00	51.08	
MassFlow [kg/h]	23546.63	20216.80	3329.82	
Fraction [Fraction]				
WATER	0.6063	0.6315	0.1687	
CARBON DIOXIDE	0.0625	0.0660	0.0006	
CARBON MONOXIDE	1.32E-05	1.40E-05	6.98E-08	
OXYGEN	0.0052	0.0055	0.0000	
HYDROGEN	4.46E-06	4.71E-06	4.67E-08	
ARGON	0.0035	0.0037	0.0000	
NITROGEN	0.2757	0.2915	0.0011	
ExampleFeedCoal*	0.00	0.00	0.00	
gALUMINUM OXIDE	7.02E-04	2.65E-11	1.29E-02	
gCALCIUM OXIDE	3.41E-04	1.29E-11	6.25E-03	
gDIIRON TRIOXIDE	2.00E-04	7.55E-12	3.66E-03	
gMAGNESIUM OXIDE	1.49E-04	5.62E-12	2.73E-03	
gMANGANESE OXIDE	0.00E+00	0.00E+00	0.00E+00	
gDISODIUM OXIDE	7.88E-05	2.98E-12	1.44E-03	
gSILICON DIOXIDE	0.0373	0.0000	0.6837	
AMMONIA	2.47E-04	2.61E-04	5.22E-06	
HYDROGEN CYANIDE	1.04E-04	1.10E-04	8.19E-06	
CARBONYL SULFIDE	5.85E-04	6.17E-04	2.19E-05	
HYDROGEN SULFIDE	5.80E-04	6.12E-04	1.25E-05	
METHANE	0.00E+00	0.00E+00	0.00E+00	
ETHYLENE	0.00E+00	0.00E+00	0.00E+00	
ETHANE	0.00E+00	0.00E+00	0.00E+00	
PROPANE	0.00E+00	0.00E+00	0.00E+00	
n-BUTANE	0.00E+00	0.00E+00	0.00E+00	
SULFUR DIOXIDE	3.72E-05	3.93E-05	1.69E-06	
SULFUR	0.00E+00	0.00E+00	0.00E+00	
gCALCIUM CARBONATE	0.00E+00	0.00E+00	0.00E+00	
DeGypsum*	0.00E+00	0.00E+00	0.00E+00	
CalciumSulfite*	0.0065	0.0000	0.1189	

TABLE 1

/Hot_Water (Material Stream)				
Prop Pkg: APRNGL				
Connections				
Material Inlets				
	Connection	Up Stream Unit Op		
In	Water_Recovery_Tower	---		
Material Outlets				
	Connection	Down Stream Unit Op		
Out	---	---		
External Signal Connections				
	Connection	Value		
T [C]	/CN_Hot_Water_T.In	90.0		
Equilibrium Results				
PropName	Bulk	Vapour	Liquid0	
Phase Fract	1.00	0.00	1.00	
T [C]	90.0	90.0	90.0	
P [kPa]	1050.00	1050.00	1050.00	
MoleFlow [kgmole/h]	5786.41	0.00	5786.41	
MassFlow [kg/h]	104297.98	0.00	104297.98	
Fraction [Fraction]				
WATER	0.9996	0.0691	0.9996	
CARBON DIOXIDE	3.15E-04	1.73E-01	3.15E-04	
CARBON MONOXIDE	3.66E-10	3.49E-05	3.66E-10	
OXYGEN	1.63E-06	1.38E-02	1.63E-06	
HYDROGEN	3.59E-10	1.18E-05	3.59E-10	
ARGON	1.04E-06	9.34E-03	1.04E-06	
NITROGEN	6.42E-05	7.31E-01	6.42E-05	
AMMONIA	3.93E-05	5.50E-05	3.93E-05	
HYDROGEN CYANIDE	4.12E-07	2.55E-04	4.12E-07	
CARBONYL SULFIDE	2.00E-06	1.50E-03	2.00E-06	
HYDROGEN SULFIDE	1.15E-05	1.68E-03	1.15E-05	
METHANE	1.00E-100	1.00E-100	1.00E-100	
ETHYLENE	1.00E-100	1.00E-100	1.00E-100	
ETHANE	1.00E-100	1.00E-100	1.00E-100	
PROPANE	1.00E-100	1.00E-100	1.00E-100	
n-BUTANE	1.00E-100	1.00E-100	1.00E-100	
SULFUR DIOXIDE	5.82E-06	1.56E-04	5.82E-06	
SULFUR	1.00E-100	1.00E-100	1.00E-100	

TABLE 2

[108] EXAMPLE 2: The following graph is a simulation of the system pressure's impact on the performance of the process as described in Fig. 2. The variable in this process is the system pressure. The heated process water 9 is at a temperature of 90C. The graph below is for the combustion of 1000kg/hour of petcoke as the fuel, in air. The pressure is in bars. The conclusion that can be drawn from the simulation graph is that the optimal pressure for that particular system is in the range of 10bar. Beyond that, the pressure of the recovery, the efficiency increases slightly, but the facility TIC (Total Installed Cost) and operation costs will increase dramatically due to the higher pressure.

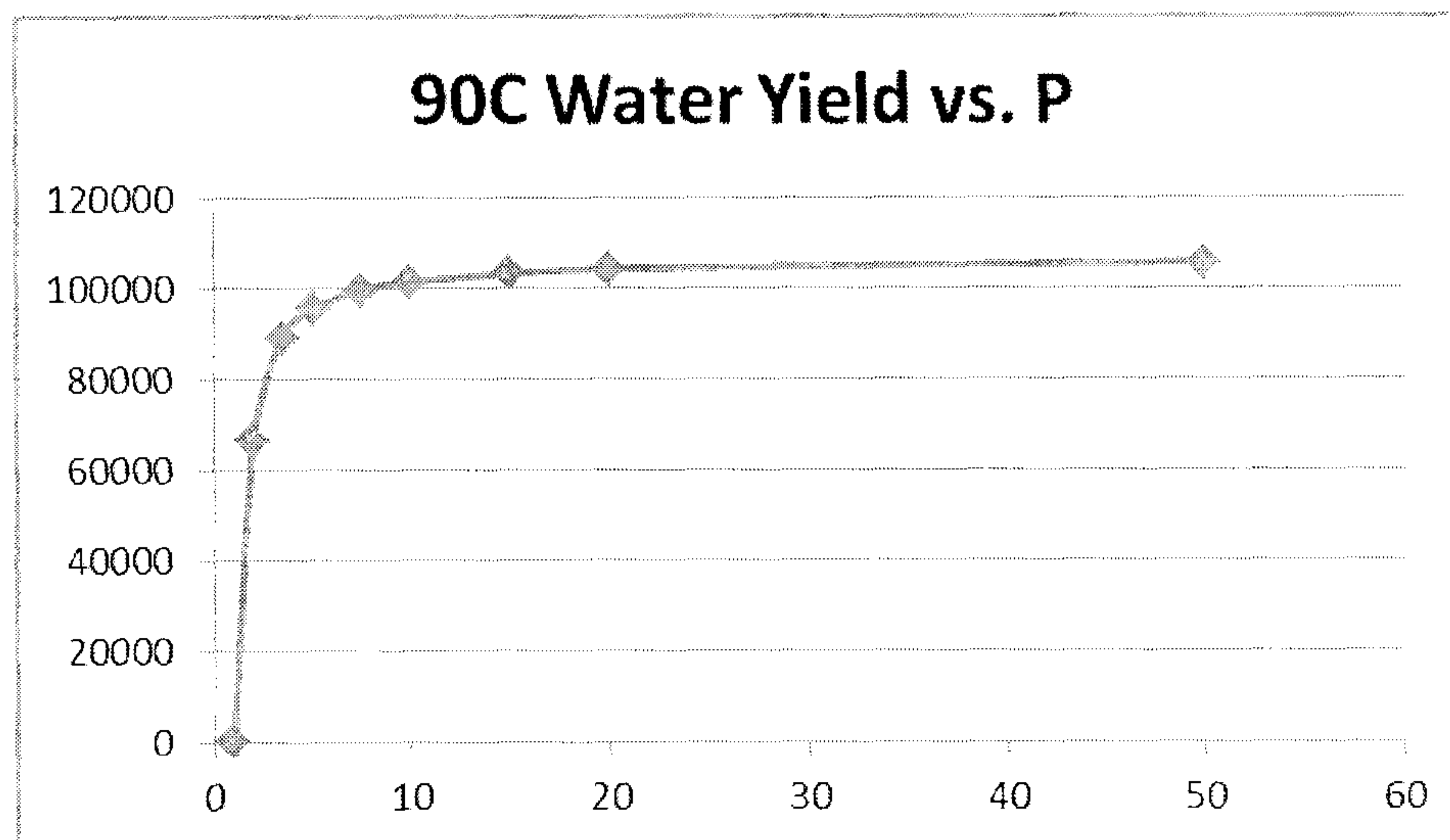


TABLE 3

[109] EXAMPLE 3: The following results show the simulation of a hot water generation system, as described in figure 12. The system pressure is 10bar. The simulation balance was done for 1 ton/hour of petcoke. Flow S-1 on the spreadsheet is stream 43 on figure 12 which is MFT with 23% solid concentration. Flow S-3 is flow 48 on figure 12 which is petcoke fuel. Flow S-2 is flow 49 on figure 12 which is the combustion gas (air). Flow S-6 is flow 47 on figure 12 which is the discharged gas and steam stream from the DCSG. The discharged gas during the simulation was at about 300C. The discharged gas temperature could change the amount of

MFT that is converted to hot water and solid waste per each ton of fuel (or per each ton of generated hot process water). Reducing the DCSG discharged gas temperature will increase the amount of MFT 43 consumed by the DCSG. Stream S-7 is stream 51 on figure 12. 90% of the MFT solids are removed through S-7 and the rest carries on to S-6. It is expected that the discharged solids will include some water. However, to simplify the simulation it is assumed that all the water evaporates. Stream S-8 is the cold process water supplied from the tailing pond 41. It is assumed that the tailing pond recycled water is at 20C. Stream S-10 is the generated hot process water. The heated process water temperature is 90C.

[110] The bottom-line is that, as the simulation results show, for each one ton/hour of combusted petcoke, about 100ton/hour of 90C heated process water is generated. About 12tons/hour of MFT are converted to process hot water and dry solids. This does not include the additional MFT that can be removed by mixing the generated “water starving” dry solids from the DCSG with additional MFT or even with the dewatered centrifuge MFT “cake”.

	S-1 (WATER)	S-2 (AIR)	S-3 (FUEL)	S-5	S-6	S-7	S-8	S-10
T, C	20.00	25.00	25.00	299.73	299.73	299.73	20.00	89.98
Enthalpy, MJ/h	165005.00	-97.30	0.00	165103.70	152754.60	-12349.13	1467370.00	1580274.00
Mass Flowrate, kg/h	12311.00	12527.84	1000.00	25833.84	23281.94	2556.90	92300.00	101463.90
H2O	9470.00	0.00	0.00	9470.00	9470.00	0.00	92300.00	101179.80

TABLE 4

[111] EXAMPLE 4: The following results show a simulation of a hot water generation system, as described in figure 11A, with different system pressures. The simulation balance was done for 1 ton/hour of petcoke. To simplify the simulation and to create a comparison base, it was assumed that all the steam generated in the pressurized boiler was used for heating the process water from 20C to 75C with no heat losses. The results were compared to a “standard” coal fired boiler and natural gas fired boiler at closed conditions. In comparison, a Natural gas boiler is presented in AREA2 in FIG. 11. The CO2 product ratio is defined as the amount of product (hot water at 75C) generated per 1 kg of generated CO2 was found to be as follows:

The ratio for “standard atmospheric coal” boiler was 33.9 [kg H₂O/kgCO₂]

The ratio for the system in FIG11A in different system pressures was as follows:

For a pressure of 103 kpa, the ratio was 34.15 [kg H₂O/kgCO₂]

For a pressure of 2 bar, the ratio was 37.9 [kg H₂O/kgCO₂]

For a pressure of 5 bar, the ratio was 41 [kg H₂O/kgCO₂]

For a pressure of 10 bar, the ratio was 43.25 [kg H₂O/kgCO₂]

The ratio for a standard atmospheric natural gas boiler was 74.9 [kg H₂O/kgCO₂]

The results show that the efficiency of the system in FIG.11A is slightly higher than the efficiency that can be expected if a “standard coal” boiler was used, this is shown even without considering the cleaning facilities required to clean the combustion gas to remove acid gases and flying particles before they can be released to the atmosphere. The efficiency of the natural gas boiler is significantly higher, even when compared to the high efficiency 10bar system. The reason for that is: burning natural gas generates water that contributes a significant amount of the heat energy.

	Flow 64 (Air)	Flow 60 (Fuel)	Flow 61 (Limestone)	Hot water generated from Flow 51	Flow 1 (combustion gas from the pressurized boiler)	Flow 30 (Cold process water)	Flow 32 (NCG)	Flow 33 (Hot process water for tar recovery)	Total hot process water (Flows 33 and 51 combined)
System Pressure: 103kpa Compressor Energy Input: 11.17 KW									
T, C	25.00	25.00	25.00	75.00	800.00	20.00	46.36	75.11	75.11
P, kPa	1.00	103.00	103.00	103.00	103.00	103.00	103.00	103.00	103.00
Vapor Fraction	1.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00
Enthalpy, MJ/h	-71.77	-16081.00	-4809.68	-1162993.00	-33389.09	-817804.00	-51502.73	-799690.00	-1962683.00
Mass Flow rate, kg/h	12672.09	2070.00	250.00	74314.05	14621.72	51500.00	15022.35	51099.37	125413.42
Petcock	0.00	1000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	0.00	1000.00	0.00	74314.05	1000.00	51500.00	1414.42	51085.58	125399.63
CO2	7.70	0.00	0.00	0.00	3671.84	0.00	3670.19	1.65	0.00
O2	2930.56	0.00	0.00	0.00	196.55	0.00	196.54	0.01	0.00
N2	9573.56	0.00	0.00	0.00	9573.56	0.00	9573.31	0.24	0.00
S	0.00	70.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SO2	0.00	0.00	0.00	0.00	6.99	0.00	6.80	0.19	0.00
CaCO3	0.00	0.00	250.00	0.00	12.50	0.00	0.82	11.68	0.00
System Pressure: 2bar Compressor Energy Input: 288.71 KW									
T, C	25.00	25.00	25.00	75.00	800.00	20.00	34.07	75.90	75.90
P, bar	1.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Vapor Fraction	1.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00
Enthalpy, MJ/h	-71.77	-16080.97	-4808.97	-1231313.00	-33395.21	-952781.00	-39998.18	-946178.00	-2177491.00
Mass Flow rate, kg/h	12672.09	2070.00	250.00	78679.63	14621.72	60000.00	14146.83	60474.89	139154.52
Petcock	0.00	1000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	0.00	1000.00	0.00	78679.63	1000.00	60000.00	543.03	60456.97	139136.60
CO2	7.70	0.00	0.00	0.00	3671.84	0.00	3667.09	4.76	0.00
O2	2930.56	0.00	0.00	0.00	196.55	0.00	196.52	0.03	0.00
N2	9573.56	0.00	0.00	0.00	9573.56	0.00	9572.84	0.71	0.00
S	0.00	70.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SO2	0.00	0.00	0.00	0.00	6.99	0.00	6.37	0.62	0.00
CaCO3	0.00	0.00	250.00	0.00	12.50	0.00	0.74	11.76	0.00
System Pressure: 5 bar Compressor Energy Input: 769.53 KW									
T, C	25.00	25.00	25.00	75.00	800.00	20.00	31.22	75.01	75.01
P, bar	1.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Vapor Fraction	1.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00
Enthalpy, MJ/h	-71.77	-16080.94	-4806.81	-1350261.00	-33412.00	-1011536.00	-36531.10	-1008416.00	-2358677.00
Mass Flow rate, kg/h	12672.09	2070.00	250.00	86280.29	14621.72	63700.00	13880.69	64441.02	150721.31
Petcock	0.00	1000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	0.00	1000.00	0.00	86280.29	1000.00	63700.00	283.40	64416.59	150696.88
CO2	7.70	0.00	0.00	0.00	3671.84	0.00	3662.58	9.27	0.00
O2	2930.56	0.00	0.00	0.00	196.55	0.00	196.48	0.06	0.00
N2	9573.56	0.00	0.00	0.00	9573.56	0.00	9571.80	1.76	0.00
S	0.00	70.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SO2	0.00	0.00	0.00	0.00	6.99	0.00	5.53	1.46	0.00
CaCO3	0.00	0.00	250.00	0.00	12.50	0.00	0.72	11.78	0.00
System Pressure: 10 bar Compressor Energy Input: 1225.74 KW									
T, C	25.00	25.00	25.00	75.00	800.00	20.00	31.24	75.02	75.02
P, bar	1.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Vapor Fraction	1.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00
Enthalpy, MJ/h	-71.77	-16080.88	-4803.19	-1463553.00	-33434.04	-1024240.00	-35423.75	-1022250.00	-2485803.00
Mass Flow rate, kg/h	12672.09	2070.00	250.00	93519.48	14621.72	64500.00	13792.76	65328.95	158848.43
Petcock	0.00	1000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2O	0.00	1000.00	0.00	93519.48	1000.00	64500.00	201.74	65298.26	158817.74
CO2	7.70	0.00	0.00	0.00	3671.84	0.00	3658.76	13.09	0.00
O2	2930.56	0.00	0.00	0.00	196.55	0.00	196.44	0.11	0.00
N2	9573.56	0.00	0.00	0.00	9573.56	0.00	9570.33	3.23	0.00
Ar	160.28	0.00	0.00	0.00	160.28	0.00	160.10	0.17	0.00
S	0.00	70.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SO2	0.00	0.00	0.00	0.00	6.99	0.00	4.69	2.31	0.00
CaCO3	0.00	0.00	250.00	0.00	12.50	0.00	0.71	11.79	0.00

TABLE 5

[112] EXAMPLE 5: The following results show a simulation of a hot water generation method, as described in figure 2B, for two different system pressures. The simulation balance was done for 1 ton/hour of petcoke. The simulation shows the amount of generated hot process water as a function of the process water temperature.

Pressure 103 kPa			Pressure 2.5 bar		
Temperature Process Water Out (9) [C°]	Process Water In (8)	Process Water Out (9)	Temperature Process Water Out (9) [C°]	Process Water In (8)	Process Water Out (9)
70.00128	144581.8	155257.7	70.0025	139427.3	149744.4
75.25	129380.70	140018.80	75.11240	125436.50	135748.00
79.99229	117567.3	128132.1	80.0909	114077	124381.4
84.74144	105612.8	115900.5	85.00117	104550.3	114845.3
86.87201	90000	98941.81	90.00063	96186.13	106467.5
87.20271	50000	54283.76	95.36803	88370	98628.12
89.10938	2000	536.7947			

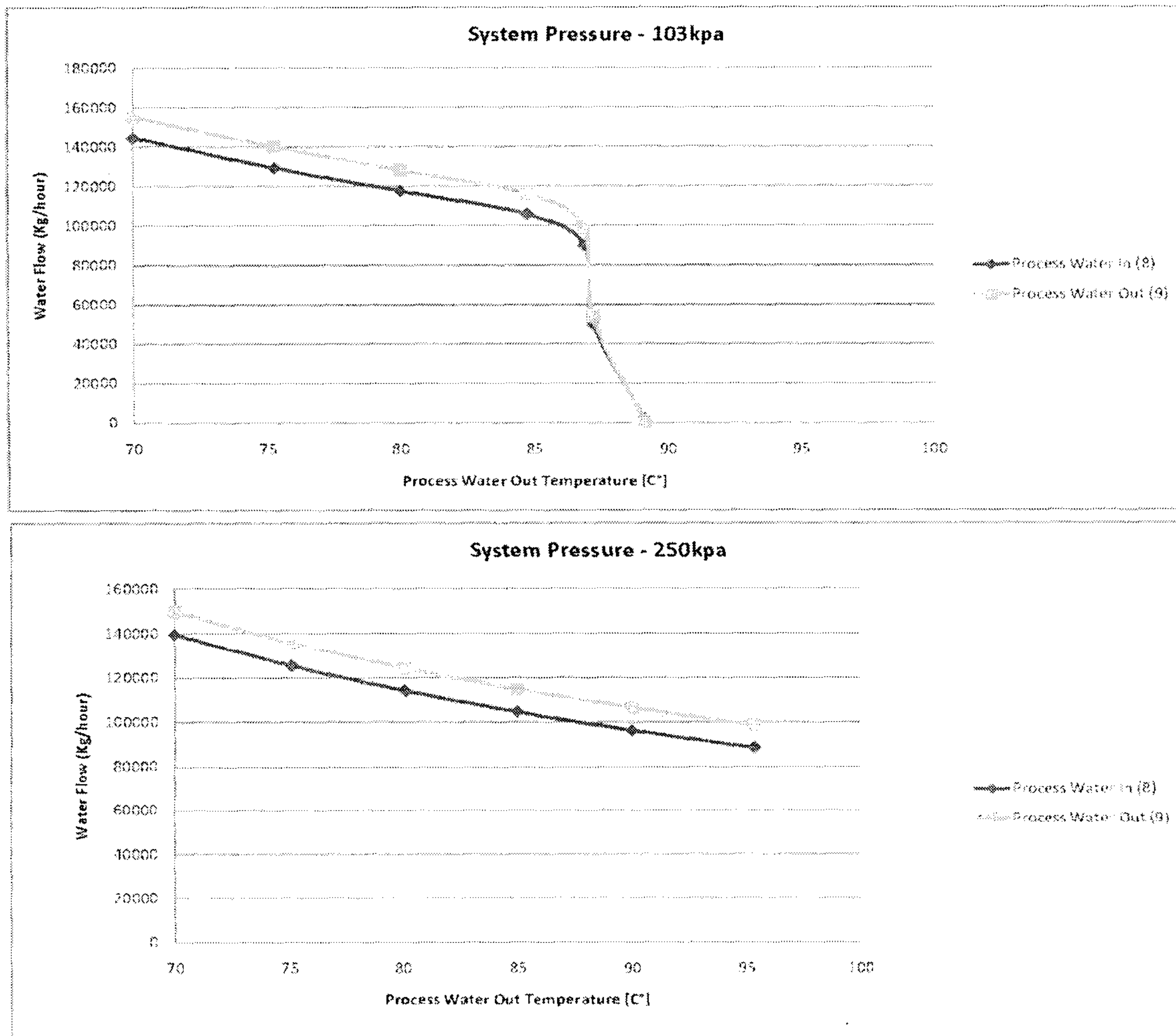


TABLE 6

[113] EXAMPLE 6: The following results show the simulation of a pH adjustment method, as described in figure 2D. The system pressure varies between 1000kpa and 90kpa. The simulation balance was done for 100 metric ton/hour of hot process water.

