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(54) Titre : PROCEDE INTEGRE DE PRODUCTION DE VAPEUR POUR RECUPERATION AMELIOREE DU PETROLE
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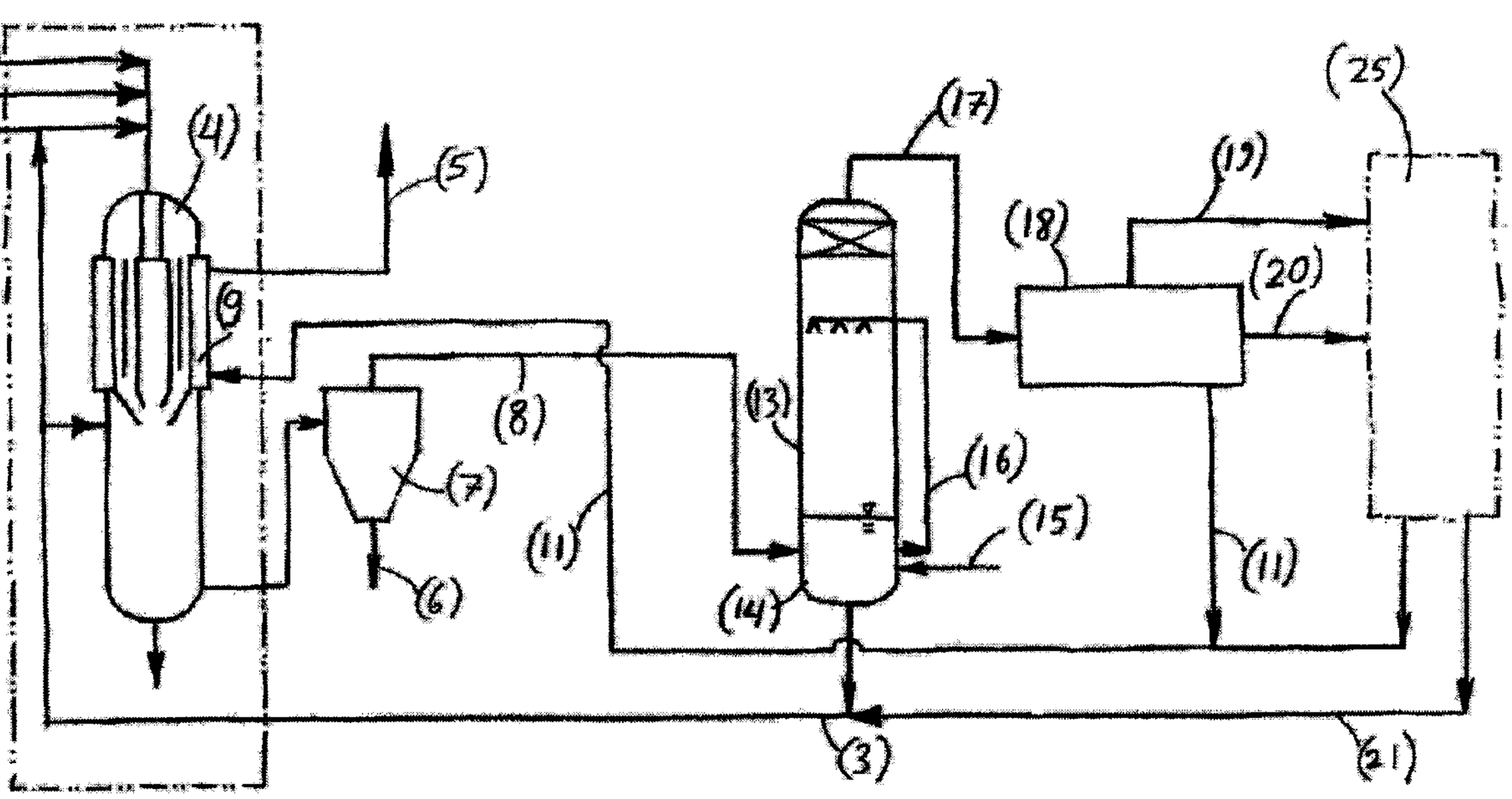

(57) Abrégé/Abstract:
A method and system for producing steam for extraction of heavy bitumen including the steps of mixing fuel with an oxidizing gas. Combusting the mixture and capturing portion of the combustion heat for generating steam from clean water. Mixing the combustion gas with low quality contaminated water and transferred the liquid water to gas phase with solids, wherein solids are separated from the gas phase. The gas phase is mixed with saturated water to scrub the remaining solids and produce saturated steam. The solid rich saturated water is recycled back and mixed with the combustion gases for liquid gasification. The saturated steam is condensed to generate heat and clean condensed water for steam generation. The heat can be used for evaporating additional low quality water at distillation facility to produce distilled water and concentrate brine. The brine is recycled back for liquid gasification. The high pressure steam is sent to an enhanced oil recovery facility for extract heavy oil.

ABSTRACT OF THE DISCLOSURE

A method and system for producing steam for extraction of heavy bitumen including the steps of mixing fuel with an oxidizing gas. Combusting the mixture and capturing portion of the combustion heat for generating steam from clean water. Mixing the combustion gas with low quality contaminated water and transferred the liquid water to gas phase with solids, wherein solids are separated from the gas phase. The gas phase is mixed with saturated water to scrub the remaining solids and produce saturated steam. The solid rich saturated water is recycled back and mixed with the combustion gases for liquid gasification. The saturated steam is condensed to generate heat and clean condensed water for steam generation. The heat can be used for evaporating additional low quality water at distillation facility to produce distilled water and concentrate brine. The brine is recycled back for liquid gasification. The high pressure steam is sent to an enhanced oil recovery facility for extract heavy oil.

INTEGRATED STEAM GENERATION PROCESS FOR ENHANCED OIL RECOVERY.

Field of the Invention

This application relates to a system and method for producing steam for Enhanced Oil Recovery (EOR) facilities. This new invention relates to processes for producing steam from any type of fuel, including low quality, solid fuels like petcoke or coal and any water source without any water treatment like brackish water containing high levels of dissolved and suspended inorganic solids or organics, such as oil.

The invention includes an atmospheric or pressurized solid fuel boiler package with low pressure and temperature water distillation package for the production of pure steam for injection into the underground formation to recover heavy crude oil. The injection of steam into heavy oil formations and especially oils and formation was proven to be an effective method for EOR and it is the only method currently used for recover bitumen from deep underground oils and formations in Canada. It is known in previous applications that EOR can be utilized to recover bitumen where the combustion gases are injected into the formation. The problem with that approach is that the oil producers are reluctant to implement significant changes, especially if they include changing the composition of gas injected to the underground formation. This problem was solved in this application with the use of "commercially available" steam boilers and water treatment facilities together with the DCSG (Direct Contact Steam Generation) and maintaining most of the advantages of the DCSG for the overall process in the integrated system

as described herein.

By integrating the boiler, the distillation facility and the other process units as described in this application, the water and combustion gas are separated with Zero Liquid Discharge. A ZLD facility is more environmentally friendly compared to a system that generates reject water and sludge. In one embodiment, most of the water vapor and the produced heat is recovered and used to generate distilled water for additional steam production. The system might also include a direct contact brine evaporator dryer (similar to DCSG), a dry solids removal system (to remove them from the gas stream), and a wet steam generator, (a scrubbing vessel for scrubbing solids, sulfur and generating wet steam). The boiler can be a low efficiency boiler (without economizer) as the heat of the discharged combustion gas is used in the direct contact dryer and in the direct contact wash vessel to evaporate water.

The brine from the distillation facility can be recycled to a liquid evaporator and dryer where additional steam is generated and dry solid wastes will be removed from the produced gas in a commercially available gas-solid separation unit.

The invention method and system for producing steam for extraction of heavy bitumen including the steps of mixing fuel with an oxidizing gas. Combusting the mixture and capturing portion of the combustion heat for generating steam from clean water. Mixing the combustion gas with low quality contaminated water and transferred the liquid water to gas phase with solids, wherein solids are separated from the gas phase. The gas phase is mixed with saturated

water to scrub the remaining solids and produce saturated steam. The solid rich saturated water is recycled back and mixed with the combustion gases for liquid gasification. The saturated steam is condensed to generate heat and clean condensed water for steam generation. The heat can be used for evaporating additional low quality water at distillation facility to produce distilled water and concentrate brine. The brine is recycled back for liquid gasification. The high pressure steam is sent to an enhanced oil recovery facility for extract heavy oil.

The above-mentioned invention also relates to processes for making SAGD and CSS facilities or other EOR facilities more environmentally friendly by using low quality fuels, like petcoke or coal instead of natural gas. It reduces the amount of greenhouse gas emissions through thermal efficiency. The generated CO_2 gas can be recovered for underground sequestration or for usage in EOR.

BACKGROUND OF THE INVENTION

Steam injection into deep underground formations has proven to be an effective method for EOR facilities producing heavy oil. It is typically done through SAGD (Steam Assistant Gravity Drainage), Steam Drive or by Cyclic Steam Stimulation (CSS). In recent years, the SAGD method has become more popular, especially for heavy oil sand formations. Presently, different forms of steam injection are the only method commercially used on a large scale for recovering oil from oil sands formations.

The use of DCSG (Direct Contact Steam Generator) to generate high pressure steam and

flue gas mixture has many advantages; however it might have some significant disadvantages resulting from the presence of the combustion gases, mainly CO2, within the steam. That might present a problematic situation when used in combination with particular types of underground formations and recovery processes.