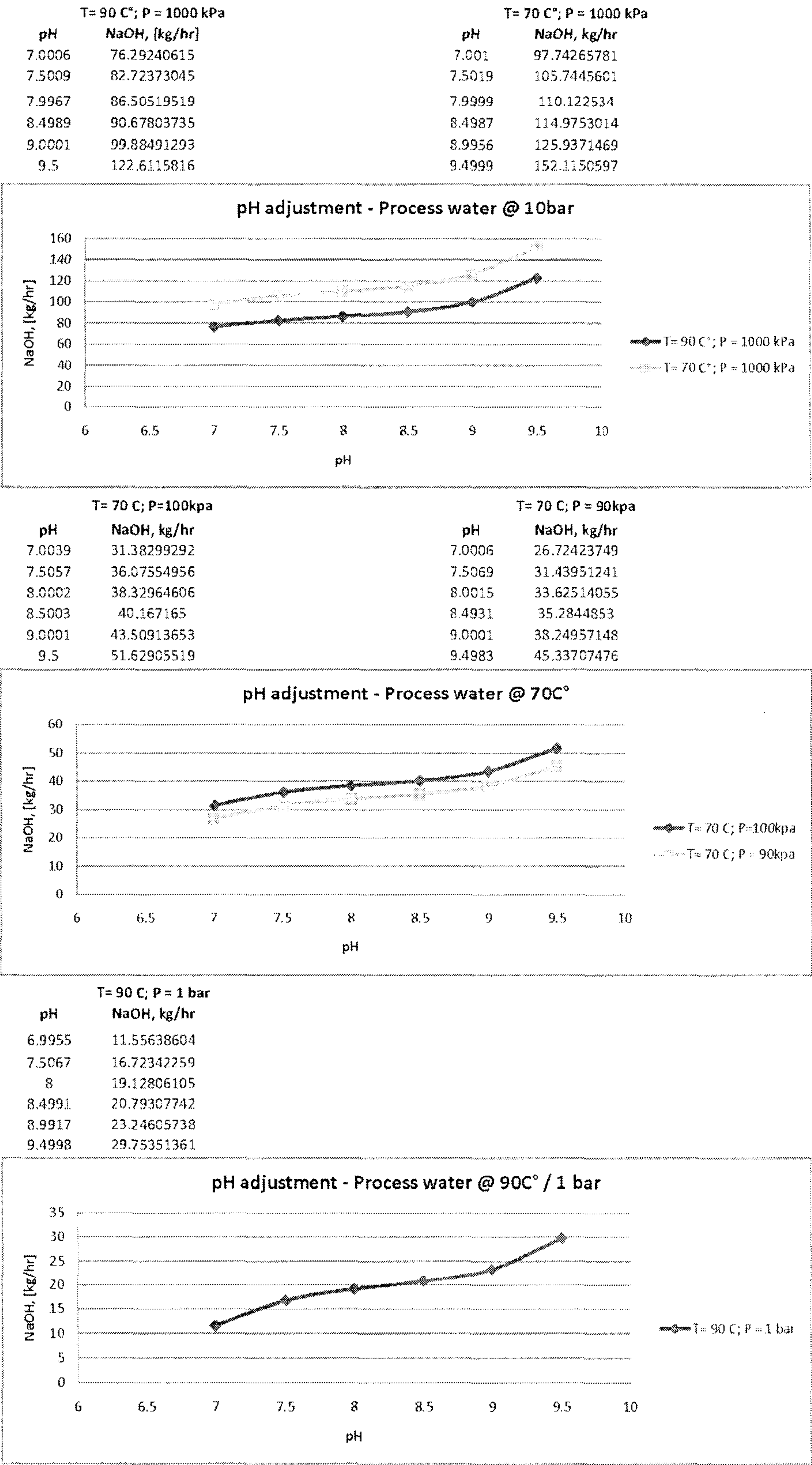


TABLE 7

I claim:

1. A method for producing bitumen, the method comprising the steps of:

combusting fuel while generating combustion heat;

evaporating solids-rich water with said combustion heat so as to generate steam, solids and combustion gas mixture;

separating said solids from the gas mixture to generate a solid lean gas stream;

extracting heat from said solid lean gas stream while condensing the steam to condensed water;
and

extracting bitumen with said extracted heat.

2. The method of claim 1, wherein the solid rich water includes at least one of: tailings, fine tailings, non-segregate fine tailings, mature fine tailings, lime softener sludge and evaporator effluent.

3. The method of any one of claims 1 and 2, wherein the solid rich water includes at least one of: solvents, hydrocarbons and asphaltene.

4. The method of any one of claims 1-3, further comprising the steps of:

after the step of extracting heat from said solid lean gas stream, using said condensed water to extract bitumen.

5. The method of any one of claims 1-4, wherein the step of separating the solids further comprises:

mixing saturated liquid water with said solid lean gas stream at a controlled pressure to scrub remaining contaminants selected from a group containing solids and contaminant gases to produce a saturated steam and solids free combustion gases mixture.

6. The method of any one of claims 1-5, further comprising recycling at least a portion of said saturated liquid water with scrubbed solids back to the step of evaporating solids rich water with combustion heat to generate steam, solids and combustion gas mixture.

7. The method of any one of claims 5 and 6, further comprising:

condensing the saturated steam to generate heat and demineralized additional condensed water for steam generation.

8. The method of any one of claims 5-7, where the fuel contains sulfur, the method further comprising the steps of:

adding alkaline chemicals to said saturated water;

scrubbing remaining solids and acid gases with said alkaline chemicals;

producing saturated steam and solid rich saturated water; and

recycling at least a part from said alkaline chemicals rich saturated water back to a solids-rich water feed for the step of evaporating said solids-rich water with combustion heat.

9. The method of any one of claims 5-8, further comprising the steps of:

condensing the saturated steam to generate heat and clean condensed water;

generating steam with the heat and clean condensed water; and

injecting the steam into an underground formation through an injection well for enhanced oil recovery.

10. The method of any one of claims 1-9, where the fuel contains sulfur, the method further comprising the steps of:

adding an alkaline chemical to at least one of said fuel and said solids rich water so as to reduce an amount of generated acid gases.

11. The method of any one of claims 8-10, wherein said alkaline chemical is comprised of lime sludge from a water softening process.

12. The method of any one of claims 1-11, further comprising the steps of:

heating boiler feed water with the extracted heat; and recovering oil with steam from the boiler feed water.

13. The method of any one of claims 1-5, wherein the combustion is a partial combustion generating synthetic gas.

14. The method of claim 13, further comprising:

combusting at least a portion of the synthetic gas with oxidizing gas;

mixing non-segregating fine-tailings with the gas to evaporate water from the fine- tailings and to generate a stream of steam, solids, and combustion gas; and

separating the solids from a gas phase to generate a solid lean gas stream of steam and combustion gas.

15. The method of any one of claims 1, 13 and 14, wherein synthetic gas is a fuel source.

16. The method of claim 13, further comprising the step of: Producing hydrogen with said synthetic gas.

17. The method of any one of claims 1-12, further comprising the steps of:

mixing at least a portion of said produced combustion gas, after the step of extracting heat from the solid lean gas stream, with liquid tailings containing water, to reduce the pH by creation of carbonic acid with CO₂ in the combustion gas and increasing the settling of different components in the liquid tailings.

18. The method of any one of claims 1-11, further comprising the steps of:

mixing the generated solid with mature fine tailings slurry; and

forming a construction material that can be back-fill and support traffic.

19. The method of any one of claims 1-11 and 18, wherein:

a portion of said generated solids generated during said combustion and steam generation stages, is comprised of hydraulic material; and

wherein mixing said solids with said mature fine tailings water generates hydrates, said hydrates stabilizing said construction material.

20. The method of any one of claims 1-11 and 17-19, further comprising:

mixing the solids-rich water with combustion gas to form a mixture, wherein combustion heat energy changes liquid phase water in said mixture into steam.

21. The method of any one of claims 1-11 and 17-20, further comprising the steps of:

mixing the generated solid with de-watered mature fine tailing to generate stable material that can be back-fill and support traffic.

22. The method of any one of claims 1-13 and 17-21, further comprising the step of:

scrubbing remaining solids into said condensed water to produce a saturated steam and solids free combustion gases mixture.

23. The method of any one of claims 1-11 and 17-22, wherein said solids-rich water is comprised of fine tailings generated during oilsands bitumen extraction.

24. A system for extracting bitumen from oilsands, the system comprising:

a combustor means for combusting fuel with oxidation gases to generate combustion gases;

a gas-solids separation unit in fluid connection with said combustor means, wherein combustion gases transfer to said gas-solids separation unit, said gas-solids separation unit separating solids from the combustion gases to generate a solid lean gas;

a heat exchanger being in fluid connection with said gas-solids separation unit, said heat exchanger extracting heat from said solid lean gas flow; and

an oil sands extraction facility in fluid connection with said heat exchanger, heating process liquid with said extracted heat and extracting bitumen with said heated process liquid.

25. The system of claim 24, further comprising:

a direct contact steam generator in fluid connection between said combustor means and said gas-solids separation unit, wherein said direct contact steam generator receives liquid tailings from said oilsands extraction facility, said direct contact steam generator mixing said liquid tailings with combustion gas to generate solids, steam and combustion gases mixture, the mixture being transferable to said heat exchanger after said gas-solids separation unit.

26. The system of any one of claims 24 and 25, further comprises:

a solids mixer in contact with said gas-solids separation unit, wherein separated solids from said gas-solids separation unit are mixed with at least one of the following: tailings and thickened tailings to form a material that can support traffic.

27. A system for extracting bitumen from oilsands, the system comprising:

a combustor, combusting fuel while generating combustion gases;

a direct contact steam generator being in fluid connection with said combustor and being formed integral with said combustor, said direct contact steam generator containing waste liquid with solids, said combustion gases of said combustor mixing with said waste liquid in said direct contact steam generator to evaporate liquids and generate additional steam, combustion gases, and solids; and

a heat and liquid recovery unit in fluid connection with said direct contact steam generator, wherein said recovery unit recovers heat and liquids from said steam and combustion gases flow, said heat and liquids recovery unit being fluidly connected to an oilsands bitumen production facility.

28. The system of any one of claims 24-27, wherein said direct contact steam generator is a dryer that can consume the highly contaminated liquid and convert the water to steam and solids with the combustion heat.

29. The system of any one of claims 24-28, further comprises:

a gas-solid separation unit fluidly connected with said direct contact steam generator, said gas-solid separation separating solids from said additional steam, combustion gases, and said solids mixture.

30. The system of any one of claims 24-29, wherein said combustor is comprised of a fluidized bed combustor, and wherein said combustor is made integral with said direct contact steam generator so as to form an integral unit, and wherein said integral unit comprises:

fuel injection means; and

means for injecting contaminated water into said combustor to control the combustion temperature by evaporating the water with combustion heat to form said additional steam, and said solids mixture;

31. The system of any one of claims 24-26, 29-30, further comprises:

a distillation water treatment plant in fluid connection with the gas-solid separation unit and with the combustor and placed in relation to said gas solid separation unit so as to

generate a stream of de-mineralized water with heat from said additional steam, combustion gas and said solids mixture; and

an enhanced oil recovery facility in fluid connection with said distillation water treatment plant so as to receive said stream of de-mineralized water, said enhanced oil recovery facility injecting steam for bitumen production.

32. The system of any one of claims 24-31, further comprising:

a gasifier in fluid connection with said combustor, said gasifier generating synthetic gases for combusting in said combustor, said gasifier containing fuel, said fuel being a carbon based fuel, and oxidation gases therein, forming a gasifier mixture, and combusting the gasifier mixture under controlled pressures and temperatures.

33. The system of any one of claims 24-30, further comprising:

an oilsands open mine facility in fluid connection with said combustor and said direct contact steam generator, said oilsands open mine facility generating a facility process water and a flow of fine tailings by excavating oilsands ore, mixing ore with said facility process water, separating bitumen from the facility process water, and discharging coarse tailings, wherein said flow of fine tailings is evaporated in said combustor, said fuel having carbon and being combusted in said combustor, and wherein said facility process water of said oilsands mine facility is heated by said additional steam and combustion gases of said direct contact steam generator, said oilsands mine facility being in a heat transfer relationship with said direct contact exchanger steam generator.

34. The system of any one of claims 24 and 33, where said combustor is comprised of an up- flow pressurized fluidized bed combustor.

35. A method for extracting bitumen from a minable oilsands formation, the method comprising the steps of:

extracting bitumen from an oilsands formation, the formation having bitumen and inorganic soil, the step of extracting forming liquid tailings;

combusting fuel as to generate combustion heat and combustion gas;

heating said oilsands liquid tailings with said combustion heat, while evaporating water and generating steam, solids and combustion gas phase;

separating the solids and said combustion gas to generate a solids lean gas

extracting heat from said solids lean gas phase; and

extracting bitumen with the extracted heat while generating liquid tailings.

36. A method for producing bitumen, the method comprising the steps of:

combusting fuel to generate thermal heat;

thermally evaporating liquid so as to generate a solid phase and a gas phase;

separating said gas phase from said solid phase;

extracting heat from said gas phase while condensing vapor gas phase to a liquid phase;

heating process liquid with extracted heat from the step of extracting heat; and producing bitumen with the heated process liquid.

37. The method of claim 36, further comprising the steps of:

producing bitumen with said liquid phase generated at the step of extracting heat from said gas stream .

38. The method of any one of claims 35-37, wherein said liquid is comprised of one or more of the following: tailings, water, hydrocarbons, solvents, dissolved solids, asphaltene and suspended solids.

39. The method of any one of claims 35-38, wherein injecting said liquid into said fuel combustion.

40. A method for extracting bitumen, the method comprising the steps of:

combusting fuel to generate heat;

mechanically separating a portion of the liquid in a tailings flow so as to generate a concentrated oil sands tailings material;

thermally evaporate liquid from said concentrated oil sands tailings materials with said combustion heat so as to produce a dried oil sands tailings material and gas stream;

separating the dried oil sands tailing material from said gas stream; and

transferring heat from said gas stream to a liquid stream used in an bitumen extraction process.

41. The method of claim 40, further include condensing liquid water from said gas stream for bitumen extraction.

42. The method of any one of claims 40 and 41, wherein the apparatus configured to mechanically separate said portion of the liquid in a tailings flow is selected from a group consisting of: a centrifuge, a thickener, and a cyclone.

43. The method of any one of claims 40-42, wherein said thermally evaporate liquid from said concentrated oil sands tailings materials is performed in an apparatus configured to thermally evaporate liquid selected from a group consisting of: a fluid bed, a rotary and a pressurized spray.

44. The method of any one of claims 40-43, further comprising the step of:

mixing a flocculent with the tailings flow prior to mechanically separating said portion of liquids from said tailing flow while generating said concentrated oil sands tailings material.

45. The method of any one of claims 40-44, further comprising the step of:

generating trafficable material by mixing portion of the concentrated oil sands tailings material with said dried oil sands tailings material .

46. A bitumen extraction system comprising:

a bitumen extraction facility configured to contact liquid stream with oil sands ore while generating oil sands tailings.

a liquid separation apparatus fluidly connected to said bitumen extraction facility configured to separate a portion of the liquids in oil sands tailings flow so as to generate a concentrated oil sands tailings;

an evaporation apparatus fluidly connected to said liquid separation apparatus configured to receive the concentrated oil sands tailings and to thermally evaporate liquid from the concentrated oil sands tailings so as to produce a trafficable dried oil sands tailings material and gas stream;

a combustor fluidly connected to said evaporation apparatus configured to generate heated gas that is supplied to the apparatus configured to thermally evaporate liquid; and

a thermal transfer apparatus configured to thermally contact the gas stream generated by the evaporation apparatus with a liquid stream configured for use in an bitumen extraction process.

47. The system of claim 46, further comprising a cyclone configured to separate the trafficable dried oil sands tailing material into a trafficable dried solids material and a gas stream fluidly connected between said evaporation apparatus and said thermal transfer apparatus.

48. The system of any one of claims 46 and 47, wherein the apparatus configured to separate the portion of the liquid is selected from a group consisting of: a centrifuge, a thickener, and a hydrocyclone.

49. The system of any one of claims 46-48, wherein the apparatus configured to thermally evaporate liquid include a dryer that can directly consume highly contaminated water.

50. The system of claim 49, wherein the apparatus configured to thermally evaporate liquids is selected from a group consisting of: a fluid bed, a rotary and a spray dryer.

51. The system of any one of claims 46-50, further comprising:

a mixer configured to mix the trafficable dried solids material with the concentrated oil sands tailings material to generate trafficable material.

52. A method for extracting bitumen from oil sand, comprising:

combusting fuel to generate combustion heat;

drying a solids rich stream with the combustion heat to produce dry solids;

recovering the heat from the drying step into a water-based extraction process water stream to generate heated water extraction stream;

extracting bitumen from oil sands ore with said heated water extraction stream while producing bitumen rich stream and said solids rich stream ; and

recycling said solids rich stream to said step of drying with said combustion heat.

53. The method of claim 52, wherein the dry solids are mixed with mature fine tailings to produce trafficable material.

54. The method of claim 53, wherein said mature fine tailings are mixed with dry solids in a rotating mixer to form trafficable tailings.

55. The method of any one of claims 1-23, 35-45 wherein the extracted heat energy is recovered by heating process water stream for bitumen extraction process.

56. The method of any one of claims 1-23 and 35-45 , wherein at least one of: liquid, solids rich water, liquid tailings, liquid wet tailings, concentrated oilsands tailings and solid rich stream includes liquid solvents.

57. The method of claim 56 further comprises heat and evaporate at least portion of said liquid water and solvents to produce dry tailings.

58. The method of any one of claims 1-23 and 35-45, wherein portion of the solids are separated from at least one of: liquid, solids rich water, liquid tailings, liquid wet tailings, concentrated oilsands tailings and solid rich stream in a solid-liquid separator.

59. The method of any one of claims 1-23 and 35-45, whereby the dry tailings are mixed with at least one of the following: tailings from a water-based extraction process, mature fine tailings and concentrate mature fine tailings to produce trafficable solids.

60. The method of any one of claims 1-23, 35-45 and 55-59 where at least one of the following: liquid, solids rich water, liquid tailings, liquid wet tailings, concentrated oilsands tailings and solid rich stream is generated by a froth treatment process.

61. The method of any one of claims 1-23, 35-45 and 55-60 where at least one of the following includes combustion fuel: liquid, solids rich water, liquid tailings, liquid wet tailings, concentrated oilsands tailings and solid rich stream.

62. The method of any one of claims 1-23, 35-45 and 55-61 where asphaltenes are included in at least one of: liquid, solids rich water, liquid tailings, liquid wet tailings, concentrated oilsands tailings and solid rich stream.

63. The method of any one of claims 1-23, 35-45 and 55-62 where combustion fuel is mixed with at least one of: liquid, solids rich water, liquid tailings, liquid wet tailings, concentrated oilsands tailings and solid rich stream.

64. The method of any one of claims 59-62, wherein the carbon base fuel injected to the combustion combined with the tailings.

65. The method of claim 35, further comprising the steps of:

heating a process fluid flow with said extracted heat;

mixing the mined formation with heated process fluid to generate a slurry; and recovering bitumen from said slurry while generating fine tailings.

66. The method of any one of claims 1-23, 35-45 and 55-65 wherein bitumen product is produced while produce tailings comprises water, residual solids and residual hydrocarbons.

67. The method of claim 66 wherein condensed liquid is recovered from the tailings stream.

68. The method of claim 66, wherein the tailings are partially dewatered before heated with the combustion heat.
69. The method of claim 66, wherein said condensed liquid includes at least one of:
- residual water and residual hydrocarbon solvent.
70. The method of any one of claims 1-23, 35-45 and 55-69 wherein combustion hot flue gas evaporates liquids from the liquid stream by direct contact with the liquid stream.
71. The method of claim 70, wherein heat from the hot flue gas is used to produce hot fluid for the bitumen extraction process.
72. The system of any one of claims 27-34 and 46-51, wherein the liquid stream evaporated in a rotating dryer.
73. The method of any one of claims 1-23, 35-45 and 55-70, wherein combustion performed in a rotating enclosure.
74. The method of any one of claims 1-23, 35-45 and 55-70, wherein combustion performed in a fluidized bed combustion chamber.
75. The method of claim 66, wherein solids within the liquid stream are releasing their hydrate water.
76. The method of any one of claims 1-23, 35-45 and 55-71, wherein the solids are used as construction material within a mine site.
77. The method of claim 76, wherein liquid is used for dust control of the dried solids.
78. The method of claim 77, wherein the liquid includes one or more of: process waste water that includes tailings or mature fine tailings.
79. The method of any one of claims 1-23, 35-45 and 55-71, wherein the fuel includes natural gas.
80. The method of any one of claims 1-23, 35-45 and 55-71, wherein the fuel includes hydrocarbons liquids.
81. The method of any one of claims 1-23, 35-45 and 55-71, wherein the fuel includes solid fuel.
82. The method of any one of claims 1-23, 35-45 and 55-71, wherein evaporation performs in a dryer that evaporates the highly contaminated water.
83. The method of any one of claims 1-23, 35-45, 55-71 and 73-82 where said combustion is performed in a pressured controlled enclosure.
84. The method of any one of claims 1-23, 35-45, 55-71 and 73-83 where said combustion pressure is substantially similar to the evaporation pressure.

85. The method of any one of claims 83 and 84 where said combustion pressure is higher than atmospheric pressure.

86. The method of any one of claims 1-23, 35-45, 55-71 and 73-85 where the combustion energy generated by said combustion is directly used for said evaporation.

87. The system of any one of claims 27-34 and 46-51 where said combustion is performed in a pressured controlled enclosure; and

said combustion pressure is substantially similar to the evaporation pressure.

88. The system of any one of claims 27-34, 46-51 and 87 where the combustion energy generated by said combustion is directly used for said evaporation.

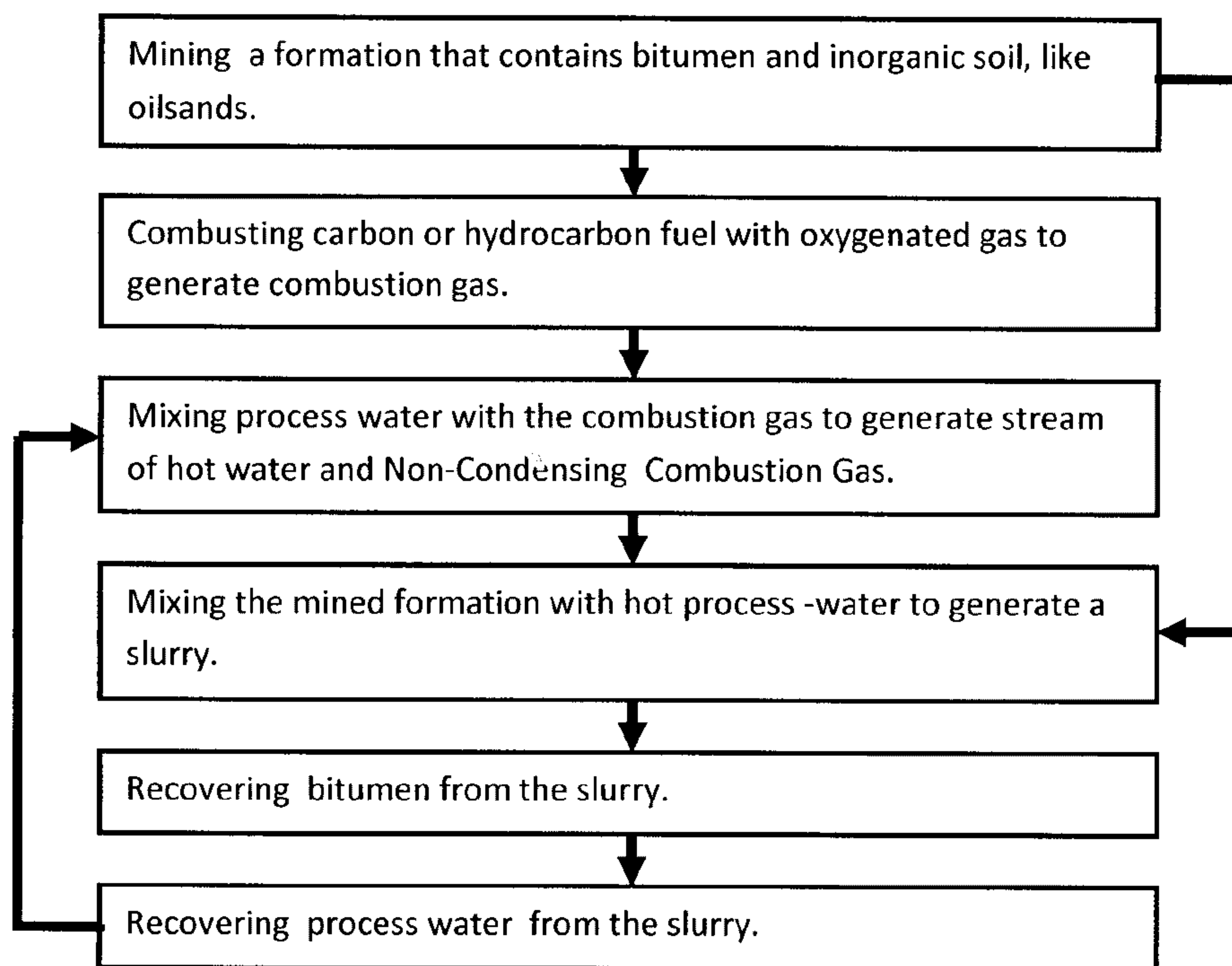


FIG. 1

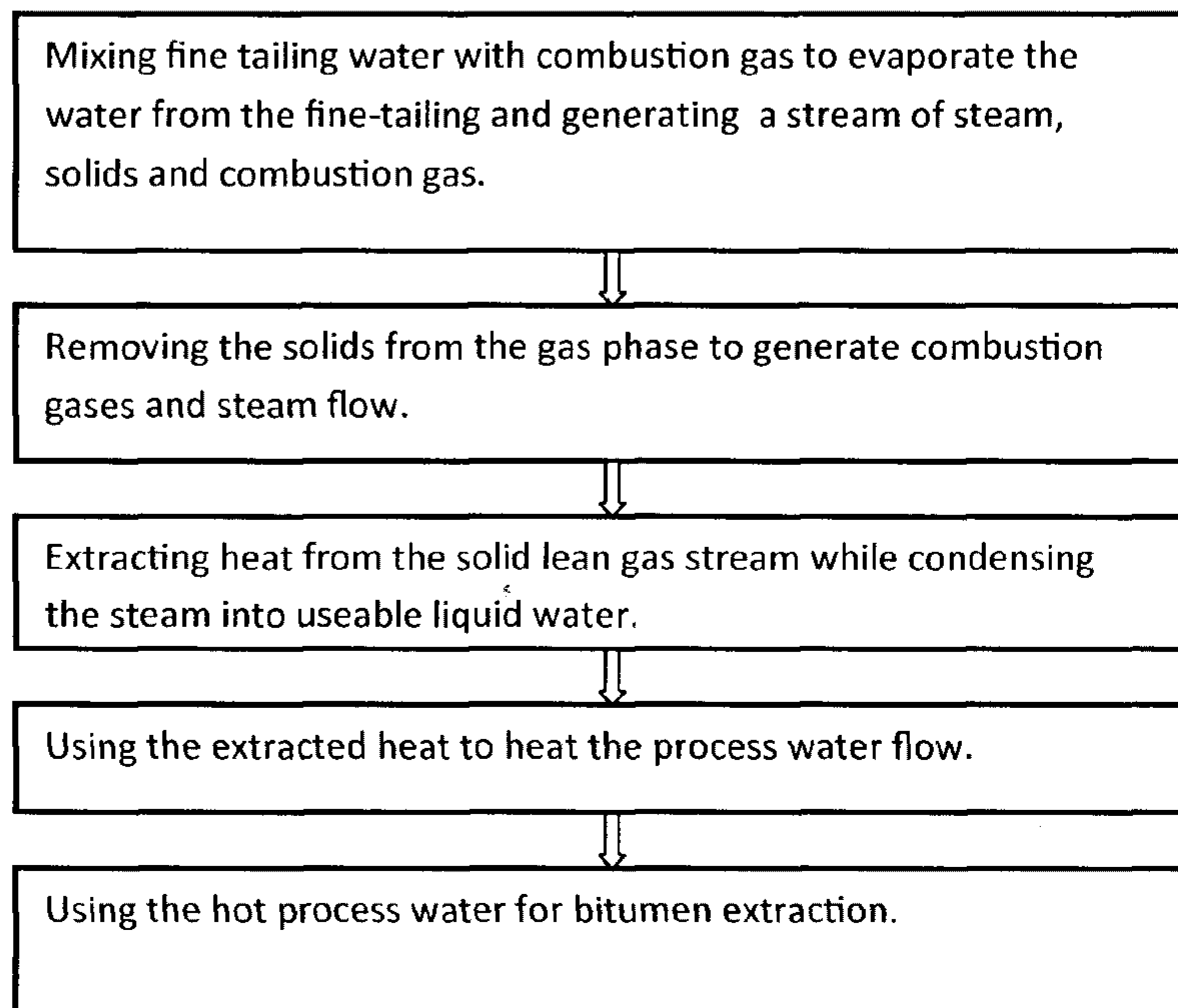


FIG. 1A

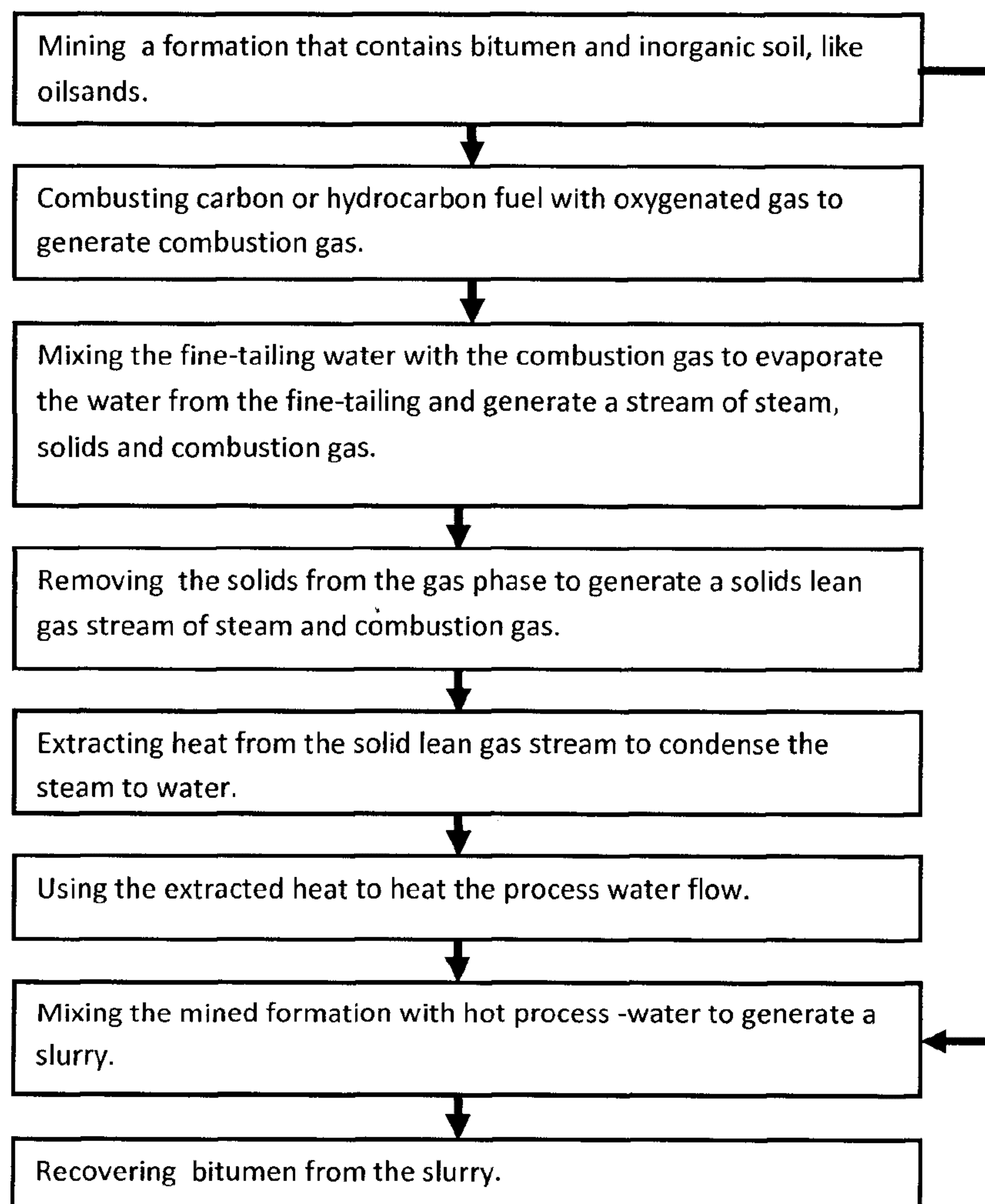


FIG. 1B

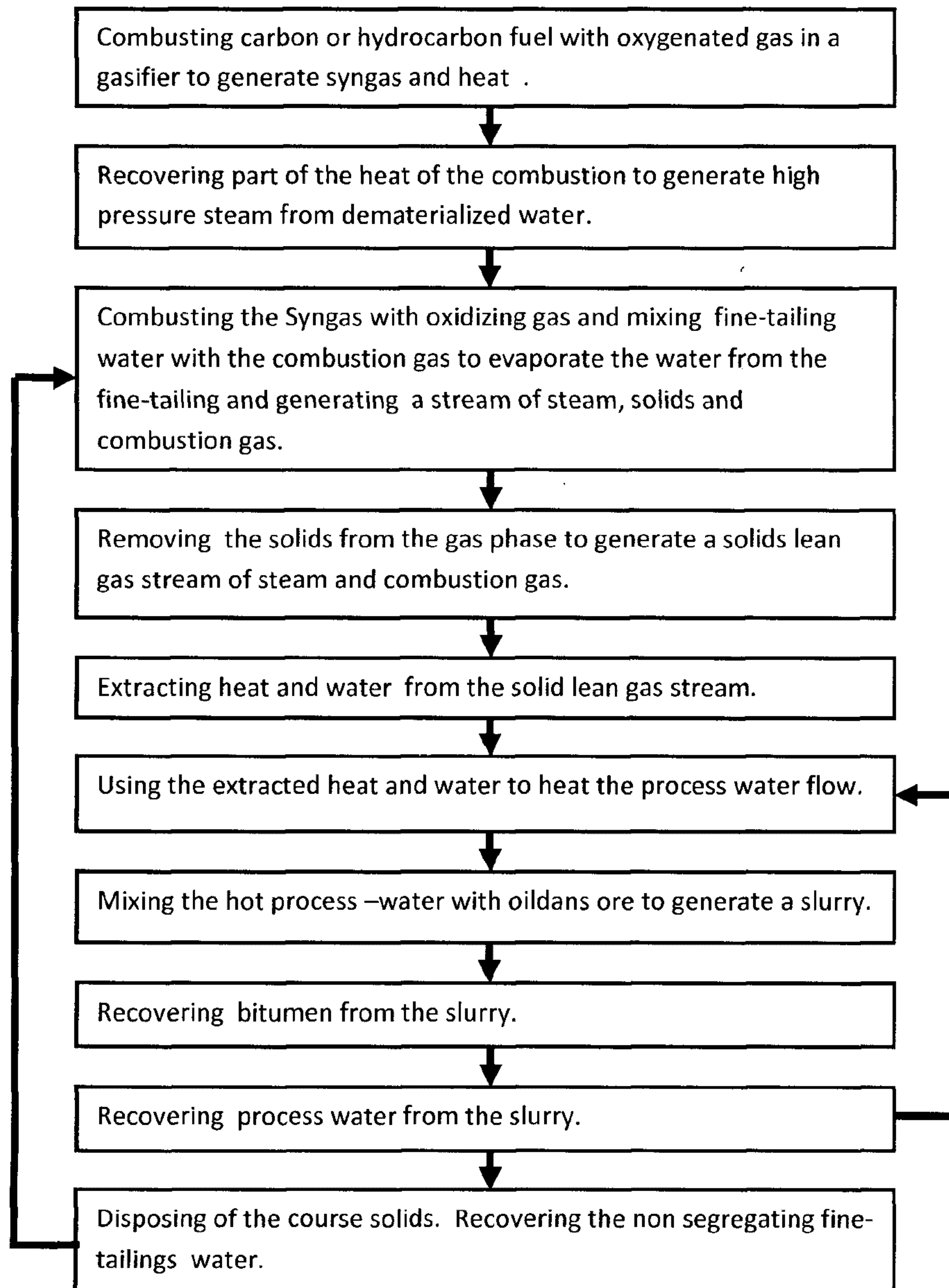


FIG. 1C

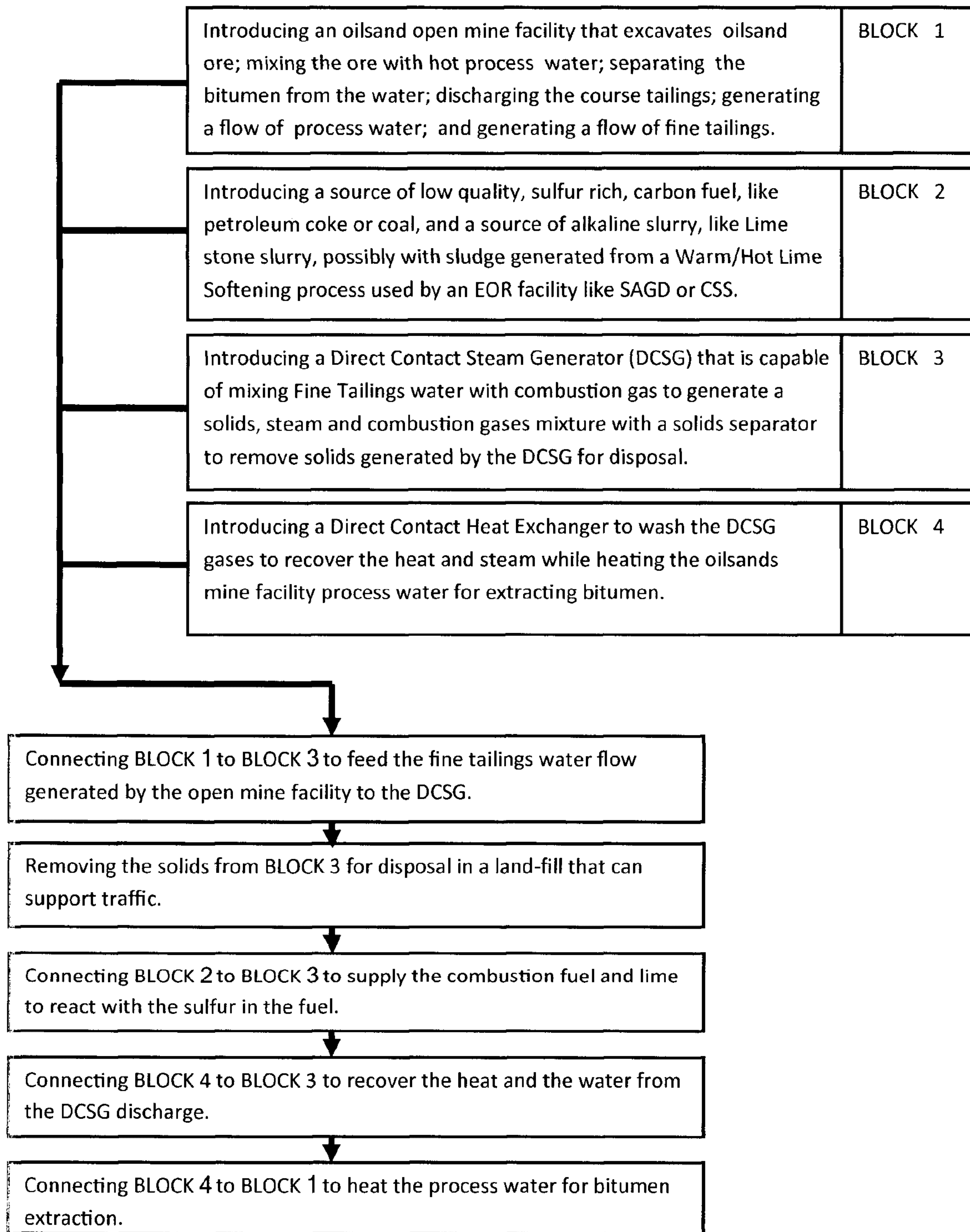


FIG. 1D

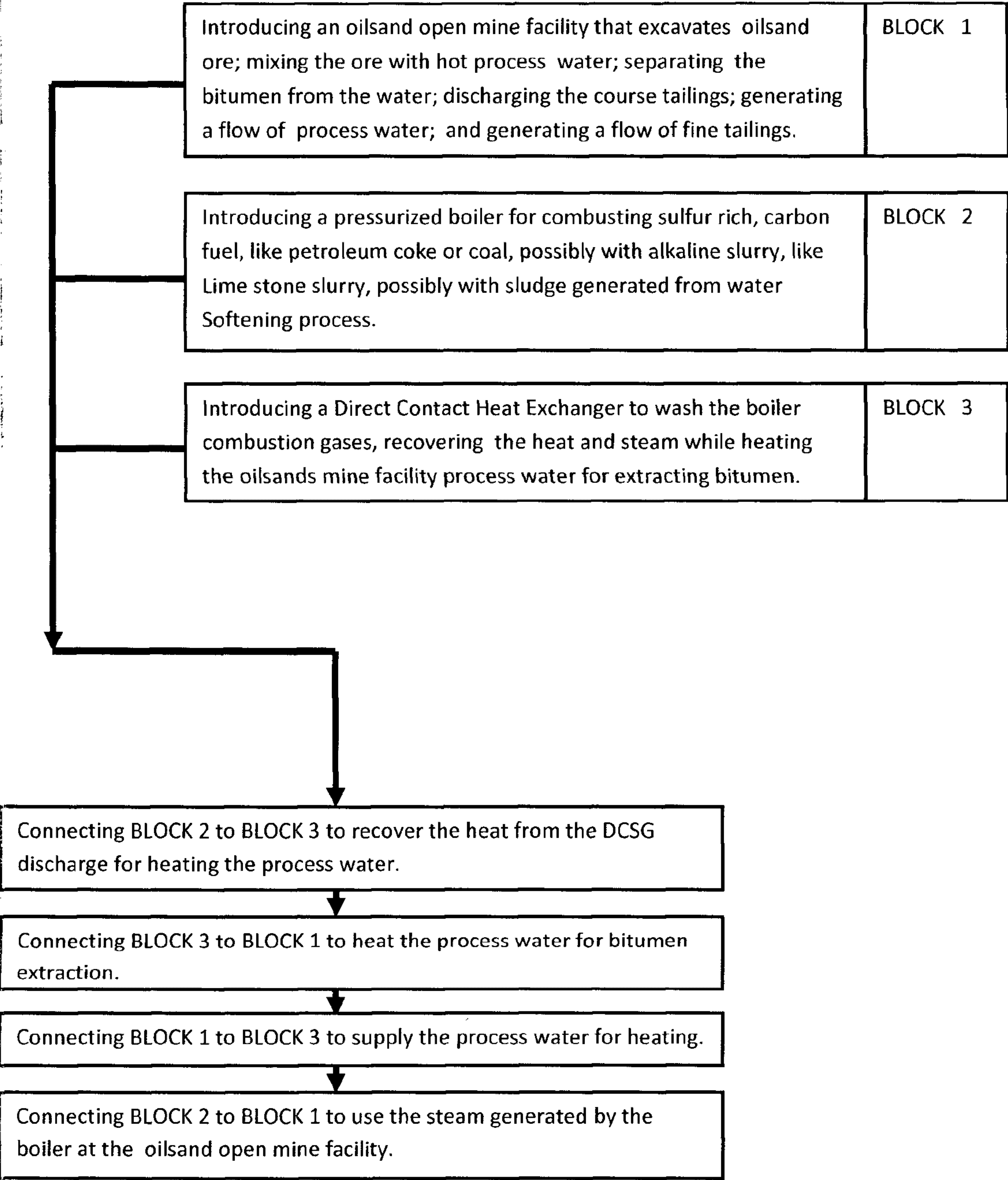


FIG. 1E