It is a goal of the present invention to provide a system and method for the improvement of EOR facilities like SAGD, through a supply of high – pressure steam for underground injection wells.

It is another objective of the present invention to provide a system that can produce steam from distilled water and the brine produced by the distillation facility without liquid discharge.

Another objective of the invention is to provide a system and method that utilizes low-grade fuel with commercially available solid fuel burner packages.

An additional objective of the present invention is to provide a system and method that will remove produced solids from the system by converting the liquids to gas phase and removing solids from the gas phase. The solids are as result from the fuel and the evaporated water. The solids can be silicon base materials, calcium based material, different type of salts carried by the water etc.

Furthermore, it is another objective of the present invention to provide a system and

method that enhances thermal efficiency and minimizes the amount of energy used to produce the steam injected into the underground formation to recover heavy oil.

It is a further objective of the present invention to provide a system and method that minimizes the amount of greenhouse gases released out into the atmosphere.

A further purpose of the present invention to provide a system and method that serve to make EOR facilities, like SAGD, more environmentally friendly by using low - quality fuel.

It is still a further objective of the present invention to provide a method for steam production for the extraction of heavy bitumen.

It is an object of the present invention to provide a method for producing super-heated, dry, solid- free steam.

It is still a further objective of the present invention to provide a method that uses discarded water, possibly mixed with oil, clay or silica sand from a SAGD facility.

It is another objective of the present invention to provide a system for oil recovery using heat injection.

These and other objectives and advantages of the present invention will become apparent

from a reading of the attached specifications and appended claims.

SUMMARY OF THE INVENTION

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 from an above ground oil extraction facility includes the following steps: (1) mixing a low quality fuel containing heavy bitumen, solid hydrocarbons or carbon emulsions and oxidizing gases like oxygen, enriched air or air; (2) combusting the mixture under high pressure and temperature while transferring the liquid phase to a gas phase; (3) evaporating de-oil produced water and make-up water at distillation facility to produce distilled water and concentrate brine; (4) recovering heat from the combustion reaction 2 for generating high pressure steam; (5) separating the solids from the gas phase in a dry form; (6) mixing the gas with liquid water, possibly with lime or other alkaline materials for SO2 removal, at saturated temperature and pressure in order to produce a saturated, clean wet steam and gas mixture, while removing most of the SO2 and scrubbing any remaining solids from the gas; (7) Injecting the produced steam into underground formation for EOR (Enhanced Oil Recovery)

If a ZLD (Zero Liquid Discharge) process is preferable, then prior to step (5) there an additional step may be added (3A); solids rich water is injected to the flow of the combustion gases to generate steam and solid waste. The water contains high levels of total dissolved and suspended solids (like silica, calcium, magnesium, sodium, carbonate or organics and the gypsum generated from the scrubbing of the SO2). This step should be fulfilled before step 5,

due to the fact that the solids carried with the water are separated from the gas phase in a dry form. Step 3A can be done in a pressurized rotary kiln, in a fluidized bed type pressurized spray dryer design where the low quality water slurry is sprayed into the flow of the combusted gas or by integrated water injection as part of the boiler.

If a pressurized boiler is used and a thermal distillation process (like Multi-Effect Distillation), then prior to step (7) there an additional steps may be added; (6A) Separating the combustion NCG (Non Condensable Gases) from the steam by condensing the steam. (6B) Recovering the condensed water and condensed heat from the gas-steam mixture. (6C) Using the condensed water, possibly with the distilled water for generating the steam in step 4. Steps 1-4 can be done using commercially - available solid fuel boiler packages and distillation units.

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.

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

According to one aspect of the present invention, there is provided a method for

producing a steam and gas mixture for injection into an underground formation to extract heavy bitumen comprising mixing fuel with oxidation gases to form a mixture; combusting 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.

According to another aspect of the present invention, there is provided a system for producing a clean steam and gas mixture for injection into an underground formation to extract heavy bitumen comprising mixing fuel with oxidation gases in a combustion boiler to form a mixture; combusting 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 the 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.

According to another aspect of the present invention, there is provided a method for producing a pure steam mixture for injection into an underground formation to extract heavy bitumen comprising mixing fuel with oxidation gases to form a mixture; combusting 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, heat from the clean steam and gas mixture being used to heat water supplied from a distillation facility, the water from the distillation facility being combusted 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

FIGURE 1 is a schematic view of an illustration of the current invention for an integrated solid fuel boiler and distillation for EOR;

FIGURE 2 is a schematic view of an illustration of a boiler, solid removal, wet steam scrubber and integrated distillation unit for the production of steam for heavy oil recovery;

FIGURE 3 is a schematic view of an illustration of a boiler, direct contact steam generator with dry solid generation, solid removal, direct-contact scrubber with wet steam generator, direct-contact condenser and low - pressure steam generation and distillation facility for generating distilled water for steam generation during EOR;

FIGURE 3A is a schematic view of an illustration of an atmospheric boiler, direct contact drier with dry solid generation, solid removal, direct-contact scrubber with wet steam generator, and Mechanical Vapor Compression distillation facility for generating distilled water for steam generation in the boiler for EOR;

FIGURE 4 is a schematic view of: a direct contact steam generator, solids separator, heat exchanger for steam generation, scrubbing vessel and condenser for generating low pressure steam for distillation facilities;

FIGURE 5 shows an illustration of: a boiler, direct contact steam generator with dry solid generation, solid removal system, direct-contact scrubber with a wet steam generator, direct-contact condenser and a low pressure steam generation and distillation facility for producing distilled water for steam generation during EOR;

FIGURE 6 is a schematic view that shows one possible option, which makes use of an MED (Multi Effect Distillation) unit. This type of commercially available distillation unit may be used within the present invention; and

FIGURE 7 is a schematic view of the combustion side of the system described in Fig. 6. with water injected Pressurized Fluidized-Bed Boiler.

DETAILED DESCRIPTION OF THE DRAWINGS

FIGURE 1 shows a block diagram. Boiler 1 combusts low quality fuel 4. For example: untreated, heavy crude oil, vacuum residue (VR), coal, asphaltin or petcoke in slurry form, the fuel is injected simultaneously with oxidation gas 5 (oxygen, air or enriched air). Next, they are combusted. The combustion boiler can be any boiler capable of combusting the particular fuel. Water 7 is used to generate high-pressure steam 6 for EOR. The discharged combustion gases 8 are treated in block 2, where they are used to generate additional water vapor, remove the SO2 and the waste solids. This is done by injecting slurry water with the high levels of solids into the combustion gases that are discharged from the boiler. The amount of the injected water is controlled, so that all the injected water evaporates, leaving the solids it carried in a dry form. This can be done in a rotating kiln type unit used by different industries to dry solids; or by an up - flow high pressure drier, capable of eliminating the internal solids deposits. The solids rich gas further flows to a gas-solid separator unit. Such units are commercially available and are capable of removing most of the solids in a dry form. The removed solids are released through the de-compression hopper system, possibly with heat exchange to remove their heat before they are discharged. For dust control, the low quality water can be utilized by spraying it onto the dry powder. After most of the solids have been removed in a dry form 9, the solid, lean gas flow 10 flows to liquid scrubber and steam generation vessel where the gas is washed by water at a saturated temperature. To remove the SO2 the water can contain lime as well as other alkali materials. Removing heat separates the saturated gas from the steam; the water is recovered in a liquid form. For pressurized boiler the liquid water can be flashed to generate low-pressure steam. The condensation heat and steam are further used for distillation of brackish and produced water 13 in a commercially available distillation facility 3. The distillation facility can be MED

(Multi Effect Distillation) MSF (Multi-Stage Flash), or combined with VC (Vapor Compression) facilities. The distilled water 7 is used for generating steam 6 and is injected to the oil formation using injection well 16 for EOR. The brine produced by the distillation facility 3 is recycled back to generate steam and dry solids 2.

FIGURE 2 is a schematic view of one illustration of the present invention. Fuel 2, possibly with water 3 is mixed with oxidized gas 1 and injected into a pressurized steam boiler 4 where the combustion is at an elevated pressure. The boiler can have solid char discharged from the bottom of its combustion chamber. The boiler produces high-pressure steam 5 from distilled water feed 11. The steam is injected to the underground formation EOR.

Solids rich water 3 is injected to the combustion boiler 4. The amount of water 3 is controlled to make sure that all the water is converted to steam and that the remaining solids are in a dry form.

The solid rich combustion gases discharged from the boiler flow to a dry solids separator 7. The dry solid separator is commercially available in a package. There are some gas-solid separation designs than can be used. The dry solids are removed in a dry form from the separator 6. The solids lean flow 8 is mixed with saturated water 14 in a direct contact steam generation and wash vessel 13 where the heat, carried with the gas 8 generates steam. Saturated liquid water 16 washes the solids carried within the gas. The liquid water may include alkaline materials (like lime) to scrub the SO2 present in the pressurized combustion gases generated by the boiler. Make-up water 15 is added to the scrubbing vessel 13 to replace the evaporated water and the solid rich water discharged from the vessel bottom. The solids rich water 3 is discharged from the bottom of vessel 13 and recycled back to the boiler 4 where the liquid water is converted to

steam and the solids are removed in a dry form, ready for disposal. The combustion gases saturated with wet steam 17 are free of solids. Also, most of the sulfuric gas generated from burning sulfur - rich fuels can be removed in the form of gypsum. The wet gas mixture flows to condenser and heat exchanger 18. Heat is removed from the combustion gases. This results in condensed steam that is separate from the combustion gases. The recovered heat is used to generate low-pressure steam 20 for operating distillation facility 25. The saturated steam in the combustion gas condenses 20 and it is used for steam generation. It also acts as a heat source for the distillation facility 25. The non - condensable combustion gas 19 is carried out after most of the condensed water vapor has been released from the vessel for further treatment; For example, into CO2 recovery for sequestration or directly out into the environment (if there is no requirement for CO2 sequestration).