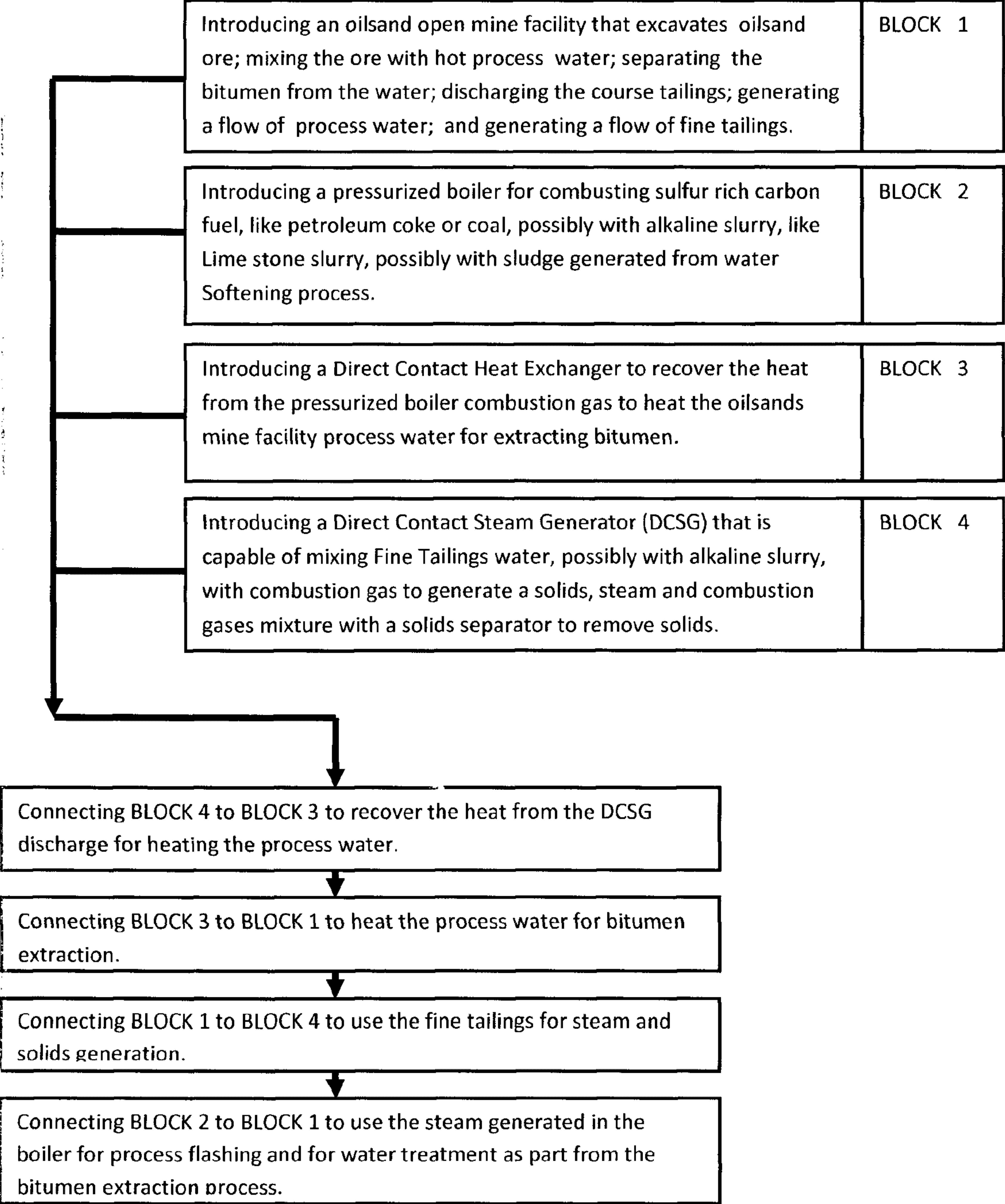


FIG. 1F

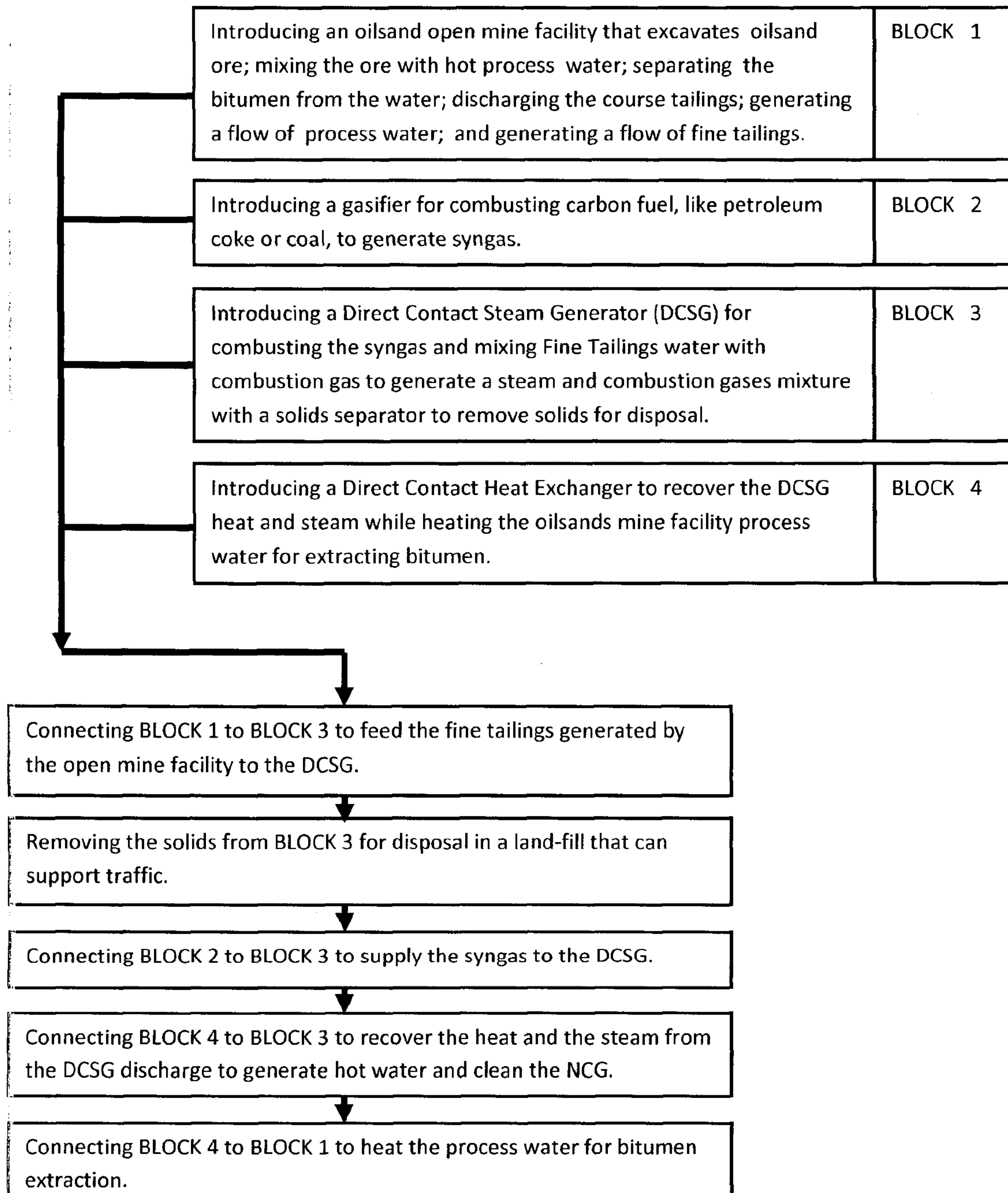


FIG. 1G

Non-Direct-Contact Vs. Direct Contact Steam Generation

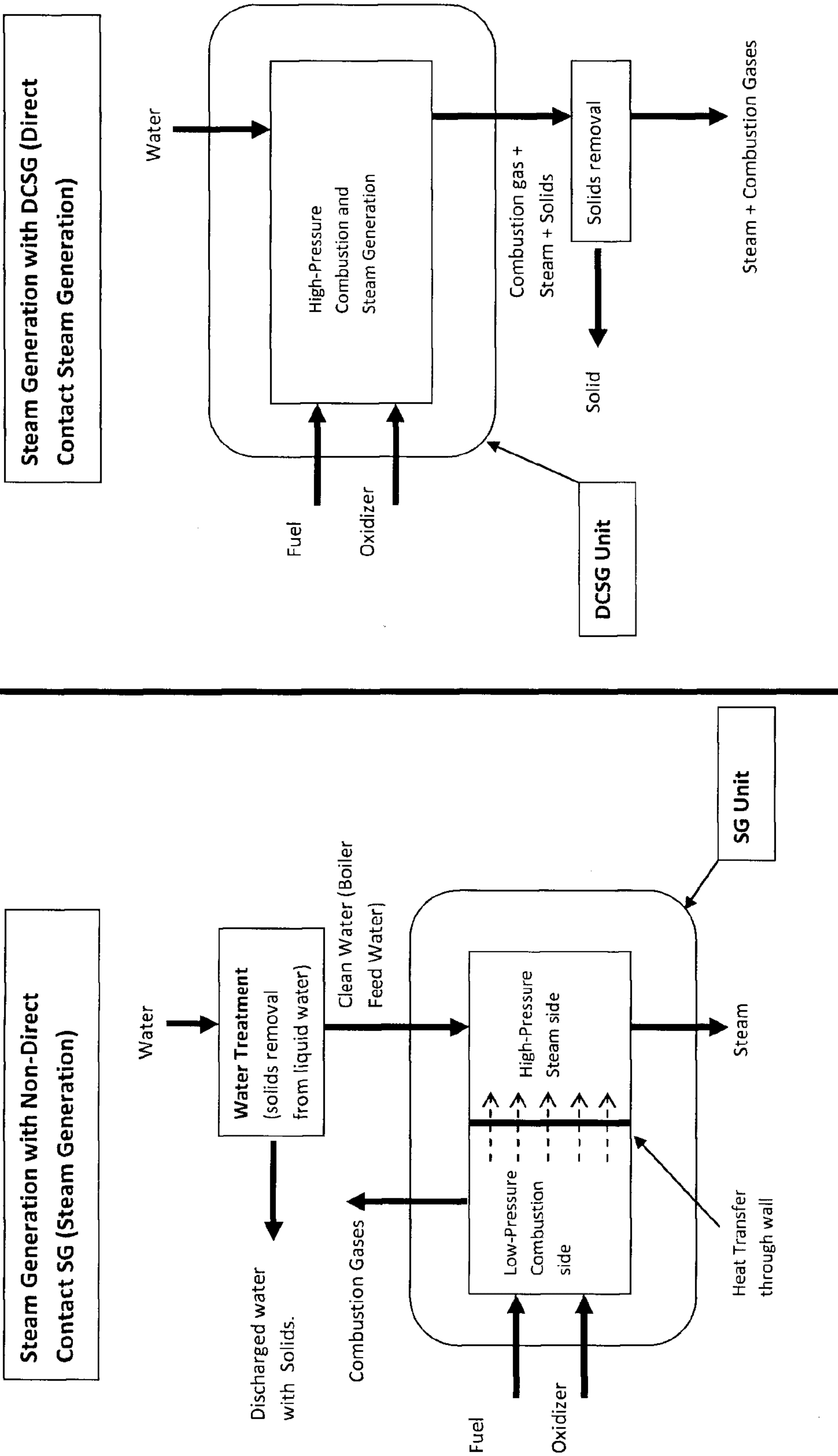


FIG. 1H

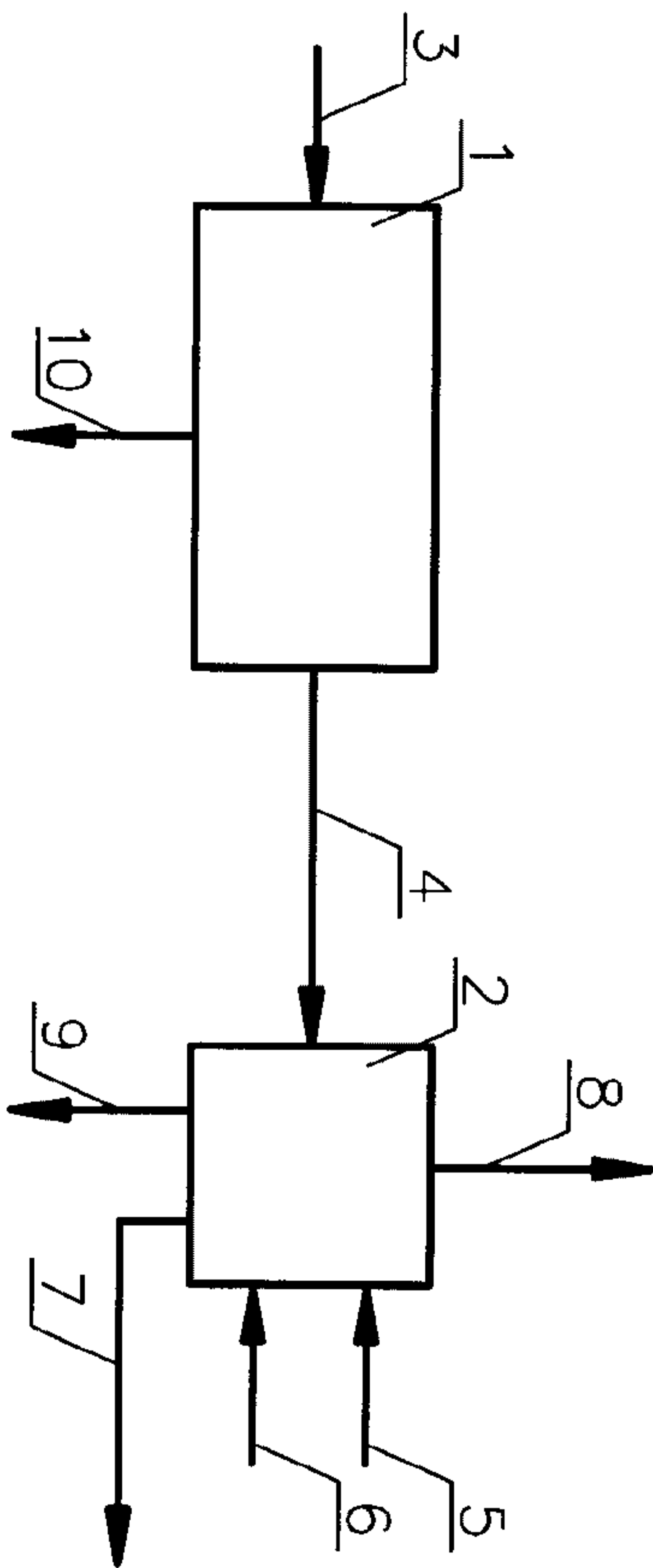


FIG.2

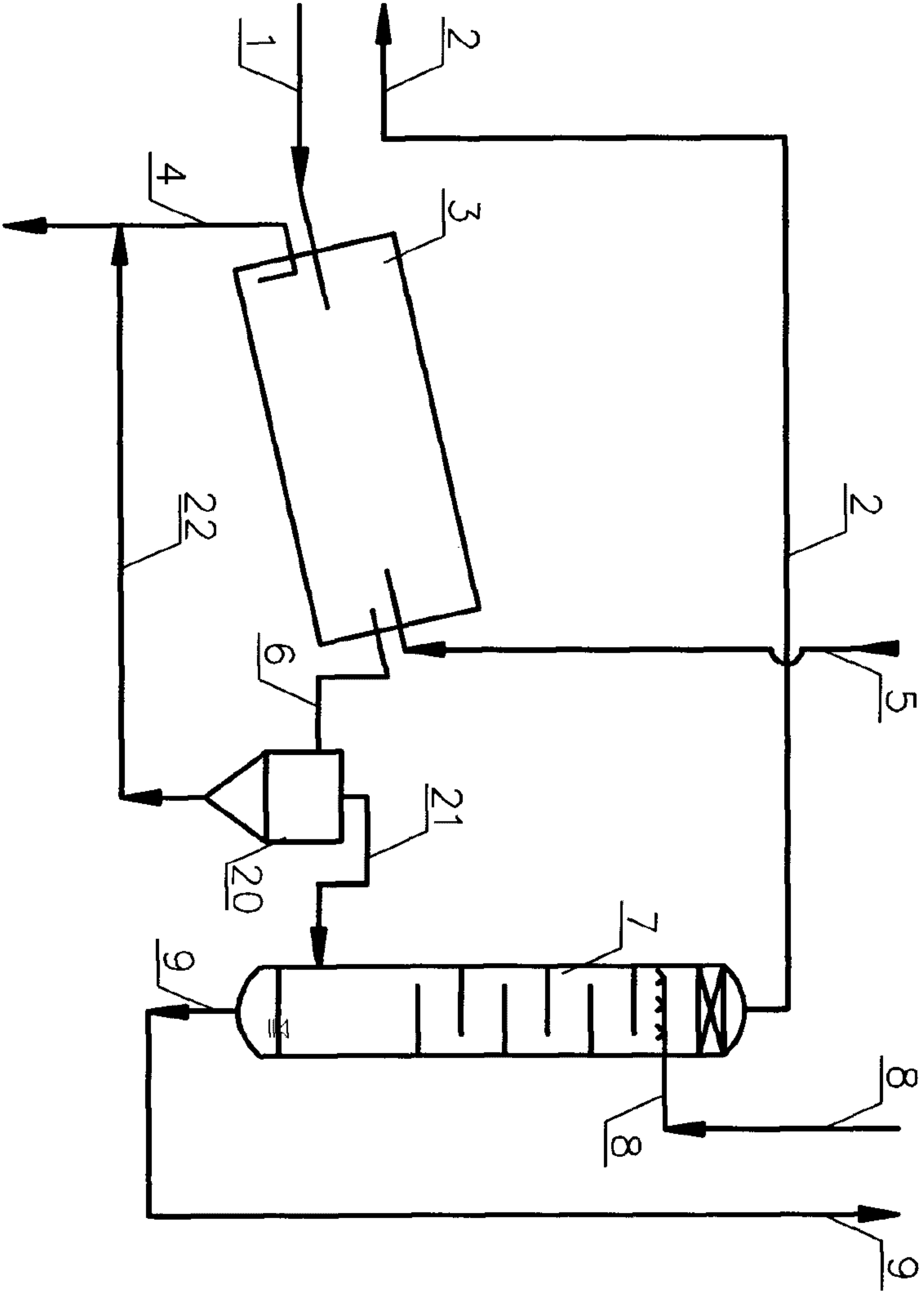


FIG. 2A

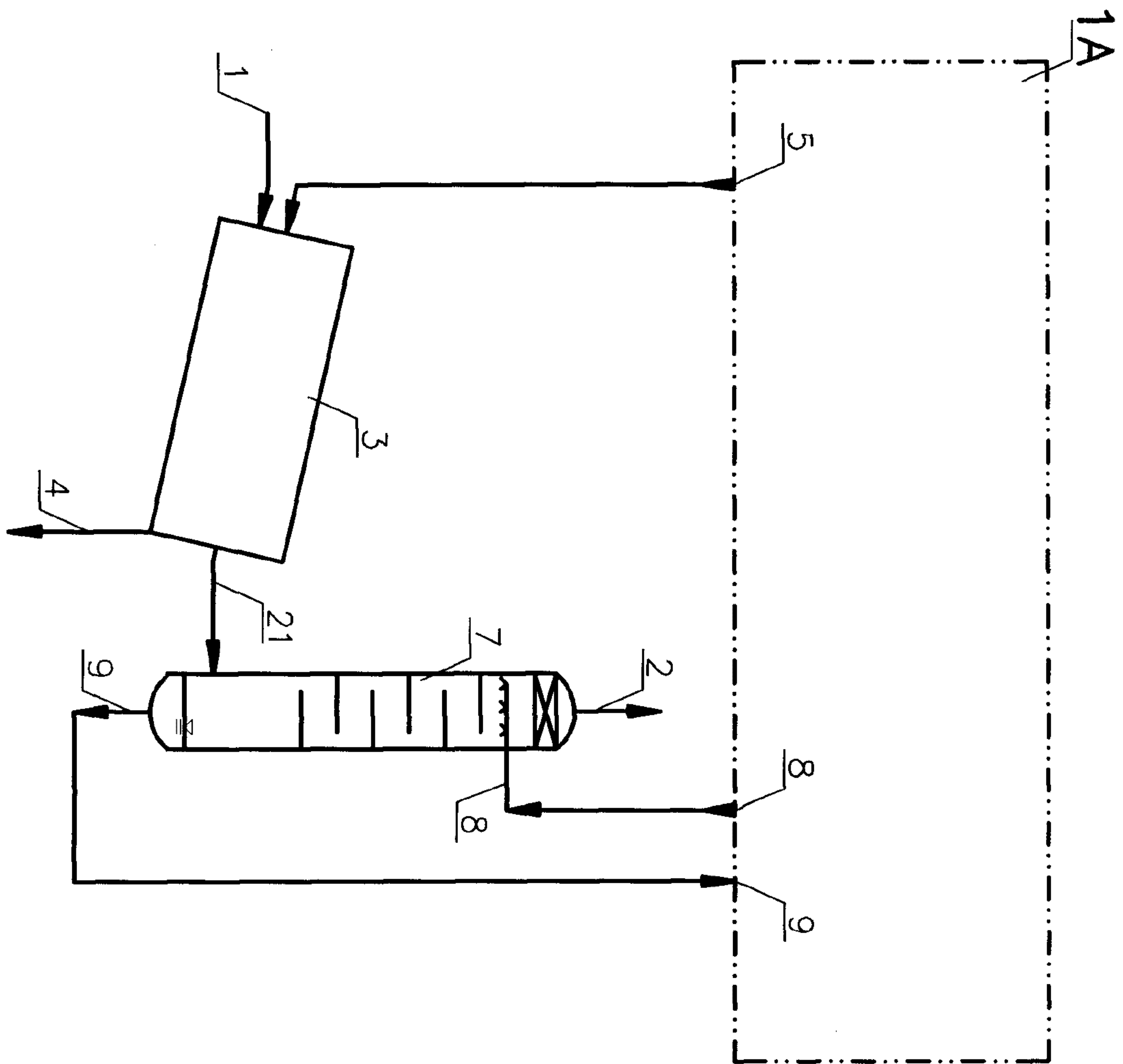