The combustion gas condensates 11 together with the distilled water from the distillation facility, which is used as boiler - fed water 11 for generating the steam for EOR injection. The distillation facility continually generates brine water with high dissolved solids concentration 21. The brine water is recycled back to boiler 4, where the liquid water is converted to steam and the dissolved solids remain in a dry form. Some of the brine water can be used as make-up water in the scrubbing and steam-generating vessel 15.

The distillation unit 25 is a commercially available facility. There are a few principles and designs that can be used with it. For example, an MED (Multi Effect Distillation system) can be used. The distillation facility treats de-oiled produced water and make up water. This could potentially be brackish water from underground wells (not shown on the sketch).

FIGURE 3 is a schematic view of one embodiment of the present invention. Fuel 2, possibly with water 3 is mixed with oxidize gas 1 and injected into steam boiler 4. The boiler can have a solid waste discharged from the bottom of the combustion chamber. The boiler produces high-pressure steam 5 from distilled feed water 19. The steam is injected to the underground formation through injection well 6 for EOR.

The combustion gases with carry - on flying solids flow to direct contact dryer 15. The dryer generates steam from solid - rich water 14. The drier discharges a stream of combustion gas 13 with dry steam and solid particles that were carried on from boiler 4 and from the solid rich water 14 that was used for steam generation. The amount of water 14 is controlled to verify that all the water is converted to steam and that the remaining solids are in a dry form. The solid - rich gas flow goes to a dry solids separator 16. The dry solid separator is commercially available package and it can be used in a variety of gas-solid separation designs. The solids lean flow 12 is mixed with saturated water 21 in direct contact steam generation and wash vessel 20 where the heat is carried in gas 12 generated steam. The solids carried with the gas are washed by saturated liquid water 23. The liquid water may include lime to scrub the SO2 discharged from the boiler, generating additional solids. The solids rich water 24 is discharged from the bottom of vessel 20 and recycled back to drier 15 where the liquid water is converted to steam and the solids are removed in a dry form for disposal. The combustion gases, saturated with wet steam 22 are solids free and most of the sulfuric gases generated from burning sulfur -rich fuel are removed in the form of gypsum. The wet gas mixture flows to a direct contact heat exchanger 25. Cold, distilled, boiler - feed quality water 18 is continually sprayed into vessel 25, thus condensing some of the steam that is part of the combustion gases. The steam operating the distillation

facility 29 supplied from the boiler 5. The saturated steam in the combustion gas continually condenses because of heat exchange with the cold distilled water 18. The non-condensable combustion gases 27 (after most of the water vapor was condensed) are released from vessel 25 for further treatment, like CO2 recovery for sequestration, or directly to the environment, if there is no requirement for CO2 sequestration.

Distillation unit 11 produces distillation water 18. Some of it is used for generating steam for the distillation unit in vessel 25 and brine water 24. The brine water 24 is recycled back to the direct contact steam generator and solids drier 15 where the liquid water is converted to steam and the dissolved solids remain in a dry form.

Distillation unit 11 receives de-oiled produced water 9 that is separated in a commercially available separation facility that is currently in use by the industry. Additional make-up water 34 is added. This water can be brackish water, from deep underground formation or from any other water source that is locally available to the oil producers. The quality of the make-up water 34 is suitable for the distillation facility 11, where there are typically very low levels of organics due to their tendency to damage the evaporator's performance or carry on and damage the boiler. Low quality water 35 with high levels of dissolved and suspended solids that include organics is not acceptable by distillation facility 11. It is sent to the direct contact steam generator and solids dryer 15, where the solids are separated in direct contact with the hot combustion gas flow to two components: gas and dry solids 13.

The cold distilled water produced by distillation facility 11 is used to recover the steam and the condensation heat in saturated gas flow 22. The condensate and the distilled water 19 are sent for the generation of high-pressure steam in boiler 4 and possibly also in a separate steam generation

facility 30 where high-pressure steam 32 is produced for EOR.

The brine 24 and the scrubbing water 21 are recycled back to 14 (to the direct contact steam generator and solid drier 15) as described before. Some brine 24 can be use in the make-up water 34. The high - pressure steam from the boiler 5 and from a possibly separate steam generator facility 32 is injected to the injection well for EOR.

The well 7 produces a mixture of tar, water and other contaminations. The oil and the water are separated in commercially available plants 10 to the de-oiled water 9 and to the oil product 8.

FIGURE 3A is a schematic view of an illustration of an atmospheric boiler, direct contact drier with dry solid generation, solid removal, direct-contact scrubber with wet steam generator, and Mechanical Vapor Compression distillation facility for generating distilled water for steam generation in the boiler for EOR. Fuel 2, possibly with water is mixed with air 1 and injected into an atmospheric steam boiler 4. The boiler can have waste discharged from the bottom of the combustion chamber. The boiler produces high-pressure steam 3 from treated distillate feed water 5. The steam is injected to the underground formation through injection well 21 for EOR.

The combustion gases with carry - on flying solids flow to direct contact dryer 9. The dryer can be commercially available direct-contact rotary drier or any other type of direct contact drier capable of generating solid waste and steam from solid - rich brine water 8. The drier discharges a stream of combustion gas 10 with dry steam and solid particles that were carried on from boiler 4 and from the solid rich water 8. The amount of water 8 is controlled to verify that all the water is converted to steam and that the remaining solids are in a dry form. The solid - rich gas flow goes to a dry solids separator 12. The dry solid separator is commercially available package and

it can be used in a variety of gas-solid separation designs. The solids lean flow 11 is mixed with saturated water 22 in direct contact wash vessel 15. The solids carried with the gas are washed by saturated liquid water 22. The liquid water may include lime to scrub the SO2 discharged from the boiler, generating additional solids. The solids rich water 14 is discharged from the bottom of vessel 22 and recycled back to drier 9 where the liquid water is converted to steam and the solids are removed in a dry form for disposal. The combustion gases are solids free and most of the sulfuric gases generated from burning sulfur -rich fuel are removed in the form of gypsum. The combustion gases are released from vessel 15 for further treatment, like CO2 recovery for sequestration, or directly to the environment, if there is no requirement for CO2 sequestration. Distillation unit 20 produces distillation water 8. . The brine water 24 is recycled back to the direct contact steam generator and solids drier 15 where the liquid water is converted to steam and the dissolved solids remain in a dry form.

Distillation unit 11 is a Mechanical Vapor Compression (MVC) distillation facility. It receives de-oiled produced water that is separated in a commercially available separation facility that is currently in use by the industry with additional make-up water 16. This water can be brackish water, from deep underground formation or from any other water source that is locally available to the oil producers. The quality of the make-up water is suitable for the distillation facility 20, where there are typically very low levels of organics due to their tendency to damage the evaporator's performance or carry on and damage the boiler. The distilled water produced by distillation facility 11 is treated by distillate treatment unit 17, typically supplied as part of the MVC distillation package. The treated distilled water 5 can be used in the boiler to produce 100% quality steam for EOR.

The brine 8 and the scrubbing water 14 are recycled back to the direct contact drier 9 as described before. Some brine 8 can be use in the make-up water 13. The high - pressure steam from the boiler 4 is injected to the injection well 21 for EOR.

FIGURE 4 is a schematic view of one embodiment of the invention. Fuel 2, possibly with water 3 is mixed with oxidizing gas 1 possibly with recycled cooled combustion gas 11 and is injected into a pressurized, direct - contact rotating steam generator 4 where the combustion is at elevated pressure. This produces high-pressure combustion gases and steam 13. Solids - rich water 12 is injected to the direct contact steam generator 4 where the water evaporates to steam and the solids are carried on with gas flow 13. The amount of water 3 is controlled to verify that all the water is converted to steam and that the remaining solids are in a dry form and at the desired temperature. The solid - rich combustion gases discharged from the steam generator flow to a dry solids separator 5. The dry solid separator is commercially available package. The dry solids are removed in a dry form from the separator 15. The solids lean flow 14 goes through heat exchanger 6 where high-pressure steam 27 is generated from distilled water 17. Some of the distilled water 28 can be used to generate steam in separate steam generation facilities. If the oxidized gas is comprised of oxygen or oxygen enriched air, some of the combustion gases can be recycled back to the direct contact steam generator 4 and mixed with the oxidizing gas to control the combustion temperature. The steam - rich combustion gases are mixed with saturated water in direct - contact steam generation and wash vessel 7 where the heat carried by the gas 32 generates steam and the solids carried with the gas are washed by the saturated liquid water 16. The liquid water may include alkali materials, like lime, to scrub the SO2 presence in the

pressurized combustion gases generated by the steam generator 4. Make-up water 33 is added to scrubbing vessel 7 to replace the evaporated water and the solid - rich water discharged and recycled from the vessel bottom 16. The combustion gases, saturated with wet steam 19 are solids - free and most of the sulfuric gas generated from burning sulfur rich - fuel is removed in the form of gypsum. The wet gas mixture 19 flows to heat exchange condenser 8 where the thermal energy is used to heat the produced and make-up water 21, used by the distillation facility 30. The distillation facility 30 is also a commercially available facility. For example, it could be a Multi Effect Distillation unit. The condensed water 23 from condenser 8 flows to a flash tank separator 10. Steam generated in flash tank 25 is used to operate the distillation facility. The distillation facility produces distillation water. The distillation water 26 together with the liquid water from the flash tank 10 is used for steam generation in the direct - contact steam generator. Brine water 29 rejected from distillation facility 30 is recycled, together with the solid - rich water discharged from vessel 12, back to the direct contact steam generator 4, where the water converted to steam and the solids were removed in a dry form. The non-condensable combustion gases are released from heat exchanger 31. The CO2 can be recovered and used for sequestration or released to the environment if there is no requirement for the CO2 recovery.

FIGURE 5 is a schematic view of one embodiment of the invention. Fuel 2, possibly with water 3 is mixed with oxidizing gas 1 and injected into a pressurized steam boiler 5 where the combustion is at elevated pressure, in the range of 2bar to 70bar. The boiler can have a solid char discharged from the bottom of the combustion chamber. The boiler produces high - pressure

steam 12 from distilled feed water 15. The steam is injected to the underground formation through injection well 49, for EOR.

The combustion gases with carry - on fly solids flow to a direct - contact pressurized spray dryer and steam generator 10. The dryer generates steam from solid - rich water 12. The fluid discharged from the drier contains fly solids that are generated from the evaporated water as well as solids that were carried within the combustion gas flow from the boiler. The amount of water 12 is controlled to verify that all the water is converted to steam and that the remaining solids are in a dry form. As a result, the discharge from drier 10 is a dry combustion gas mixture (i.e.- it has super-heated dry steam). The solid - rich gas flows to a dry solids-gas separator 8. The separator is a commercially available package and it can be used with a variety of gas-solid separation designs. Dry solids are recovered for disposal through pressure reduction chambers (not shown). The solids lean flow 12 is mixed with saturated water 19 in direct - contact steam generation and wet scrubbing vessel 17, where the heat carried by the gas 13 generates steam. The solids carried by the gas are washed by the saturated liquid water 19. The liquid water may include alkali material, like lime, to scrub the SO2 discharged from the boiler. The solid - rich water 18 is discharged from the bottom of vessel 17 and recycled 12 back to drier 10, where the liquid water is converted to steam and where the solids are removed in a dry form for disposal. The combustion gases, saturated with wet steam 20 are solid - free and most of the sulfuric gas generated from burning sulfur - rich fuel is removed in the form of gypsum. The wet gas mixture flows to a direct contact heat exchanger and also to a steam condenser 36. Cold, distilled, boiler feed - quality water 30 is continually sprayed into vessel 36 while condensing some of the steam that is part of the combustion gases. The amount and temperature of the liquid injected water 30

is controlled to maintain the heated condensing of liquid water 28 at a temperature close to (but not colder than) the saturated temperature of the partial steam pressure in the vessel. The saturated steam in combustion gas 20 continually condenses, because of its heat exchange with the cold distilled water 30 and increased quantities of the saturated liquid water 28. The non-condensable combustion gases 53 are released from vessel 36 for further environmental - related processing. This occurs after most of the water vapor is recovered and condensed. Processing may include CO2 recovery for sequestration. Otherwise, the waste products can be released directly into the environment, if there are no laws stating otherwise, or if there are no economic advantages to CO2 sequestration. There are few developed technologies that separate CO2 from the pressurized discharged flow 53 that are able to use the discharged pressure for reduction of energy consumption during separation while still pressurizing and drying the CO2. If oxygen is used as the oxidizer gas, some cooled combustion gases 27 (mainly CO2 and H2O) will be recycled back and mixed with the oxygen to maintain combustion temperatures at a usable range, typically less than 2000C. The technology for Oxy-combustion is well known; boilers designed for this process are commercially available.

The liquid water at saturated temperature 28 is delivered to flash tank 26 and flashed at a pressure lower then the partial pressure of the steam in vessel 36. It is converted to pure steam 39 that is used to drive the distillation process 40. The condensation 29 from flash tank 26 is recycled back and used for generating steam in boiler 5, or in a separate steam generator unit 43 for EOR. Distillation unit 40 is a commercially available unit. A typical distillation technology can be the Multi Effect Distillation unit, possibly with Thermal Vapor Compression that uses steam jet compressor 38 to increase system output by working as a heat pump over the multi

evaporator condensers cells, between line 32 and 33 (not shown). The distillation produces BFW (Boiler Feed Water) quality water 30 used for steam generation in boiler 5. The distillation facility produces brine water 23 with a high concentration of dissolved solids. The brine water 23 is recycled back to the direct contact steam generator and solids drier 10 where the liquid water is sprayed into the combustion gas and converted to steam and dry solids particles.

Production well 51 produces a mixture of bitumen, water and gas 48. The produced mixture is separated in commercially available treatment plants that use a variety of separation technologies to separate the produced emulsion into oil products and water. The produced hydrocarbons 47 are sold or sent for further treatment. The produced water is treated to remove carbon contaminants in commercially available processes 42. The de-oiled water 24 is used as the water source for distillation facility 40 and also possibly as make-up water for wet scrubbing and steam generation unit 17. Any oily water 25 is recycled back to drier 10 or used with the fuel 3 for preparing the solid fuel and water slurry 2 for the boiler 5. Additional make-up water 45 possibly brackish can be produced from a deep underground well 50. This water is added to the produced water and treated by distillation facility 40 or used as make-up water for the wet scrubber and steam generator 17. If an additional steam generator facility is used, like Co-Gen or OTSG where about 80%-90% quality steam is produced, then the steam is separated where 100% quality steam 44 is injected through injection well 49 for EOR. The blow-down water 46 is recycled back to the saturated water steam generator and wet scrubber 17.

Distillation unit 11 receives de-oiled, produced water 9 that is separated in commercially available separation facilities that are currently used by the industry. Additional make-up water 45 is added. This water can be brackish water from deep underground formations, 50 or from

other water sources that are locally available to the oil producers. The quality of the make-up water 45 is suitable for the distillation facility 40, where, typically the levels of organics are at very low levels, due to their tendency to damage the evaporator's performance or carry - on and damage the boiler. Low quality water, 35 with high levels of dissolved and suspended solids that include organics are not accepted by the distillation facility 40. They are sent to the direct contact steam generator within solids dryer 10, where they are converted in direct contact with the hot combustion gas flow to steam and dry solids 11.

The cold distilled water produced by distillation facility 40 is used to recover the condensed heat in saturated gas flow 20, while generating low - pressure steam 39 for running distillation facility 40. The rest of the condensation 29 and the distilled water 31 are combined and sent for the generation of high-pressure steam in boiler 5 and possibly, also in a separate steam generation facility 43 where high-pressure steam 12 is produced for EOR.

The brine 23 that is rejected from the distillation facility is recycled back to dryer 10 and to vessel 17, together with additional make-up water 4. The brine 23 and scrubbing water 18 is recycled back to 12, to the direct contact steam generator and solid drier 10, as described before.

The high - pressure steam from boiler 5 and from a possibly separate steam generator facility 43 is injected to the injection well 49 for EOR.

The produced well 51 produces a mixture of tar, water and other contaminants. The oil and the water is separated 41 to de-oiled water 24 and to oil product 47.

FIGURE 6 is a schematic view of integration with MED (Multi Effect Distillation) distillation system without Thermal Vapor Compression. Combustion gases 6 with flying solids

that were not removed by the dry solid-gas separation unit (shown on Figure 7), mixed with saturated water 9 in direct contact steam generation and wet scrubbing vessel 7. In it, heat carried by gas flow 6 generates steam and the solids carried by the gas are washed by the saturated liquid water 8. The liquid water may include alkali material like lime to scrub the SO2 discharged from the boiler. The solids rich water 9 is discharged from the bottom of vessel 7 and recycled back to the drier (shown on Figure 7), where the liquid water is converted to steam and the solids are removed in a dry form for disposal. The combustion gases saturated with wet steam 4 are solids free. Most of the sulfuric gas generated from burning sulfur rich - fuel is removed in the form of gypsum. The wet gas mixture 4 flows to a direct contact steam condenser heat exchanger 15. Cold, distilled, boiler feed quality water 3 is continually sprayed into vessel 15, while heat and some of the steam that is part of the combustion gases is recovered. The amount and temperature of the liquid injected water 3 is controlled to maintain the heated liquid water 13 at a temperature close to (but not colder than) the saturated temperature of the partial steam pressure in the vessel. The saturated steam in combustion gas 4 continually condenses because of heat exchange with the cold distilled water 3 and adding to the distilled injected water 3. The non-condensable combustion gas 5 are released from vessel 15 for further processing (like CO2 capturing) or released to the atmosphere, after most of the water vapor is recovered and condensed. The liquid water at saturated temperature 12 is delivered to flash tank 16 and flashed at a pressure lower than the steam partial pressure in vessel 15 to generate pure steam 18 that is used to drive the distillation process 30. The condensate 17 from flash tank 16 is recycled back and used (possibly after some processing) as Boiler Feed Water for generating steam for EOR.