FIG.2B

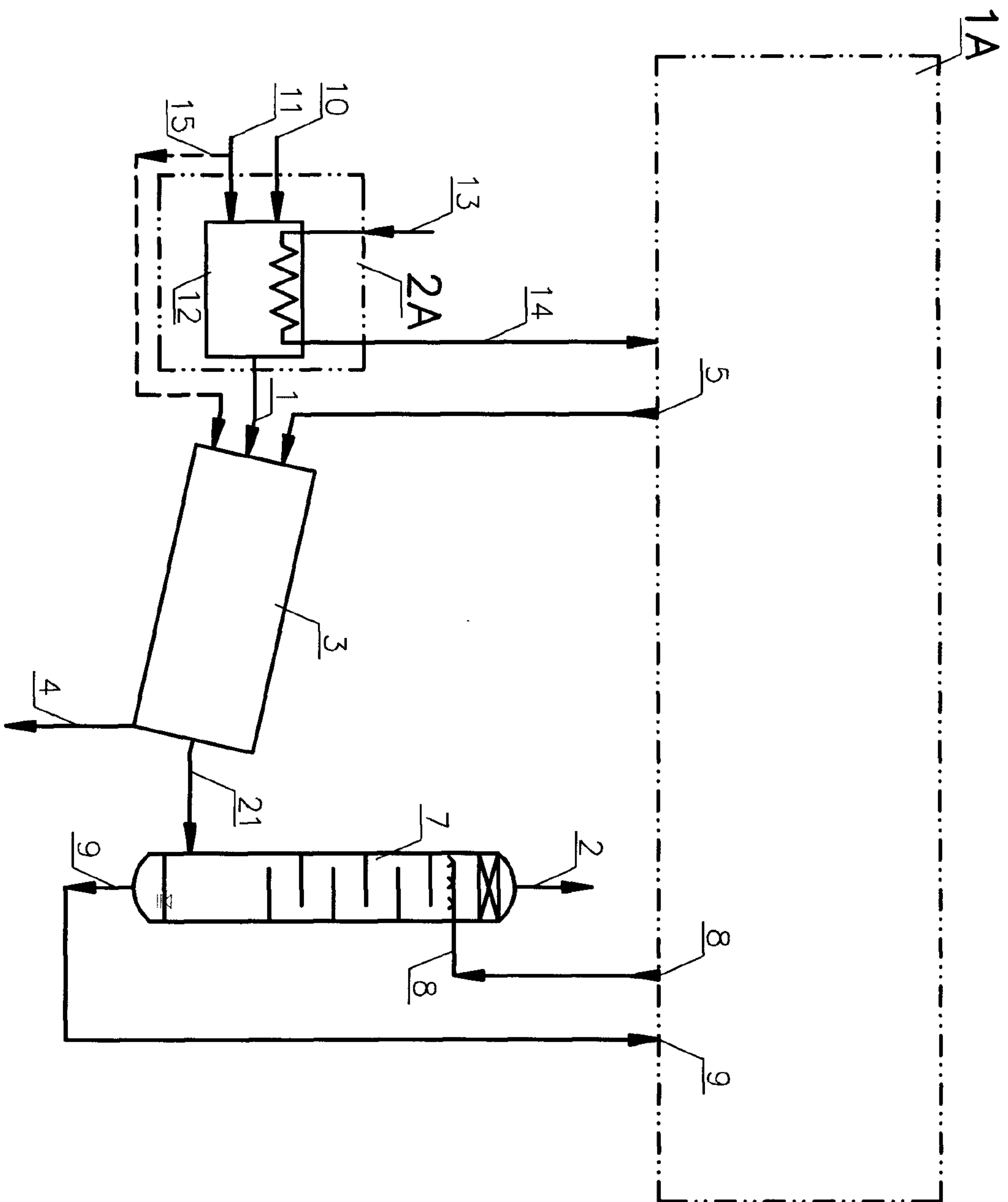


FIG. 2C

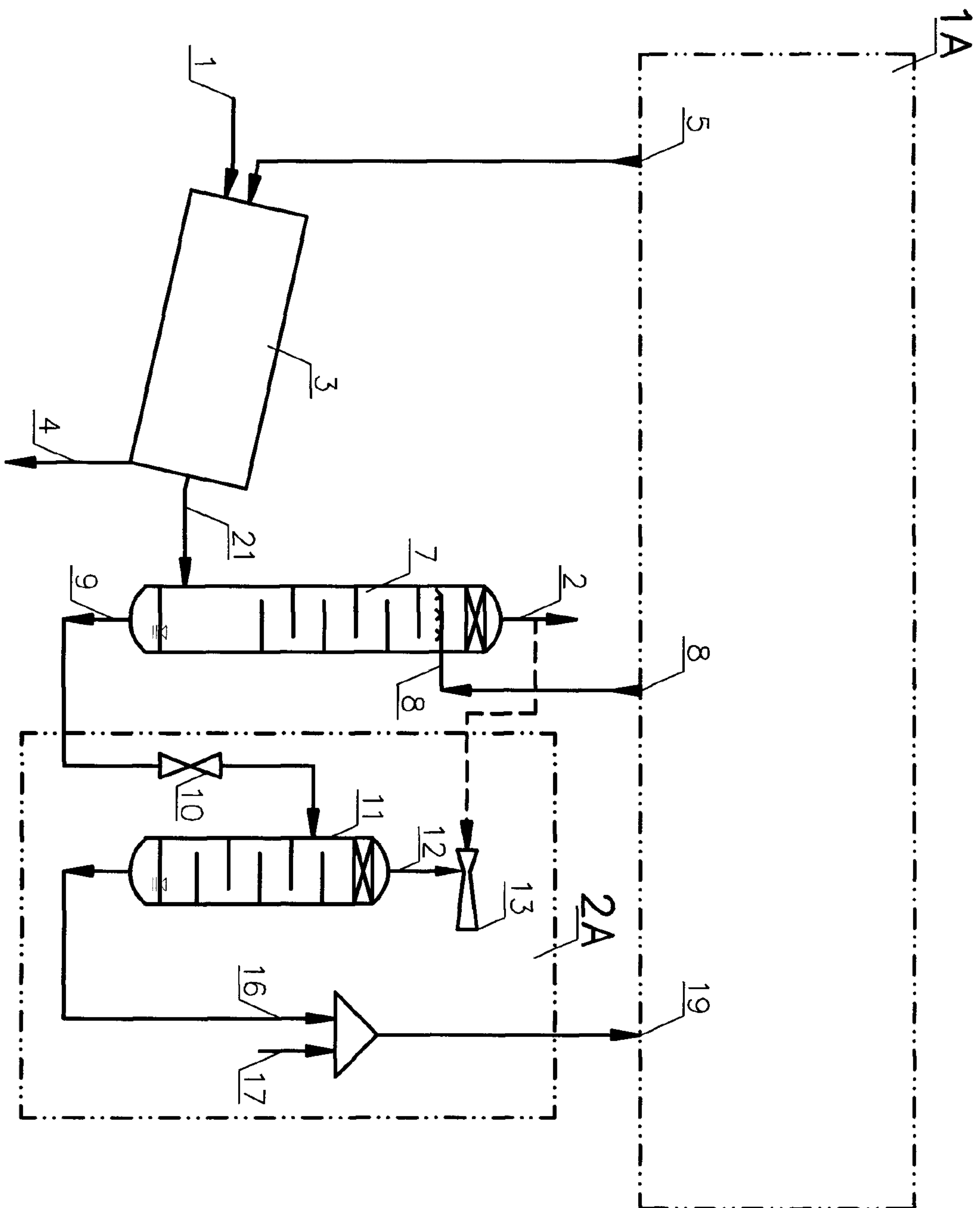


FIG. 2D

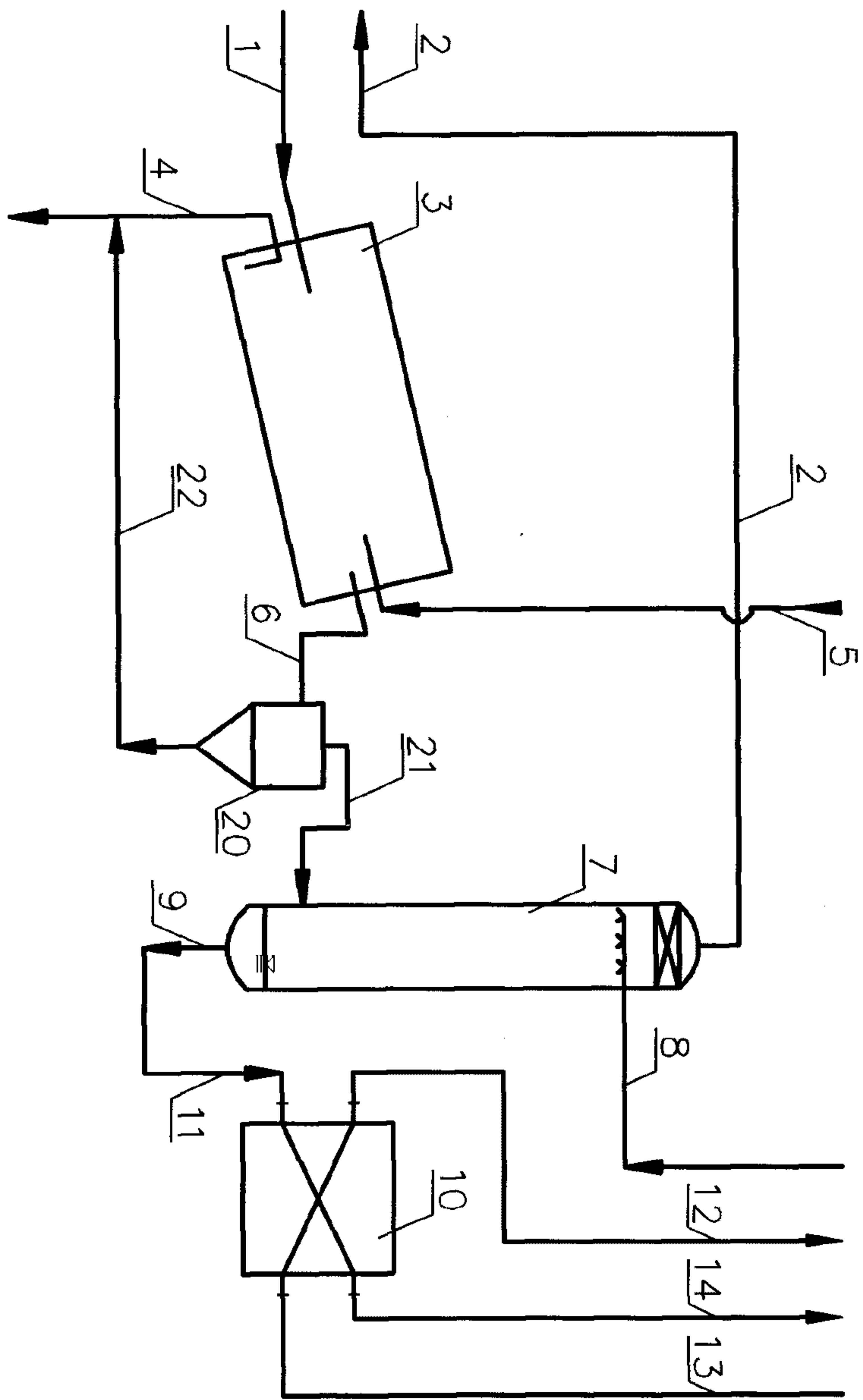


FIG. 3

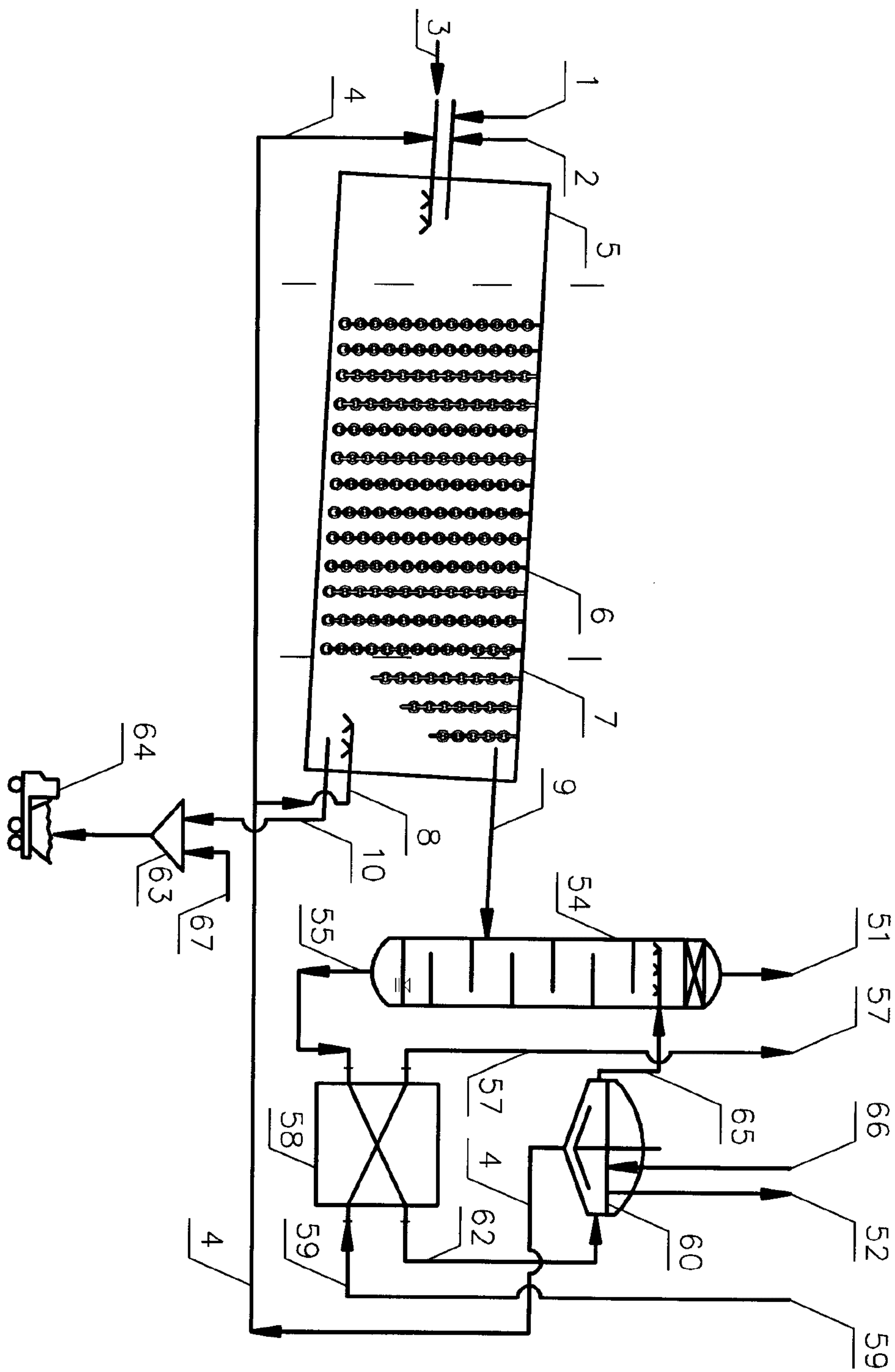


FIG. 3A

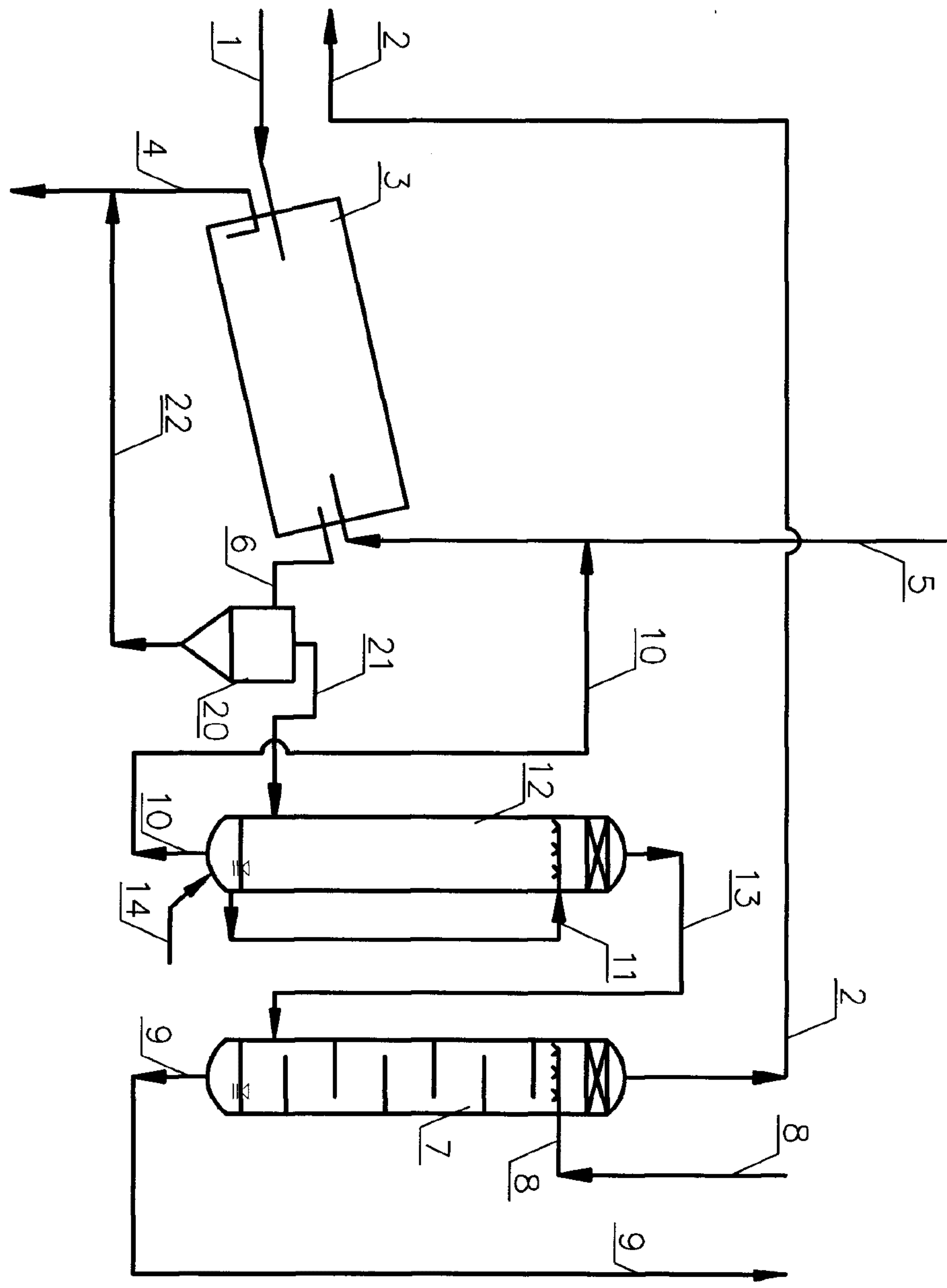


FIG.4

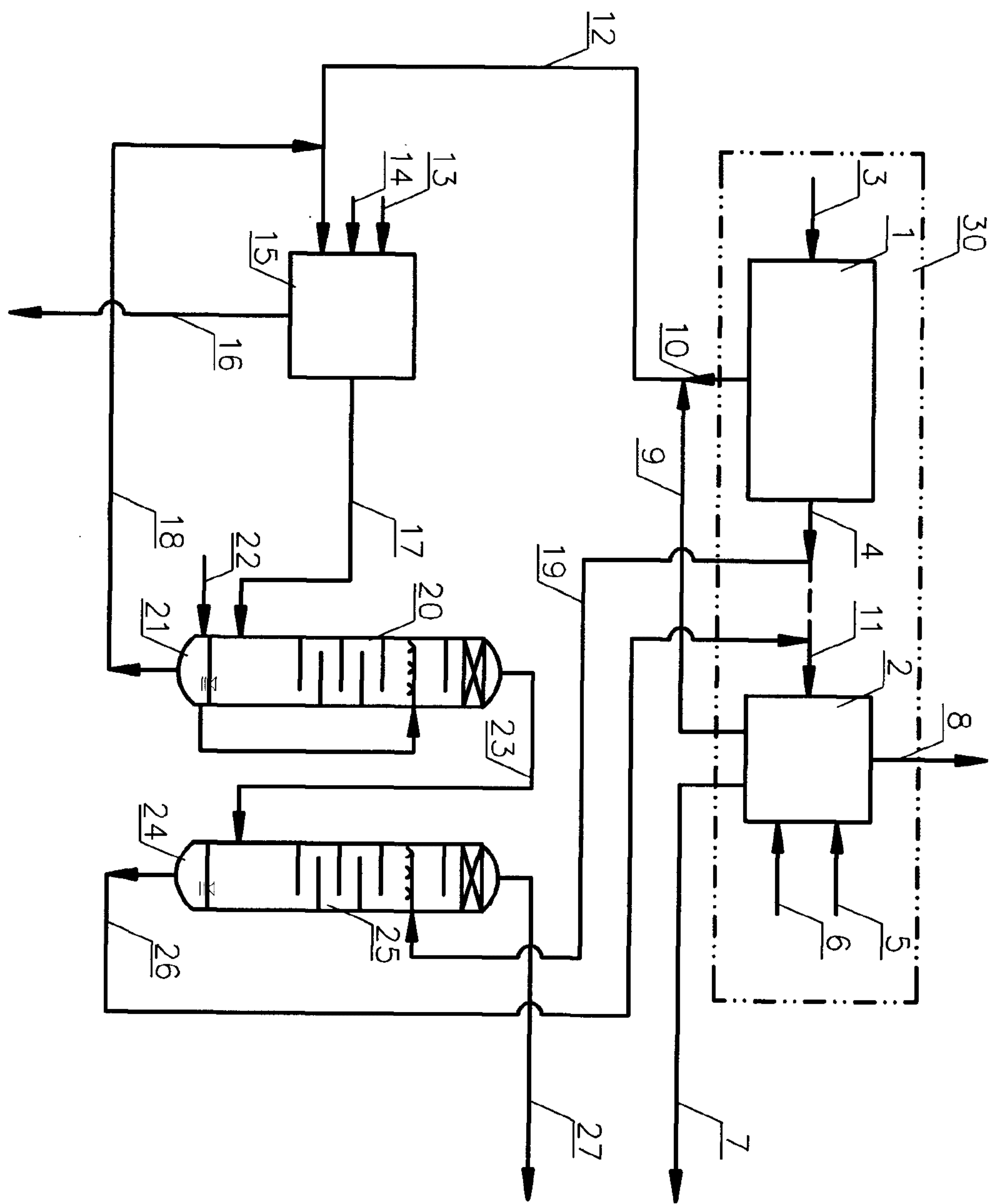


FIG. 5

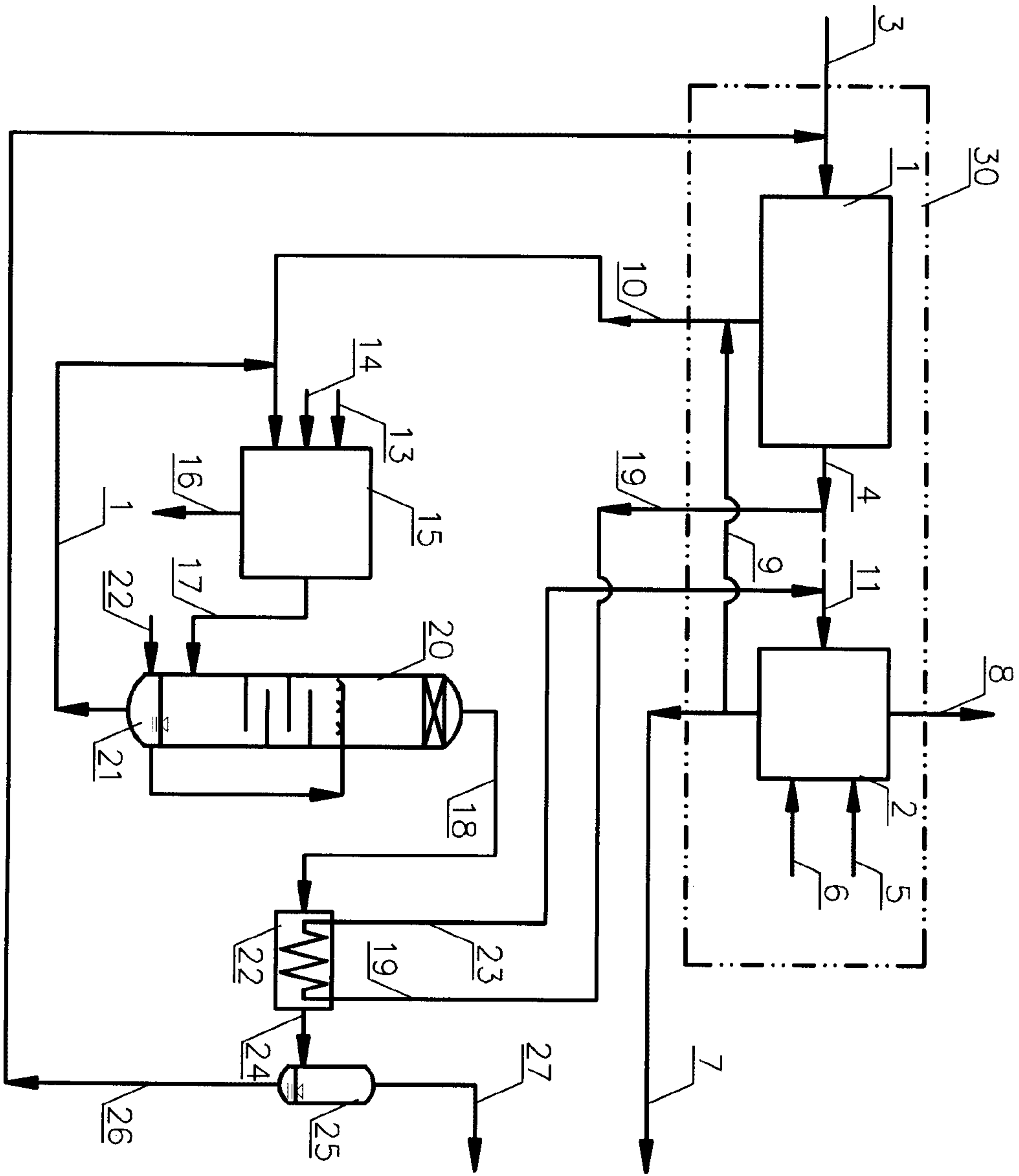


FIG.6

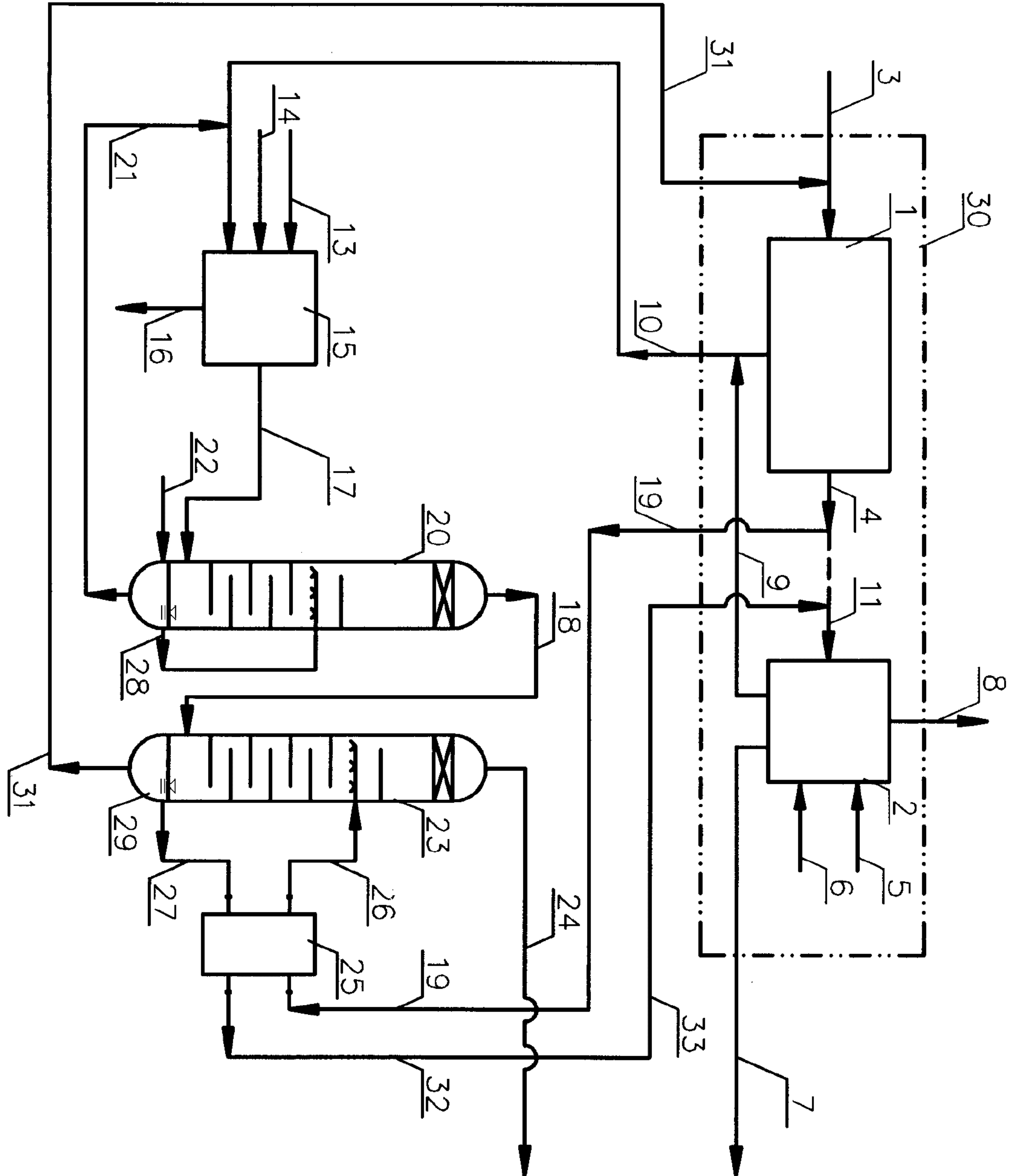
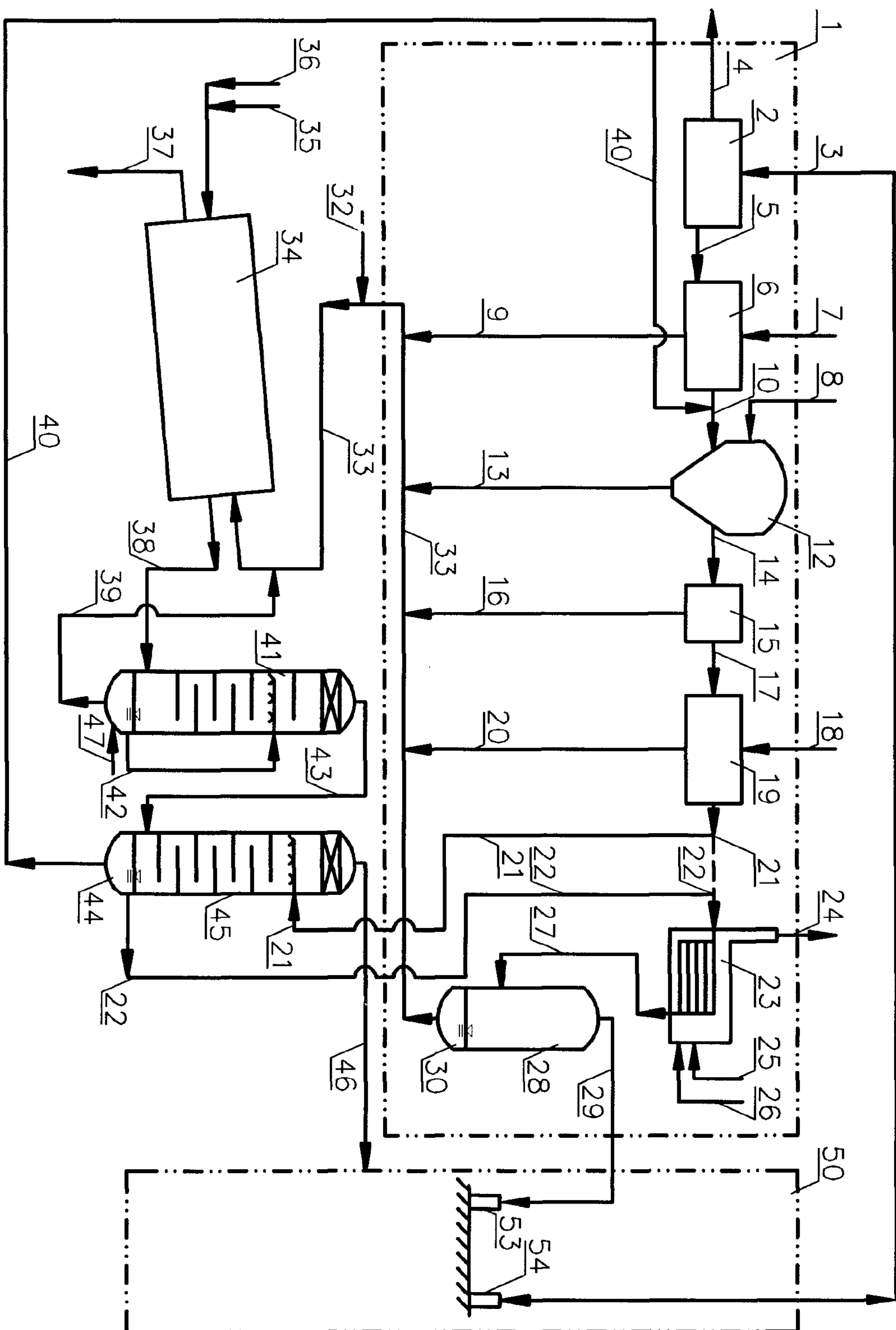


FIG. 7



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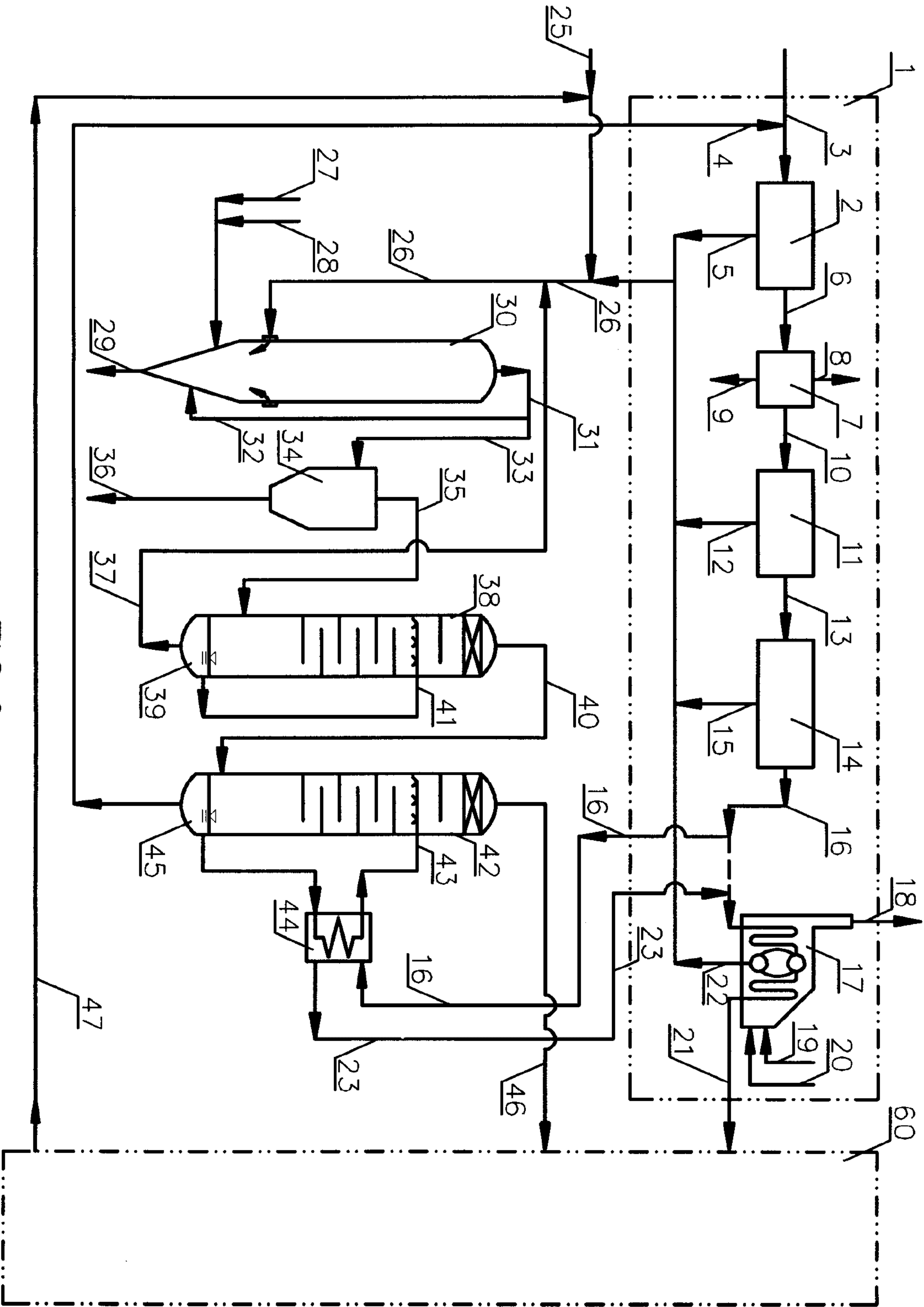


FIG. 9

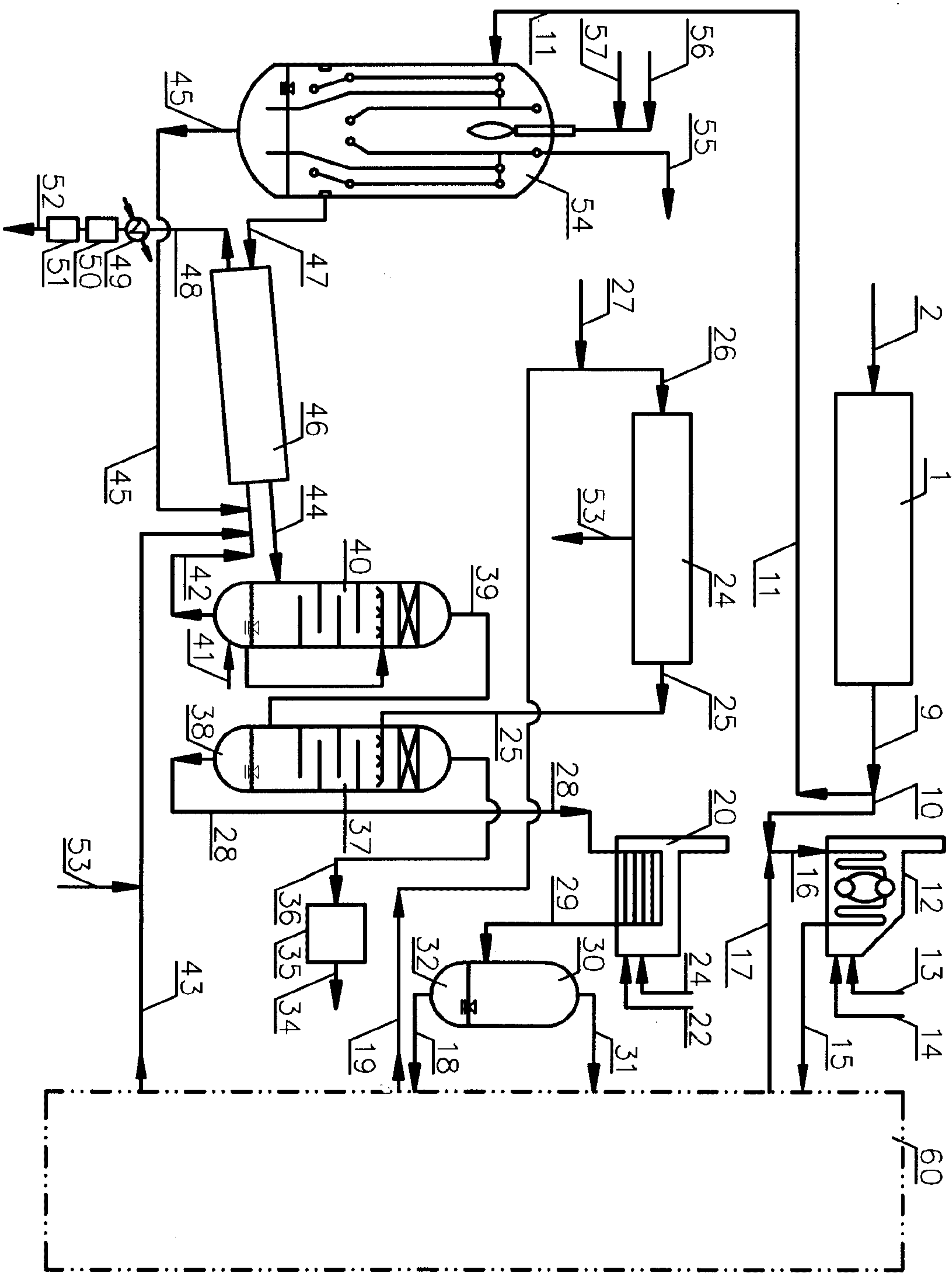
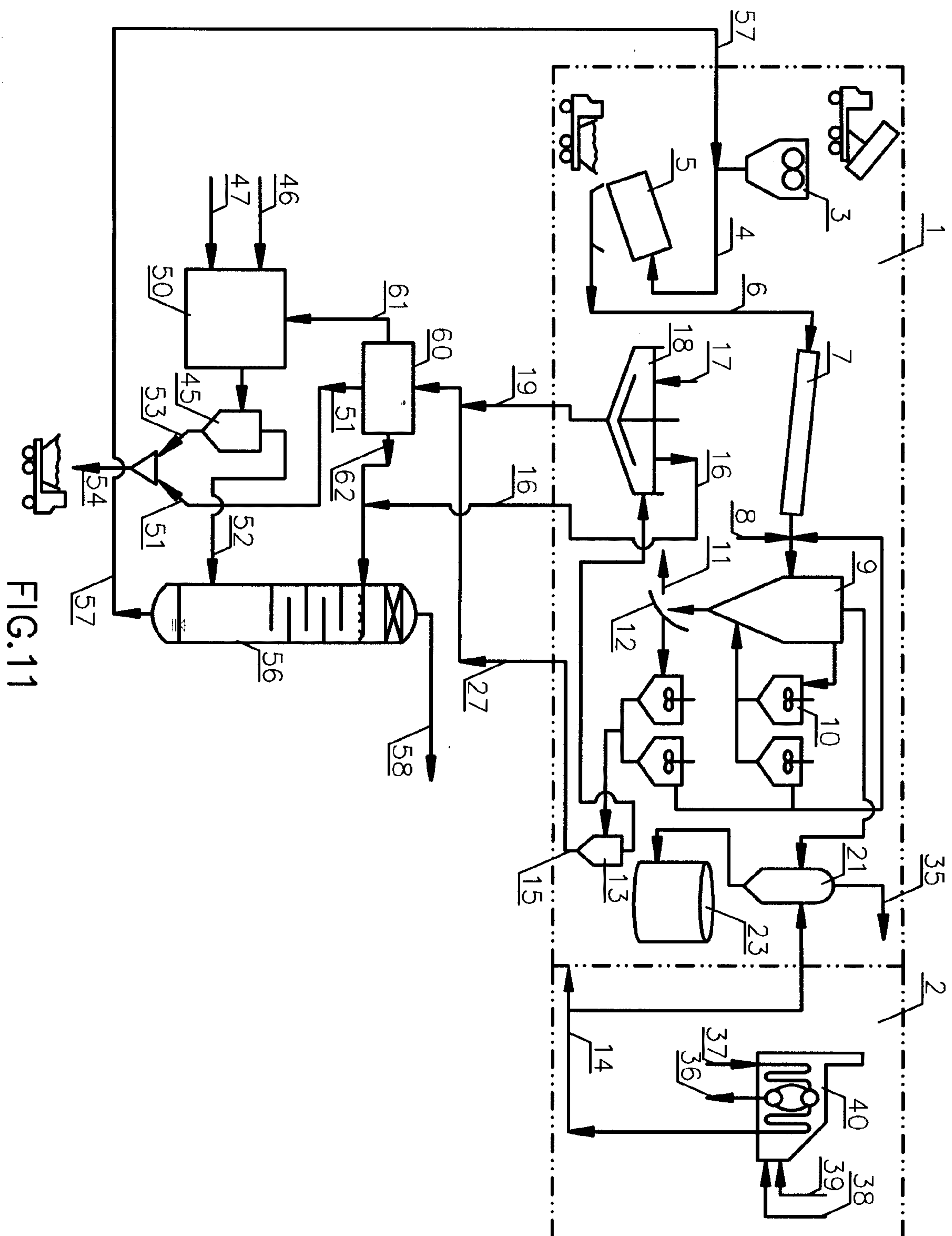