The Multi Effect Distillation takes place in a series of vessels (effects) 23 and uses the principle

of condensation and evaporation at reduced pressure. The heat is supplied to the first effect 19 in the form of steam 18. The steam 18 is injected to the first effect 19 at a pressure range of 0.2-12 bar. The steam condenses while feed water 20 is heated. The condensation 21 is collected and used for boiler feed water 3 and for injection to vessel 15. Each effect consists of a vessel 19, a heat exchanger 21 and flow connections 20 and 24. There are several commercial designs available for the heat exchanger area, that have horizontal tubes with a falling brine film or vertical tubes with a rising liquids or a falling film or plates with a falling film. The feed water 20 is distributed on the surface of the heat exchange and evaporator 21. The steam produced in each effect condenses on the colder heat transfer surface of the next effect. The last effect 22 consists of the final condenser 22, continually cooled by the feed water, thus preheating the feed water 1. The feed water comprised from de-oiled produced water, brackish water 26 wells 25 or ant other locally available water source. The brine concentrate 2 flows back, where it is sprayed and mixed with combustion gases generated by the boiler. All this is occurs while steam and dry solids are generated (shown on Figure 7).

FIGURE 7 is a schematic view of the combustion side of the system described in Fig. 6. Fuel 2 is mixed with air 55 and injected into a Pressurized Fluidized-Bed Boiler 51 with water injection. The boiler produces high-pressure steam 59 from distilled feed water 3. The steam is injected to the underground formation through injection well 73 for EOR.

The discharged NCG 5 expands to an atmospheric pressure 75 while compressing the combustion air 74 to the boiler combustion pressure 55. The CO2 can be separated from the NCG using commercially available technologies. The combustion air injected at the bottom of

the boiler to maintain the fluidized bed. High pressure 100% quality steam 59 is generated from distilled water 3 through heat exchange inside the boiler 56.

Hydrocarbons and water mixture 70 is produced from the production well 72. The mixture is separate in separation facility 68 where the heavy oil product, possibly mixed with diluent 71, is separate from the water. The produced water 69 is treated by de-oiled unit 67 where de-oiled produced water 1 generated and sent to the MED unit (see Fig. 6). The produced water that contain organics 62 together with the concentrated brine from the distillation facility 2 flows back to the boiler 52, where it is sprayed at the upper section of the boiler 53 and mixed with the up-flowing combustion gases generated by the boiler. The liquids evaporate while steam and dry solids are generated. Small solid particles carried with the up-flowing gas and large solid particles are falling to the fluidized bed by gravitation. The solid - rich combustion gases discharged from the boiler 61 flows to a dry solids separator 60. The dry solid separator is commercially available package. The dry solids are removed in a dry form from the separator 63 through heat recover 64 and de-compression 65 sections. The solids lean flow 6 flows to vessel 7 (see Fig. 6).

I CLAIM:

1. A method for producing steam comprising:

mixing fuel with oxidation gases to form a mixture;

combusting the mixture under 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; and

scrubbing any remaining solids from the combustion gas mixture to form the clean steam and gas mixture.

2. The method of claim 1, wherein the steam is used for injection into an underground formation to extract heavy bitumen.

3. The method of claim 1 further comprising the steps of:

evaporating de-oil produced water and make-up water at a distillation facility to produce distilled water and concentrate brine; and

recovering heat from the combustion reaction for generating high pressure steam in an heat exchanger from the de-oiled water.

4. The method of claim 3 further comprising the step of:

Injecting solids rich water to the flow of the combustion gases to generate steam and solid waste.

5. The method of claim 1, wherein the fuel is selected from the group consisting of heavy bitumen, heavy crude oil, solid hydrocarbons, coal, asphatin, petcoke, vacuum residue (VR) and carbon emulsions.

6. The method of claim 1, wherein the oxidation gases are selected from the group consisting of oxygen, oxygen-enriched air, and air.

7. The method of claim 1, further comprising the step of:

adding lime or other alkaline materials for SO_2 removal to the water during the step of scrubbing the any remaining solids from the combustion gas mixture.

8. The method of claim 4, further comprising the step of, after the step of evaporating the water in the combustion gas mixture to leave the solids in a dry form:

mixing further water to form a solids rich mixture to replace the evaporated water;

discharging the solids rich mixture; and

continuously recycling the solids rich mixture back to the step of combusting.

9. The method of claim 4, wherein water is mixed with the fuel and oxidation gases to form the mixture.

10. The method of claim 1, wherein the step of combusting the mixture under high pressures and temperatures to generate the combustion gases comprises combusting the mixture at a pressure in a range of between 2bar to 70bar.

11. The method of claim 1, further comprising the step of injecting the clean steam and gas mixture into the underground formation through an injection well.

12. A method for producing steam for enhanced oil recovery with no liquid waste discharge comprising:

mixing fuel with an oxidizing gas;

combusting the mixture to generate heat and combustion gases;

capturing portion of the combustion heat through an heat exchanger for generating high pressure steam from clean water;

mixing the combustion gas with low quality contaminated water and transferred the liquid water to gas phase with solids;

separating the solids from the gas phase;

mixing the gas phase with saturated water to scrub the remaining solids and produce

saturated steam;

recycling the solid rich saturated water and mixing it with the combustion gases for liquid gasification; and

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

13. The method of claim 12 further comprising the steps of:

using the water condensing heat for evaporating additional low quality water at distillation facility to produce distilled water and concentrate brine;

recycling back the produced concentrate brine by mixing it with the combustion gas and transferred the liquid water to gas phase with solids; and

using the produced distilled water for generating high pressure steam.

14. The method of claim 13, wherein the high pressure steam is used for injection into an underground formation to extract heavy bitumen.

15. A system for producing a clean steam and gas mixture for injection into an underground formation to extract heavy bitumen comprising:

mixing fuel with oxidation gases in a combustion boiler to form a mixture;

combusting 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 dry-solid separator unit;

removing the dry form solids from the dry-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.

16. The system of claim 15, wherein, after the step of scrubbing any remaining solids from the combustion gas mixture to form the clean steam and gas mixture the clean steam and gas mixture is transferred to a condenser and heat exchanger, whereby heat is removed from the clean steam and gas mixture.

17. The system of claim 16, wherein the removed heat is used to generate low pressure steam, the low pressure steam ultimately being continuously recycled back to the step of combusting.

18. A method for producing a clean steam and gas mixture for injection into an underground

formation to extract heavy bitumen comprising:

mixing fuel with oxidation gases to form a mixture;

combusting 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 the clean steam and gas mixture; and

injecting the clean steam and gas mixture into the underground formation to extract the heavy bitumen.

19. A method for producing a pure steam mixture for injection into an underground formation to extract heavy bitumen comprising:

mixing fuel with oxidation gases to form a mixture;

combusting 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, heat from the clean steam and gas mixture being used to heat water supplied from a distillation facility, the water from the distillation facility being combusted to generate a pure steam mixture that can be used to extract the heavy bitumen; and

injecting the a pure steam mixture into the underground formation to extract the heavy bitumen.