FIG.10



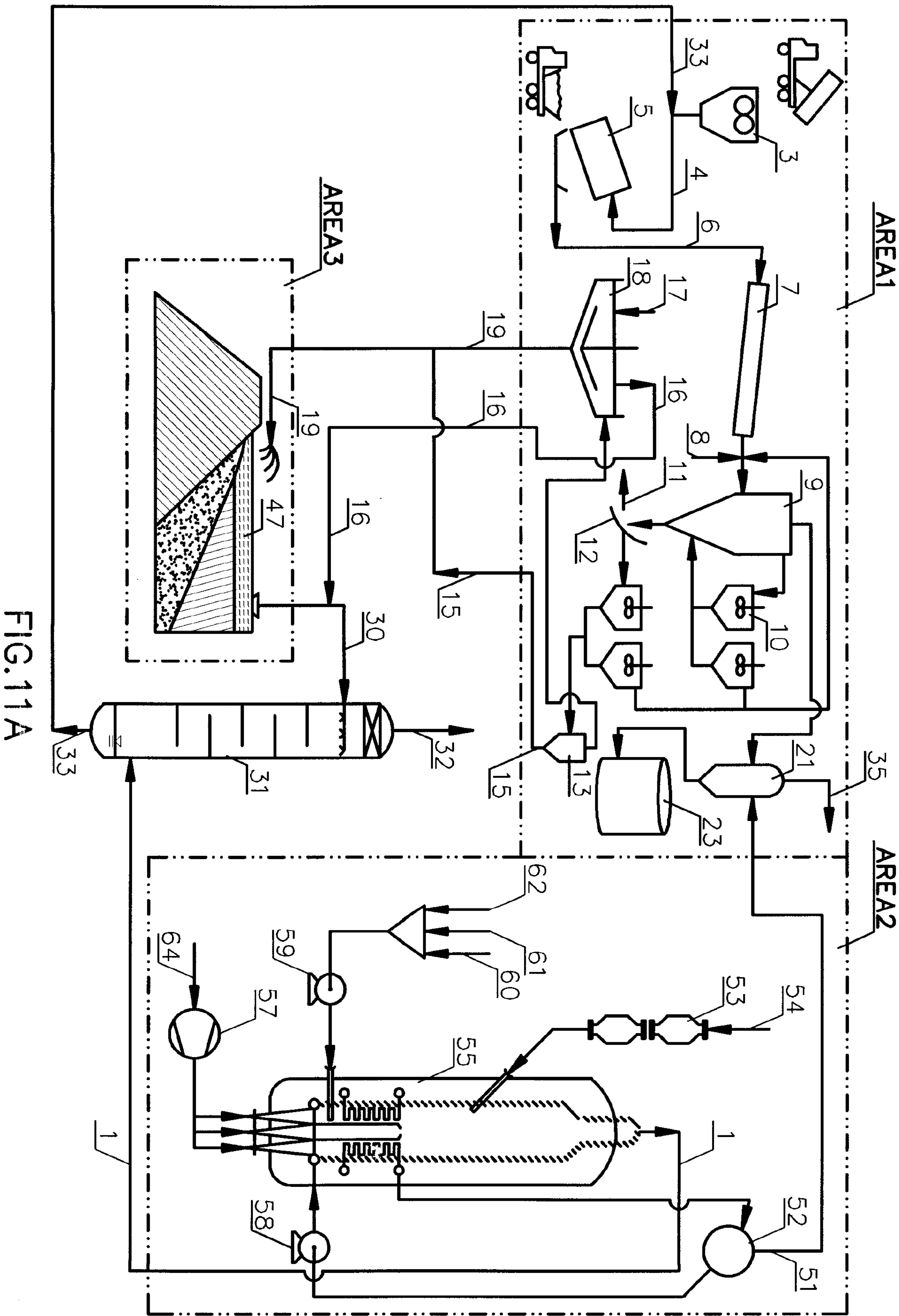


FIG.11A

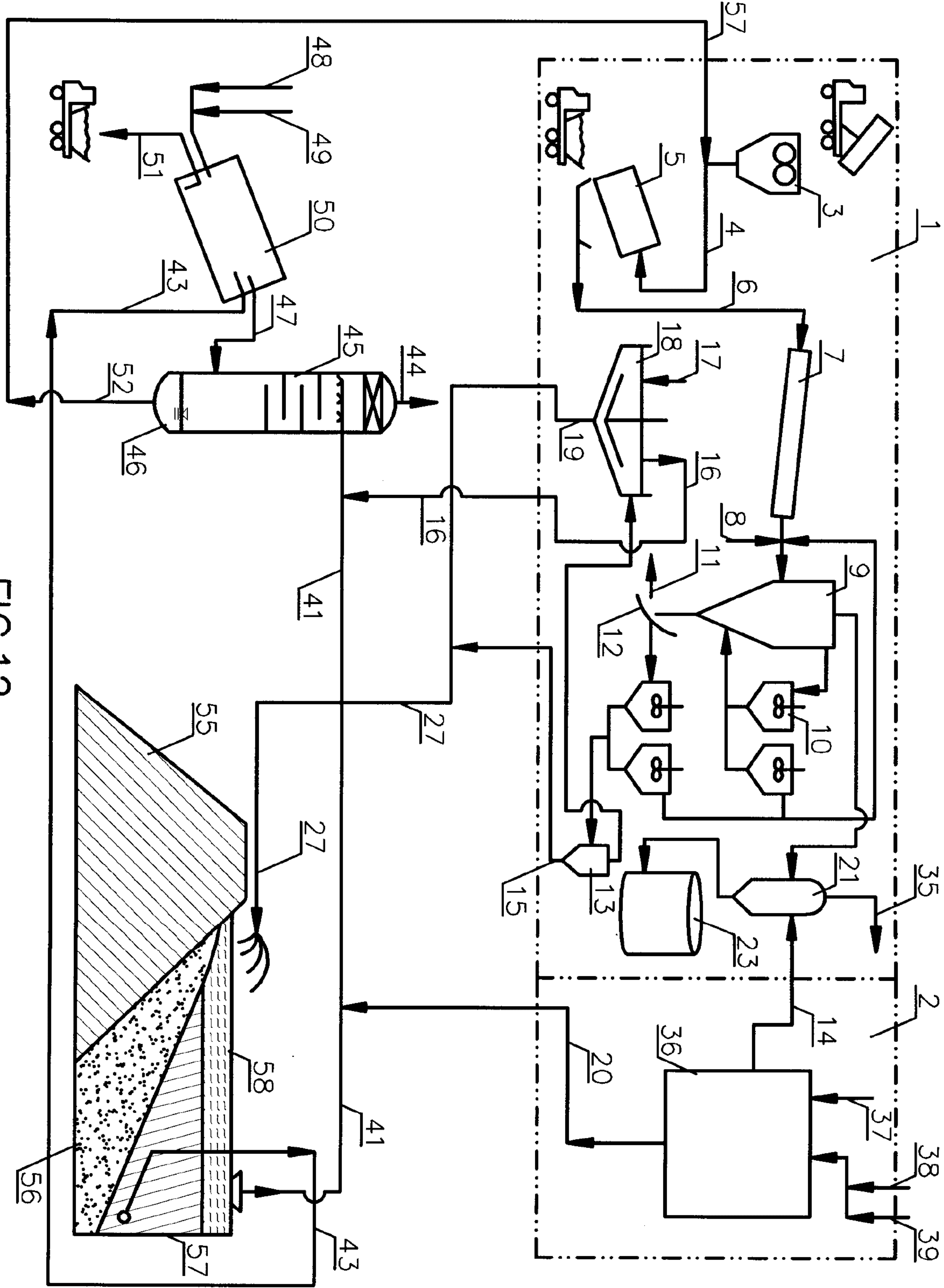


FIG.12

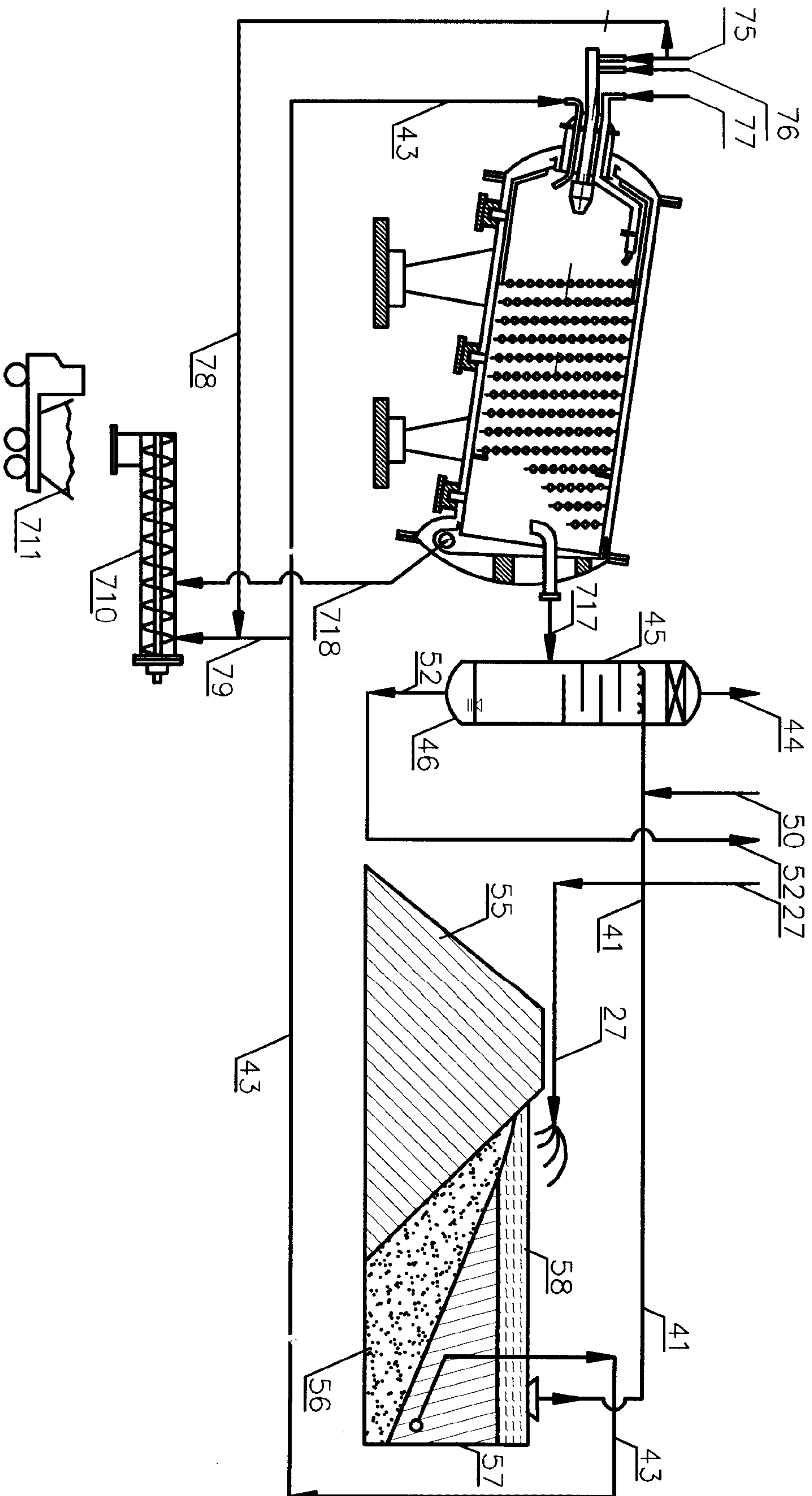


FIG. 12A

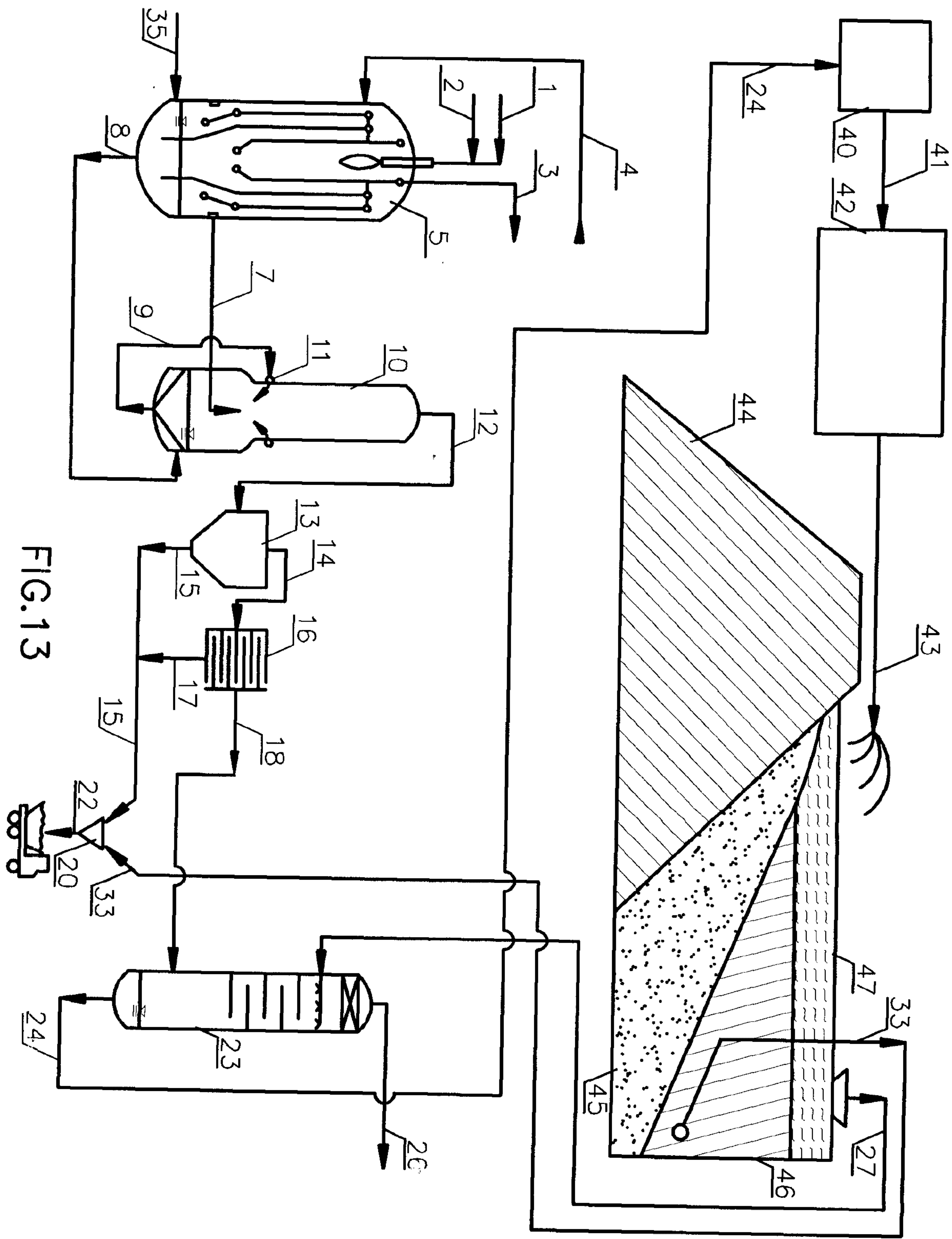


FIG. 13

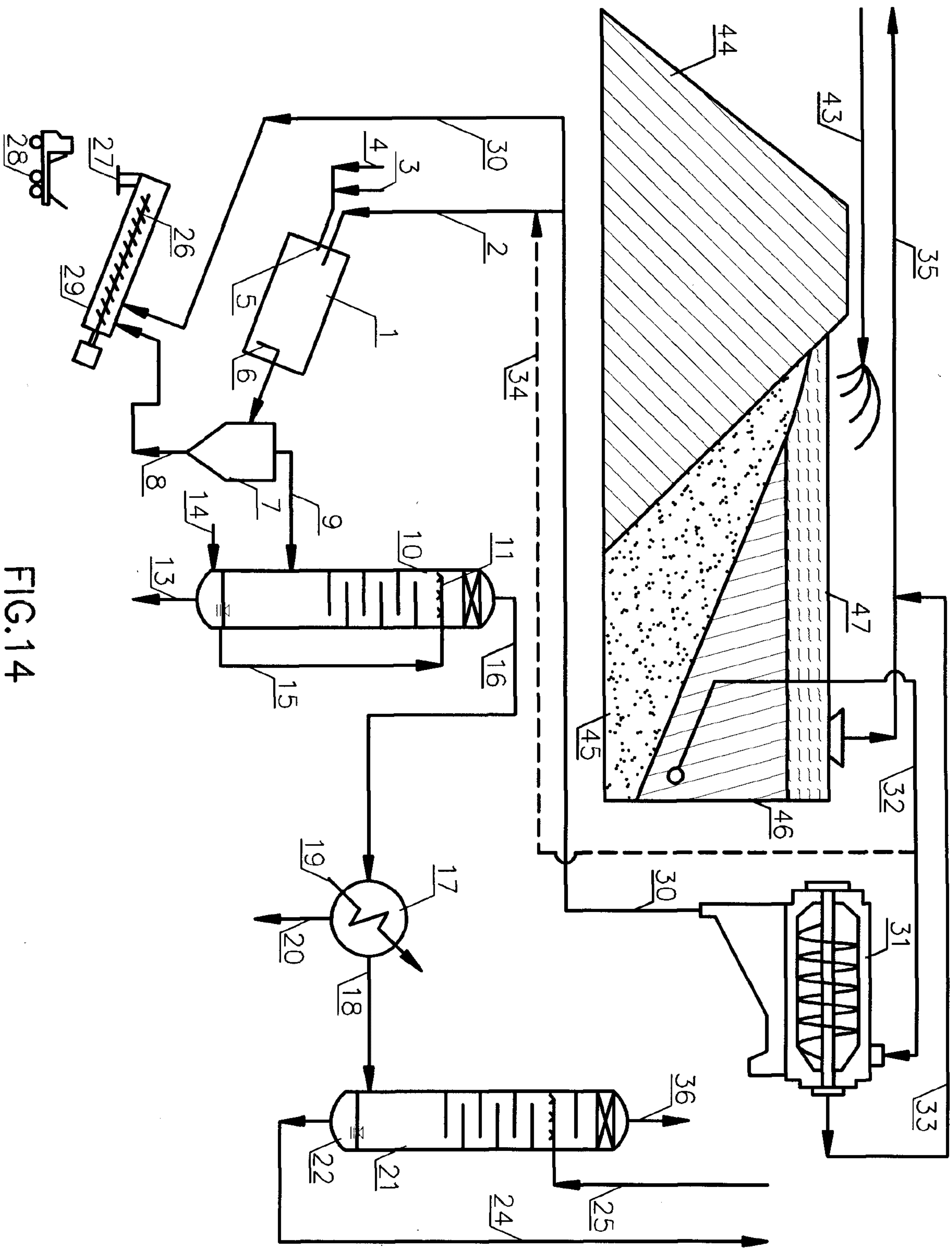


FIG. 14

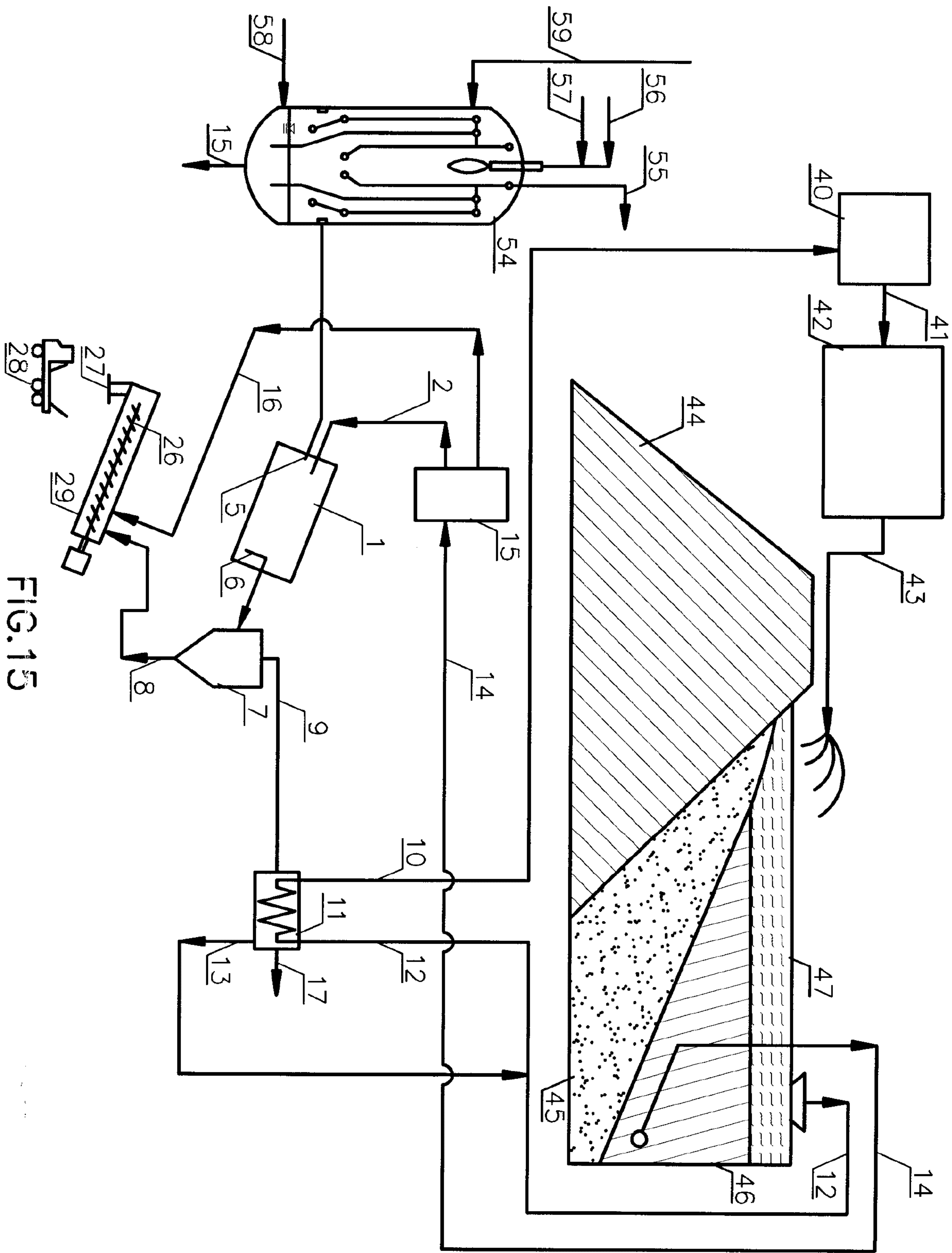


FIG.15

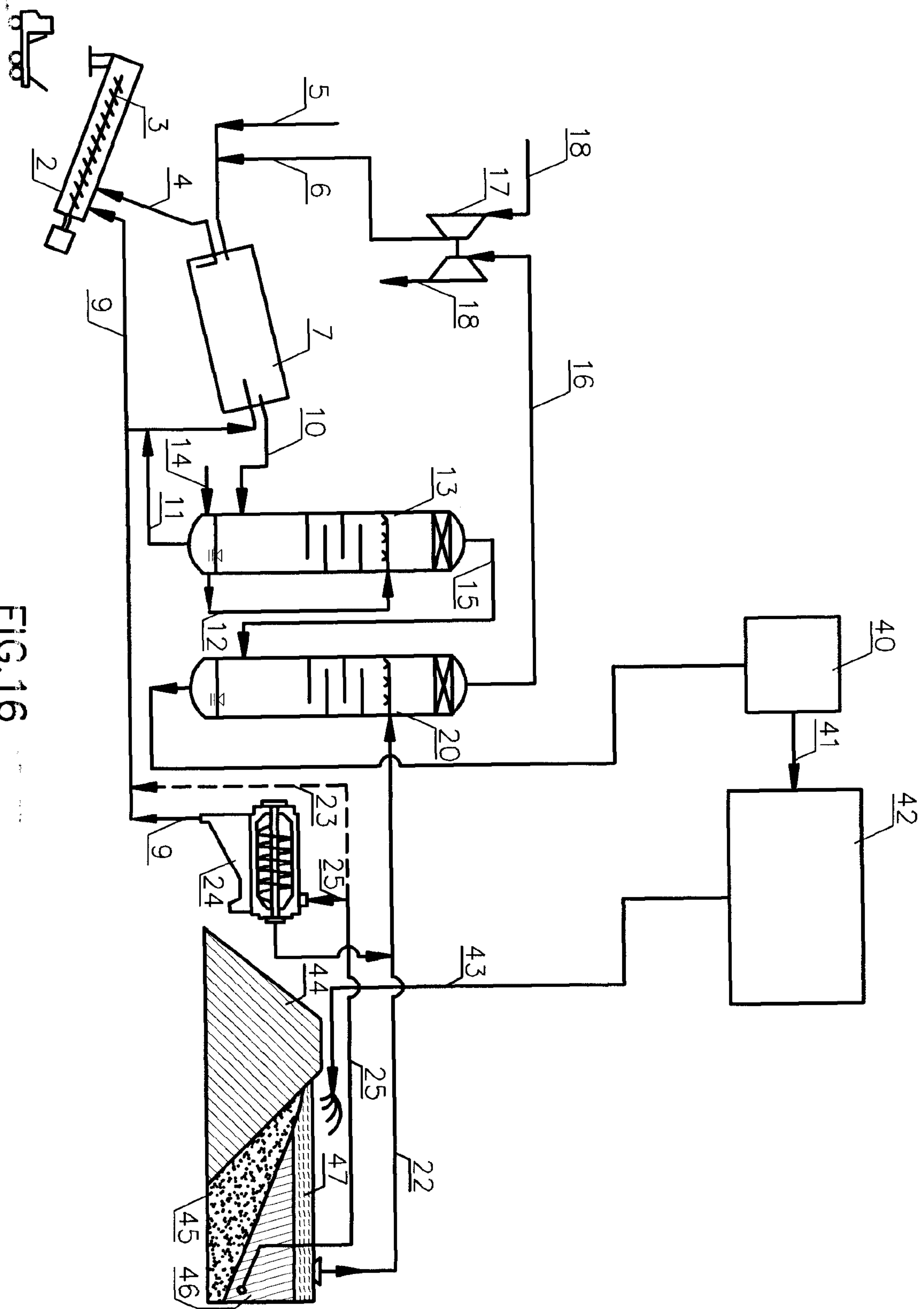


FIG.16

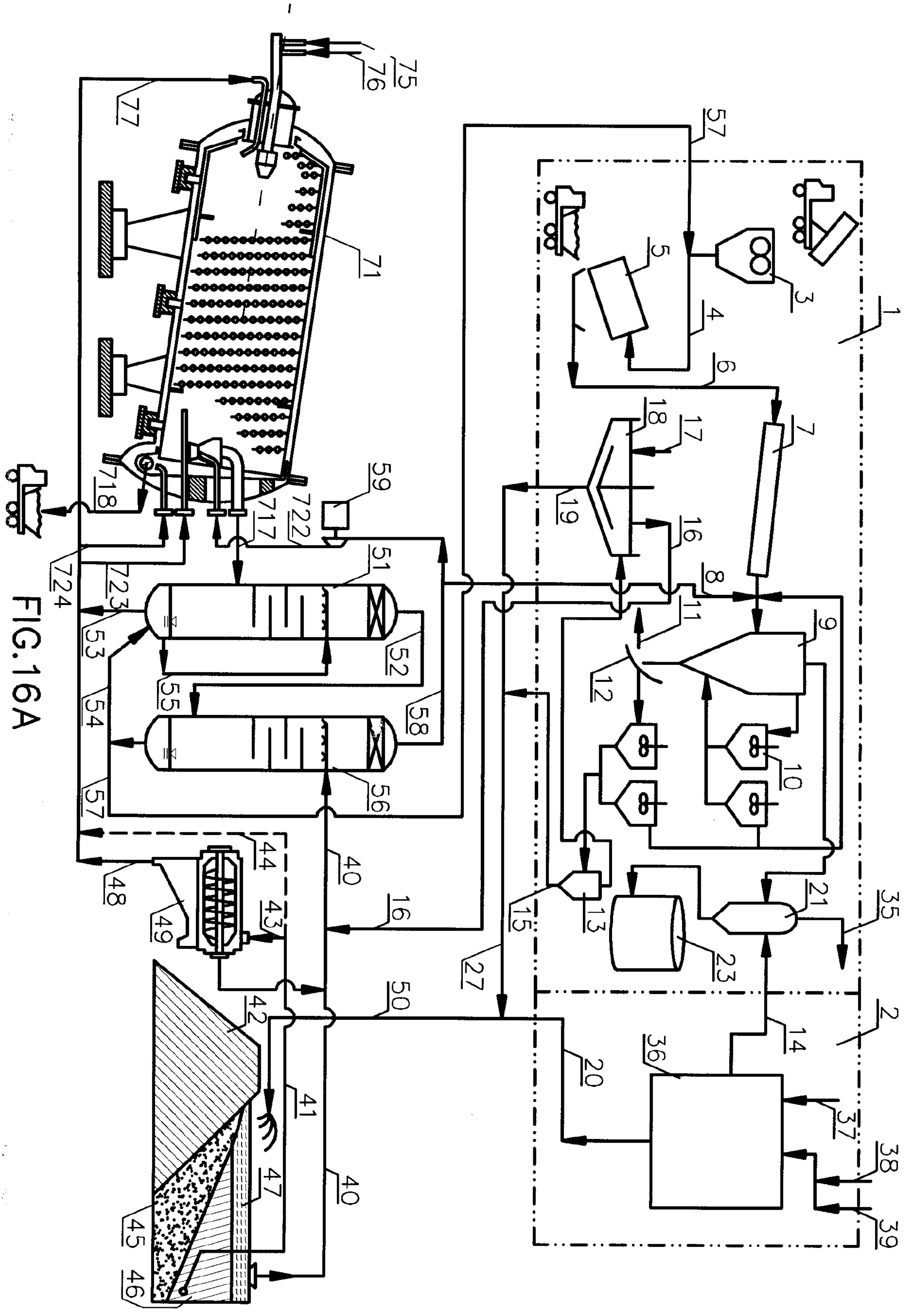


FIG. 16A

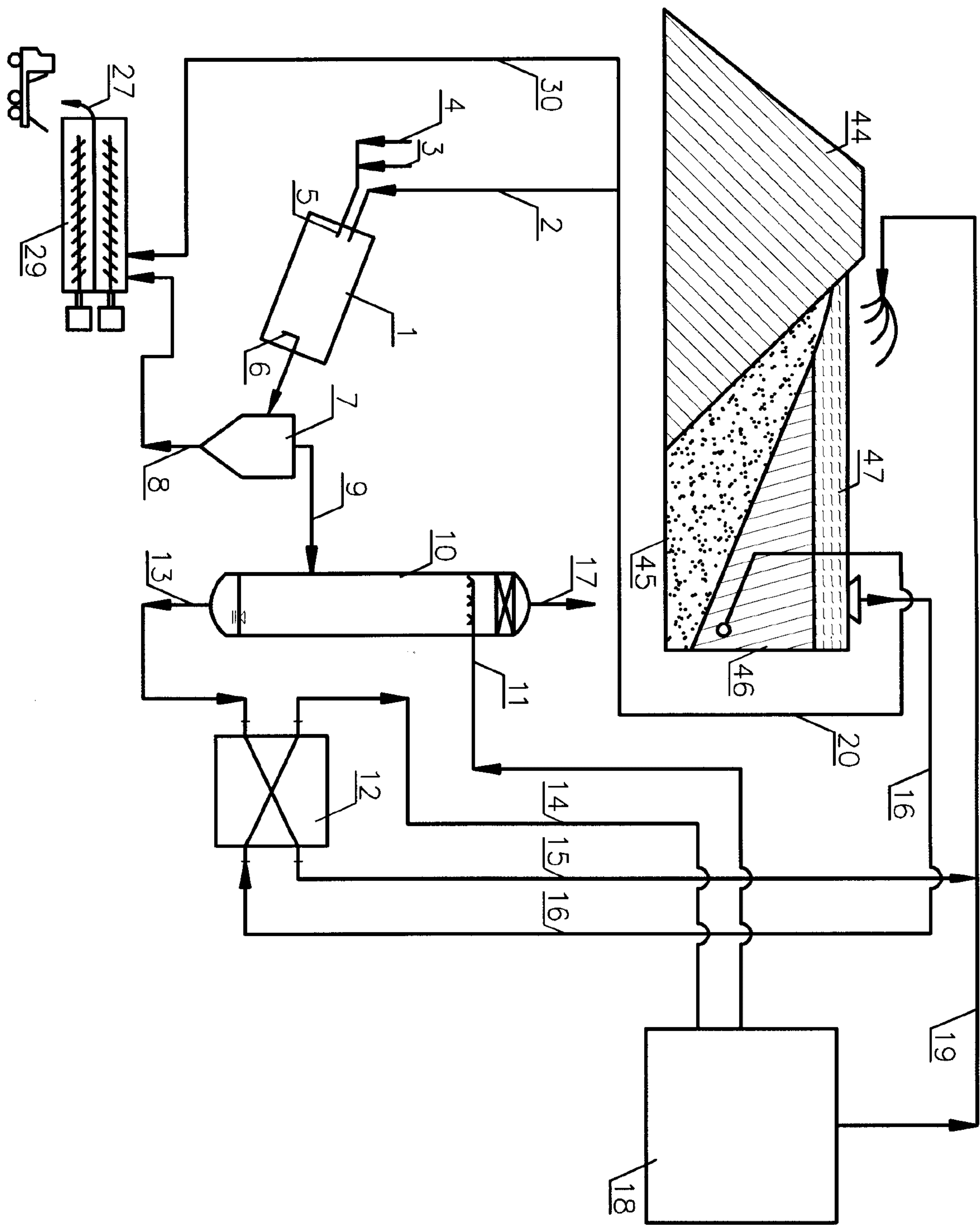


FIG.17

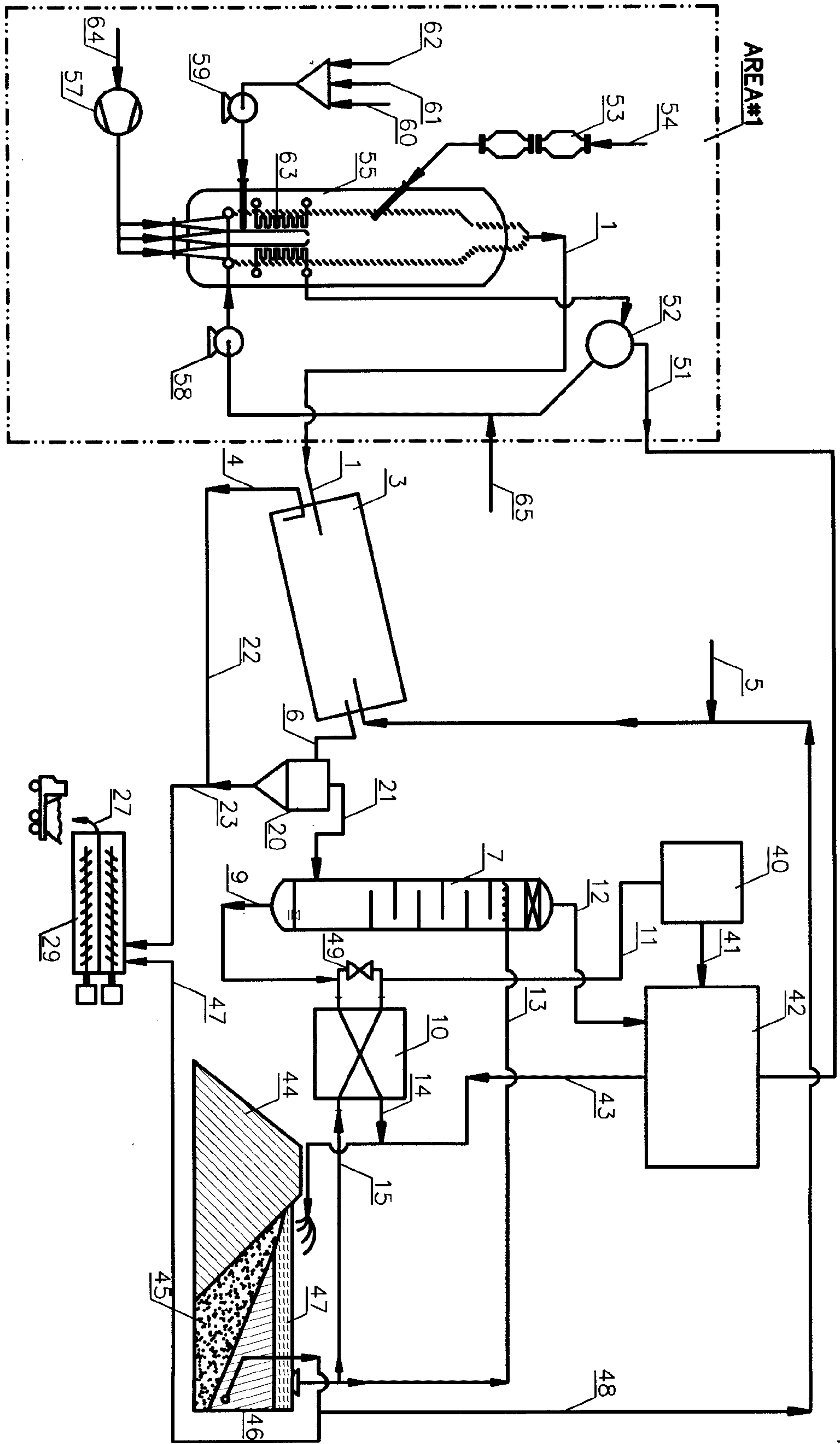


FIG.18

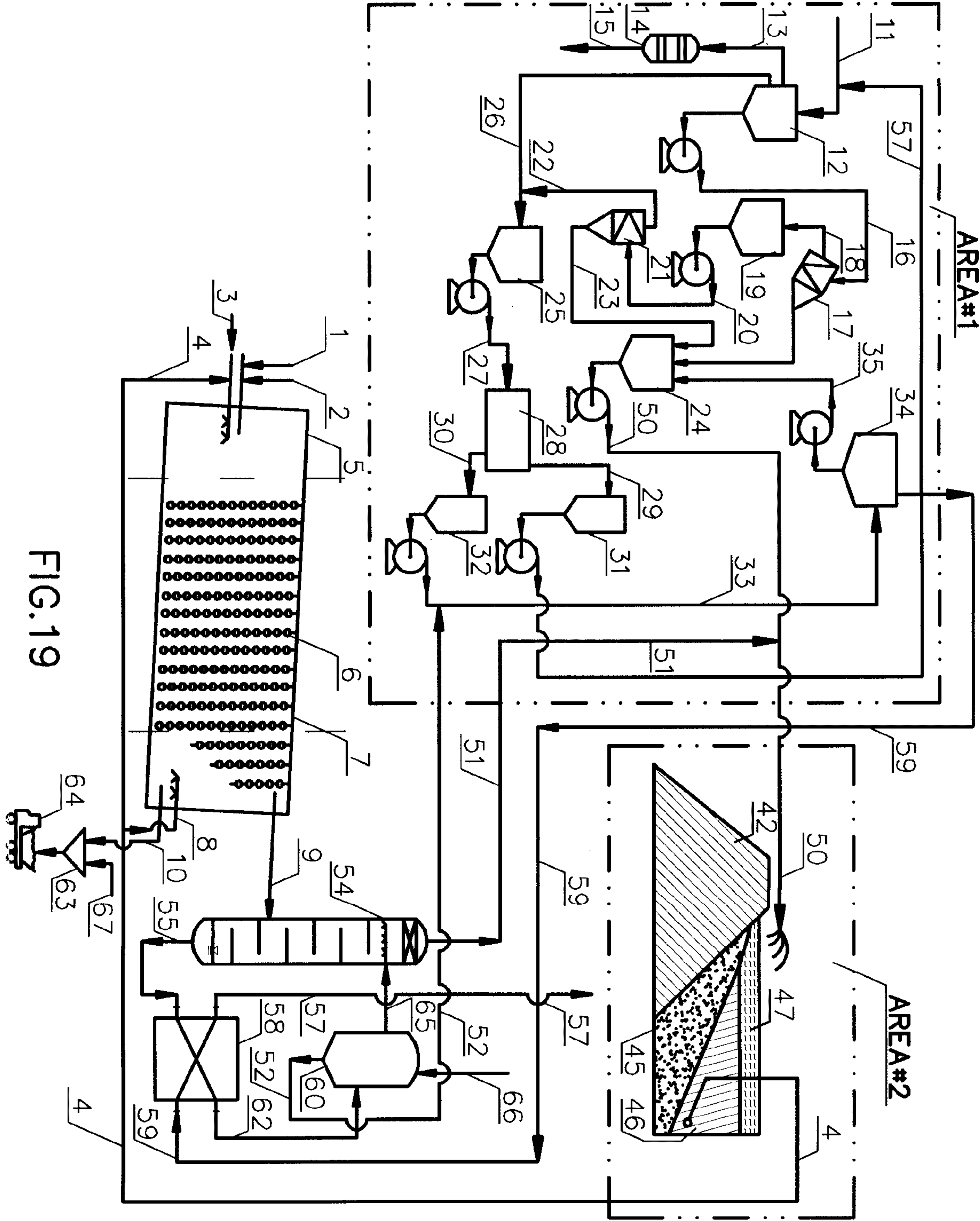


FIG.19

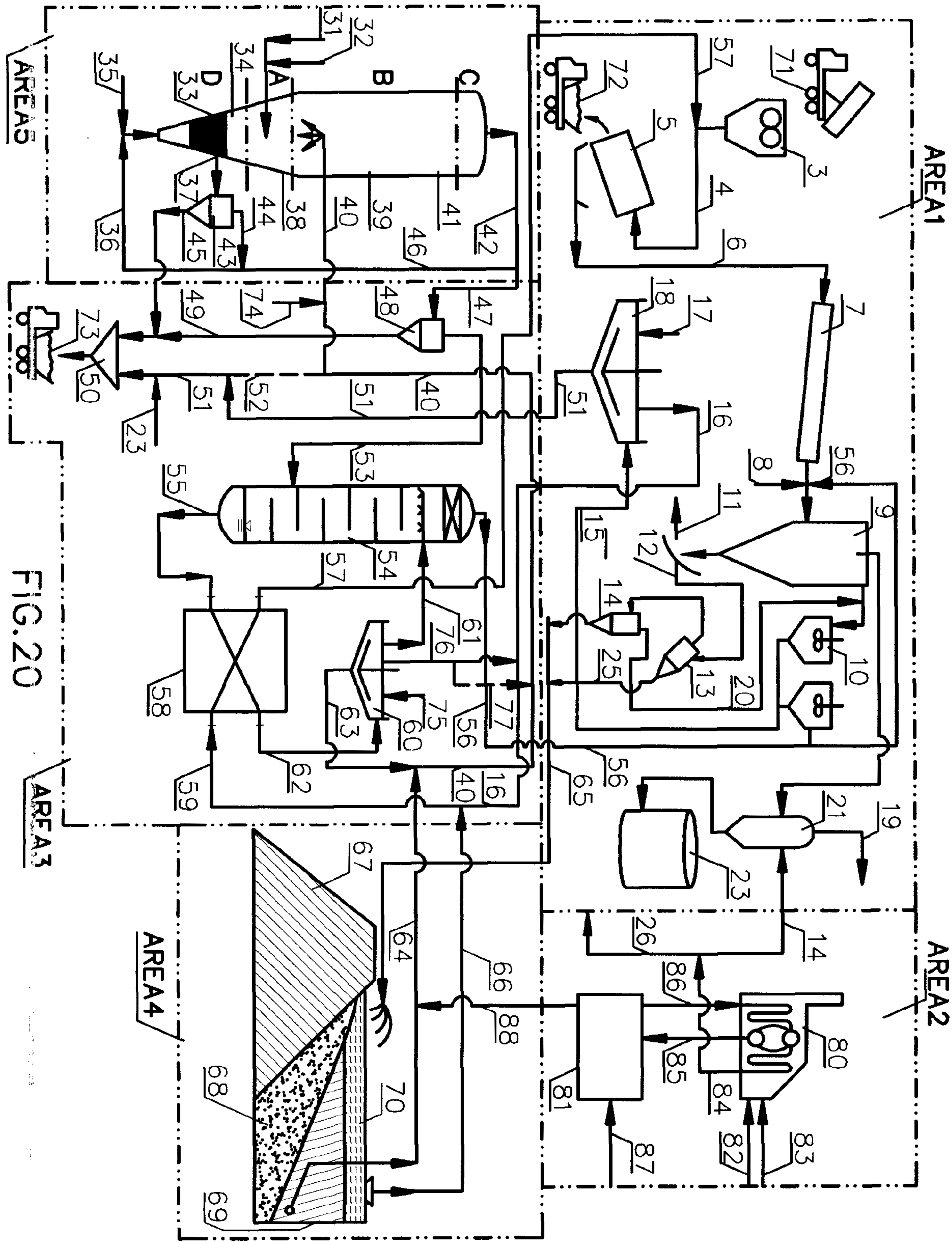


FIG.20

Fig. 21

Mixing fine tailing water with combustion gas to evaporate the water from the fine-tailing and generating a stream of steam, solids and combustion gas.



Removing the solids from the gas phase to generate combustion gases and steam flow.



Extracting heat from the solid lean gas stream while condensing the steam into useable liquid water.



Using the extracted heat to heat the process water flow.



Using the hot process water for bitumen extraction.