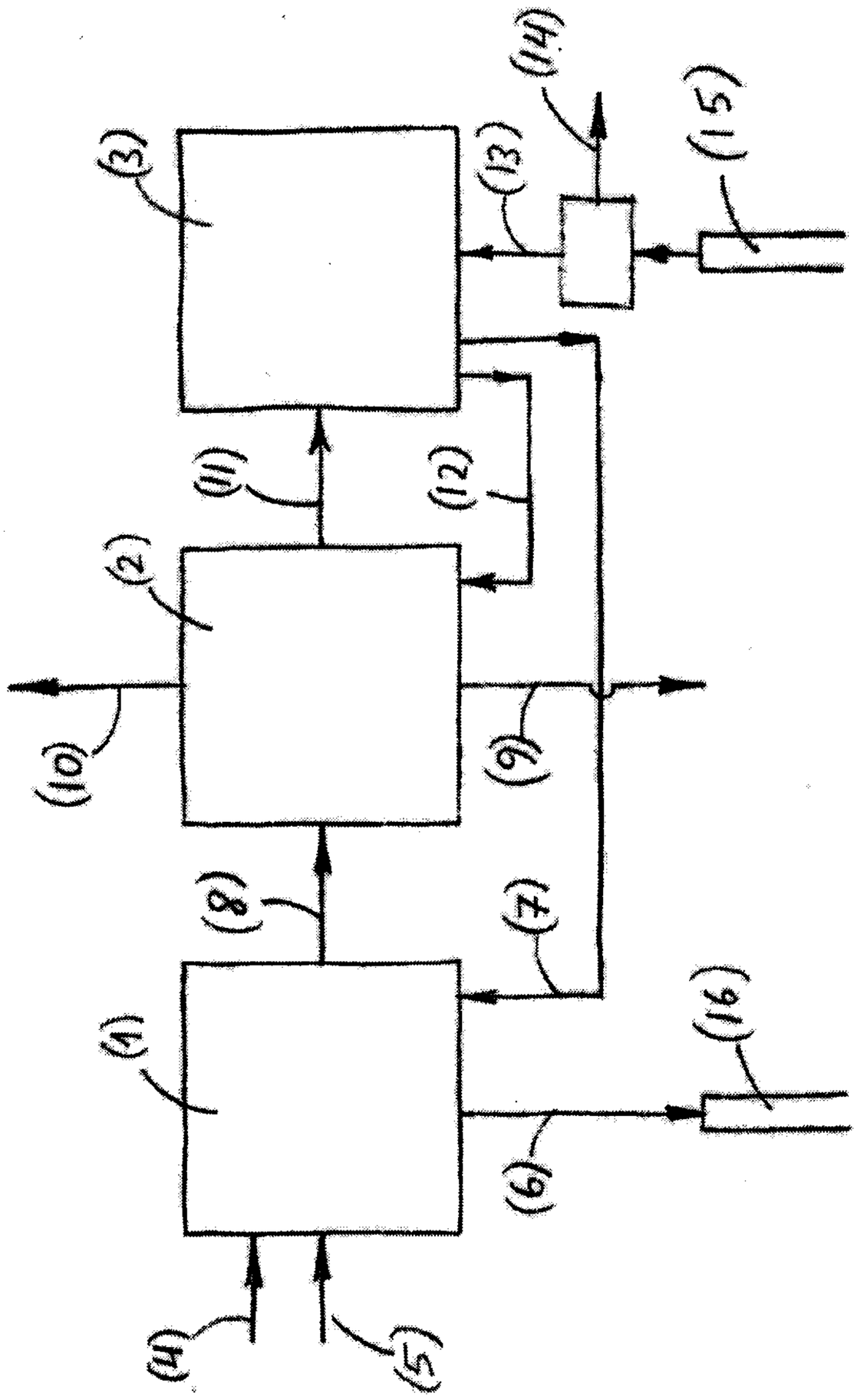

FIG. 1

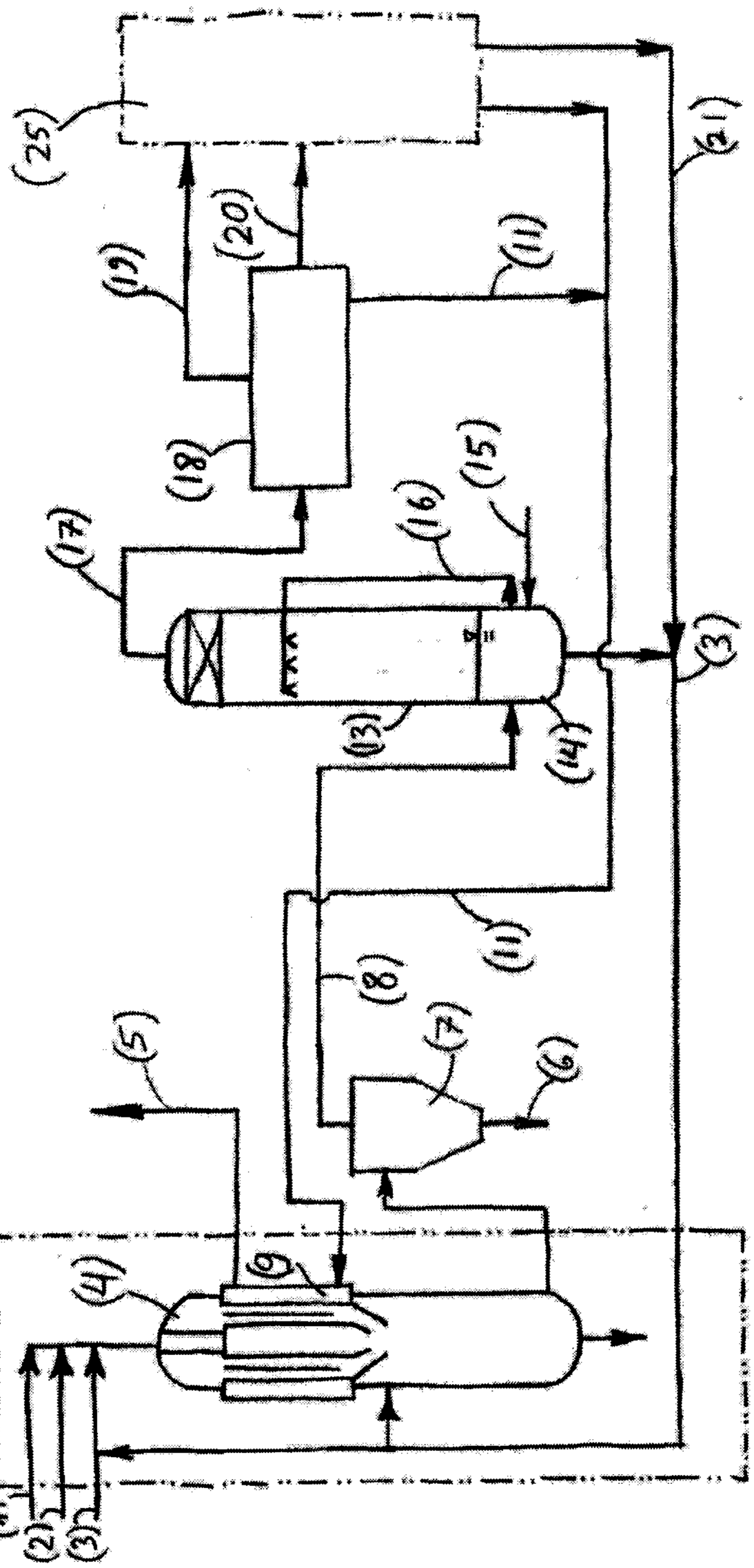

FIG. 2

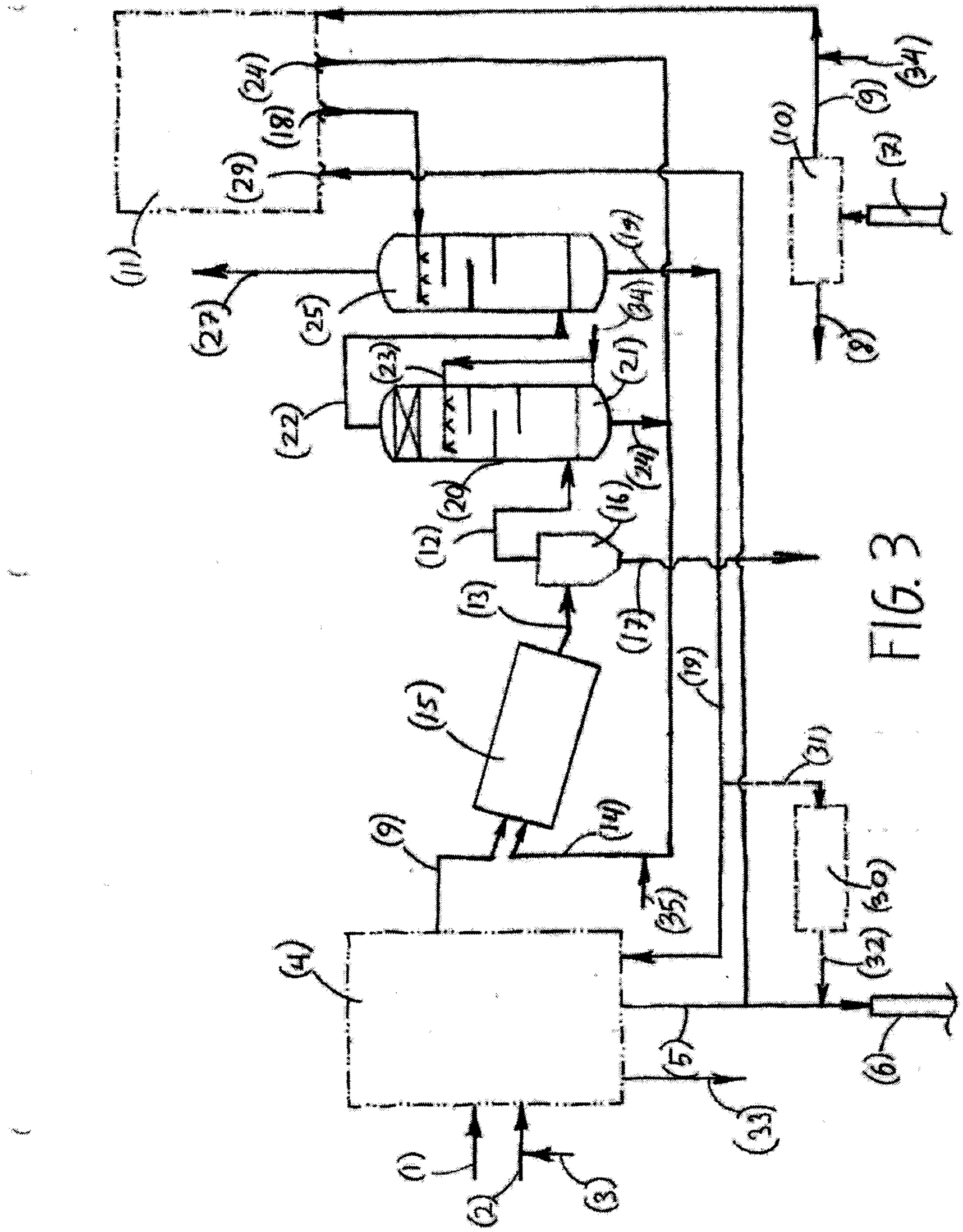
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FIG. 3

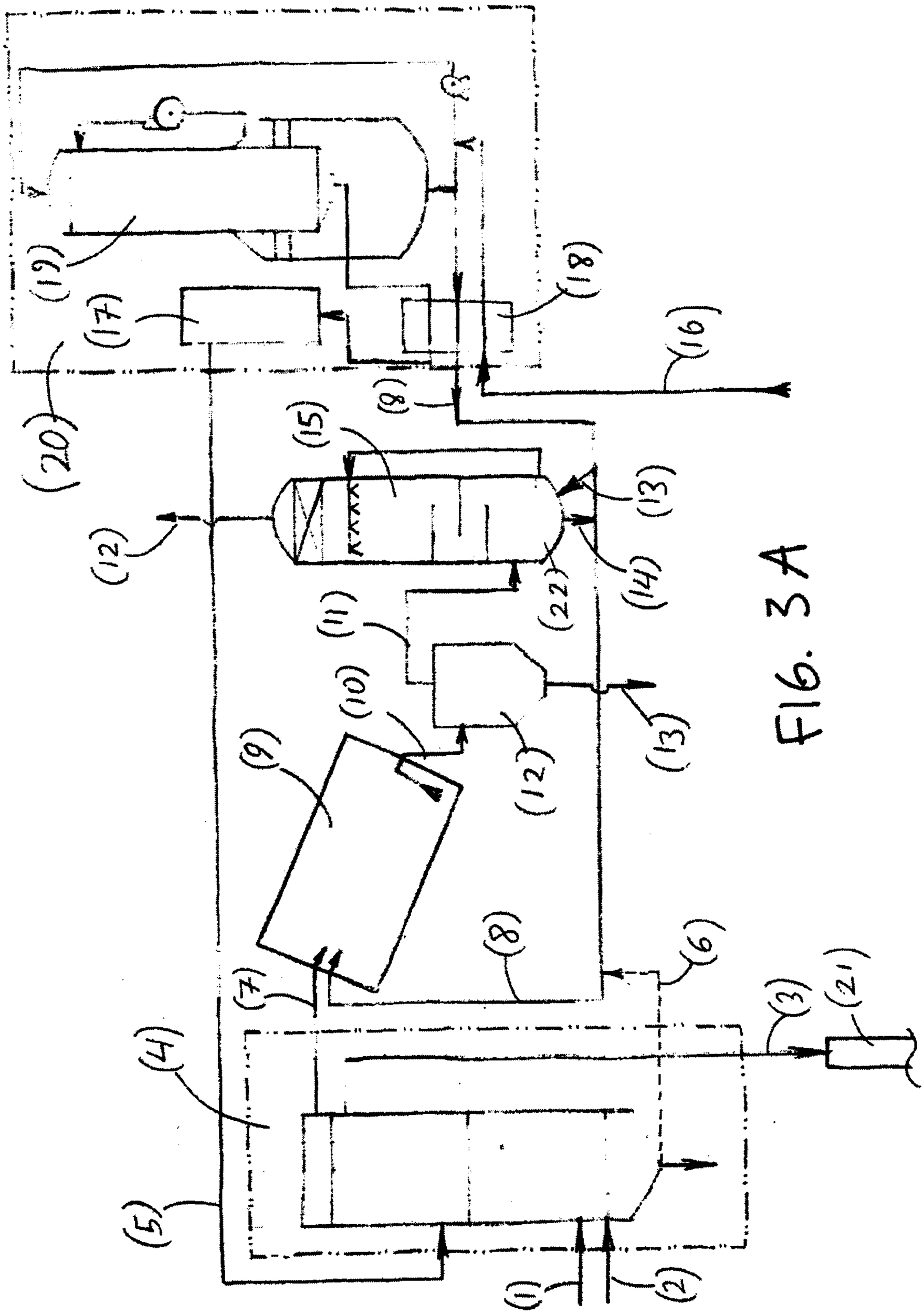

FIG. 3A

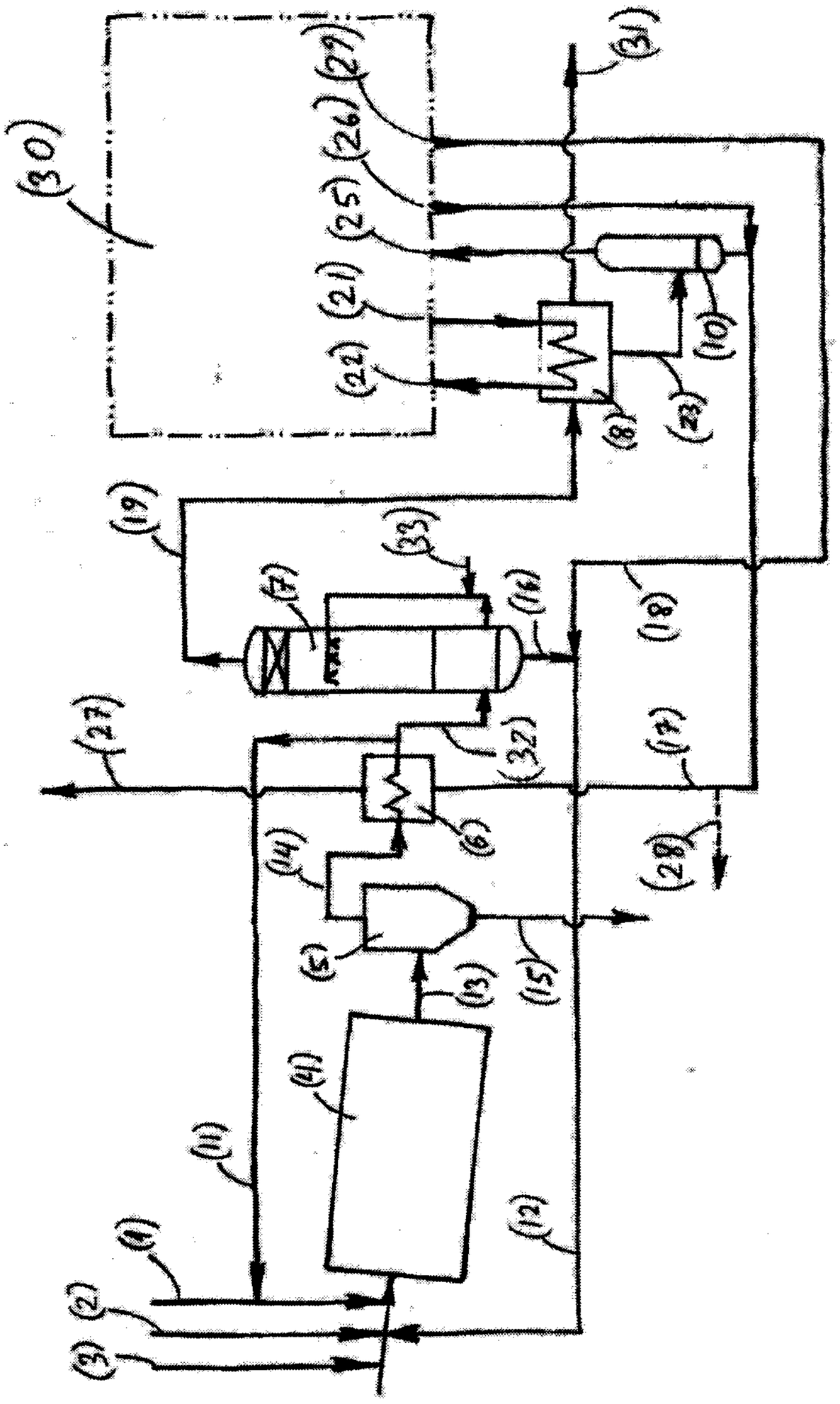

FIG. 4

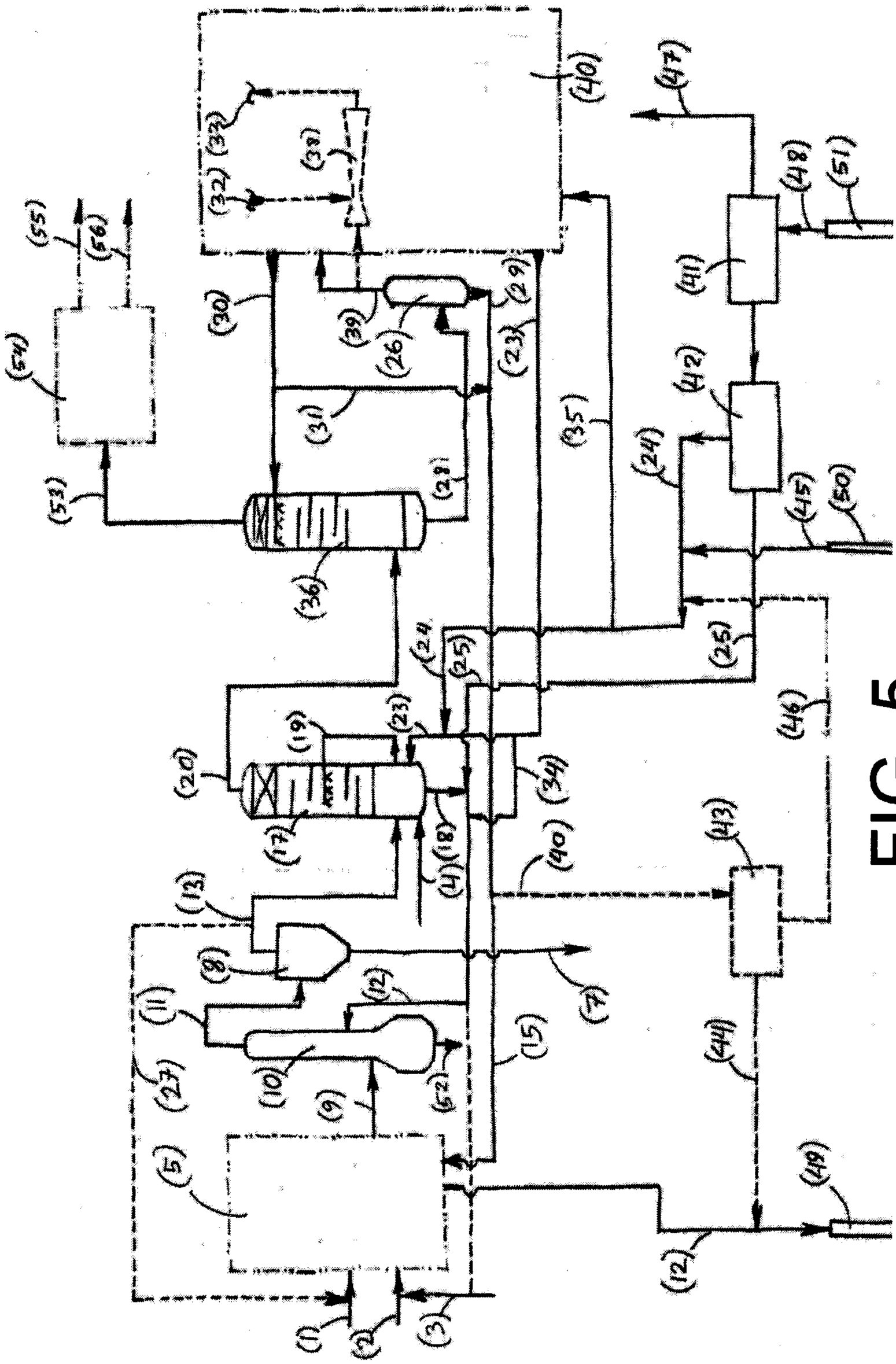

FIG. 5

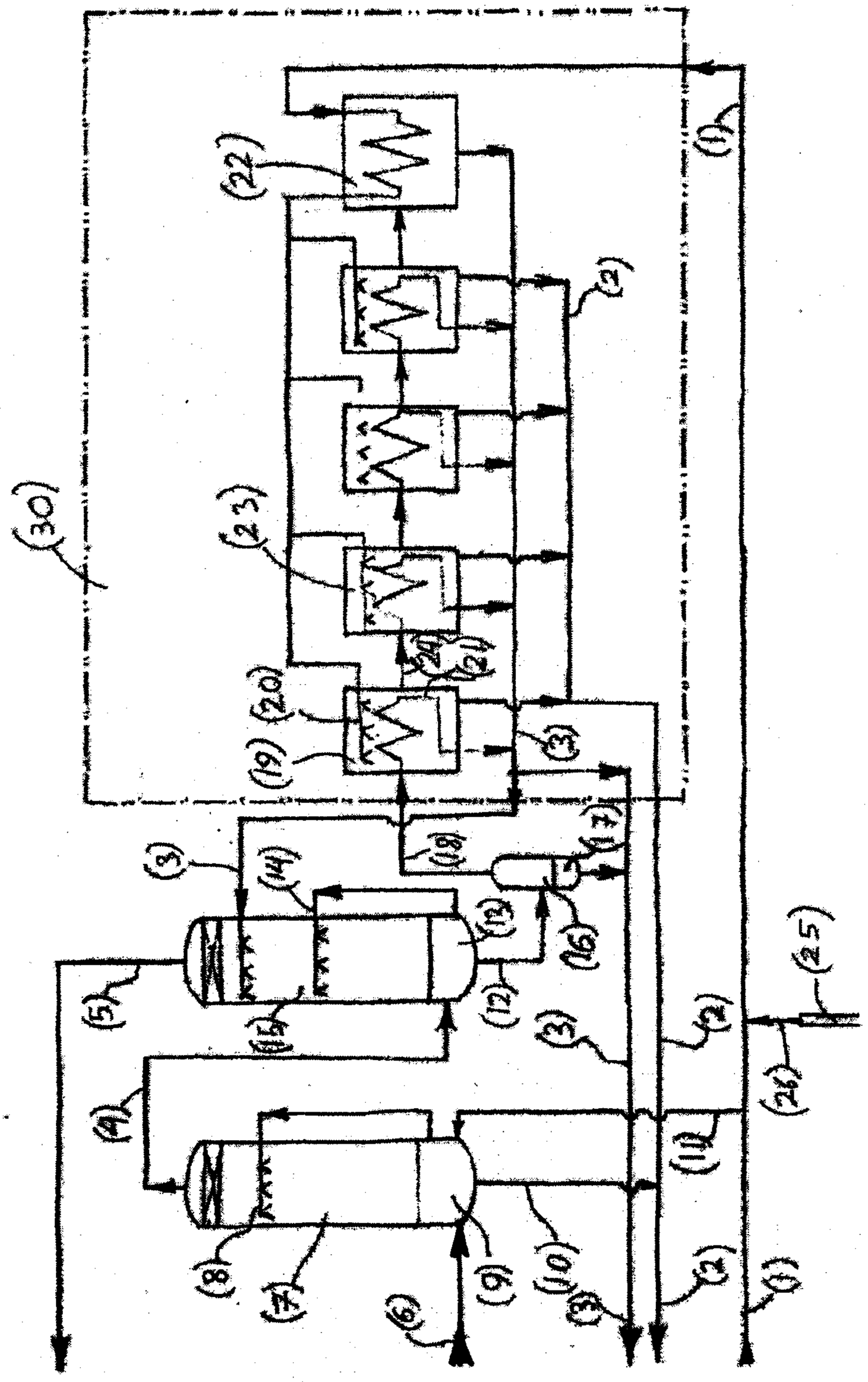

FIG. 6

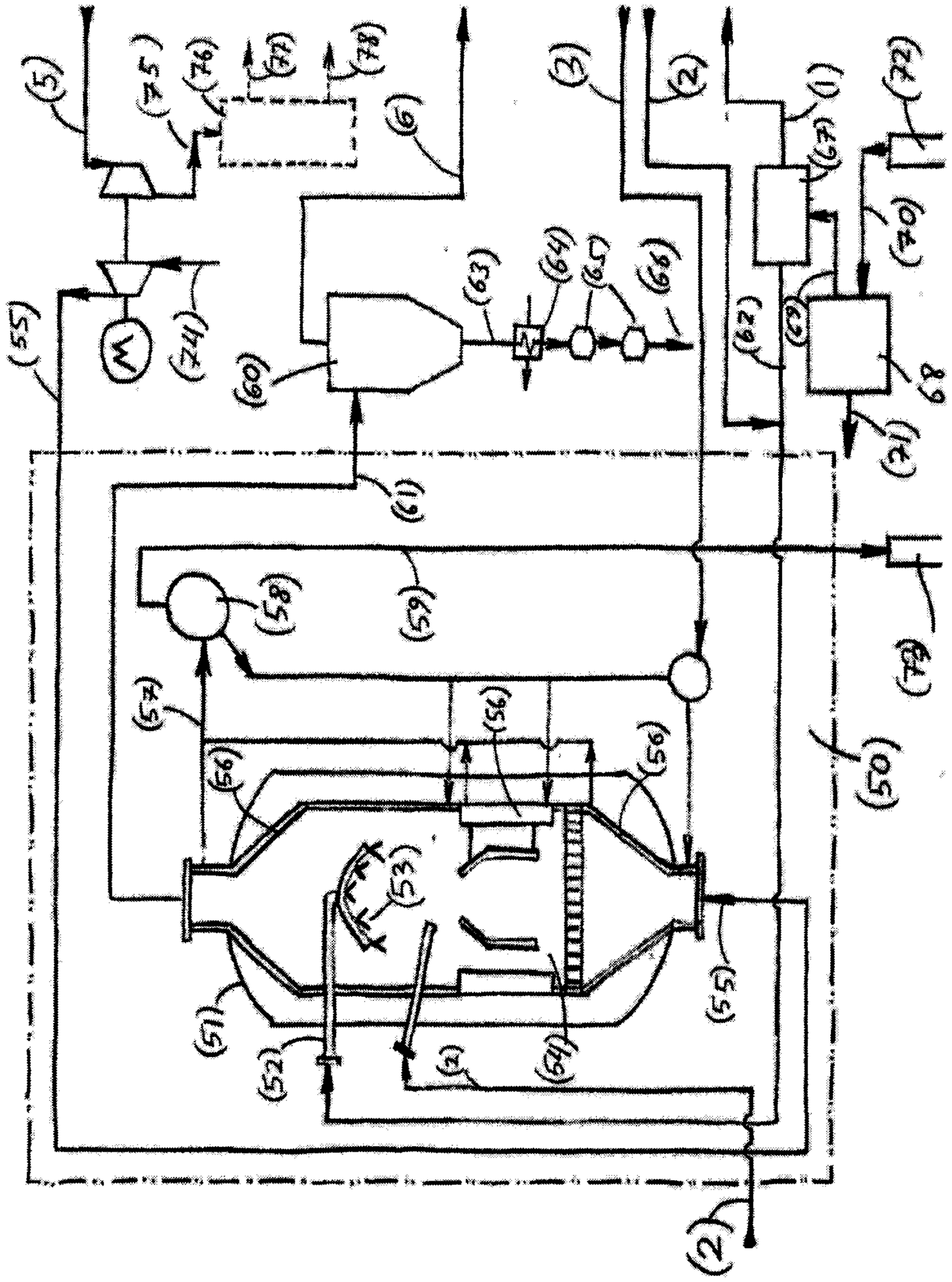
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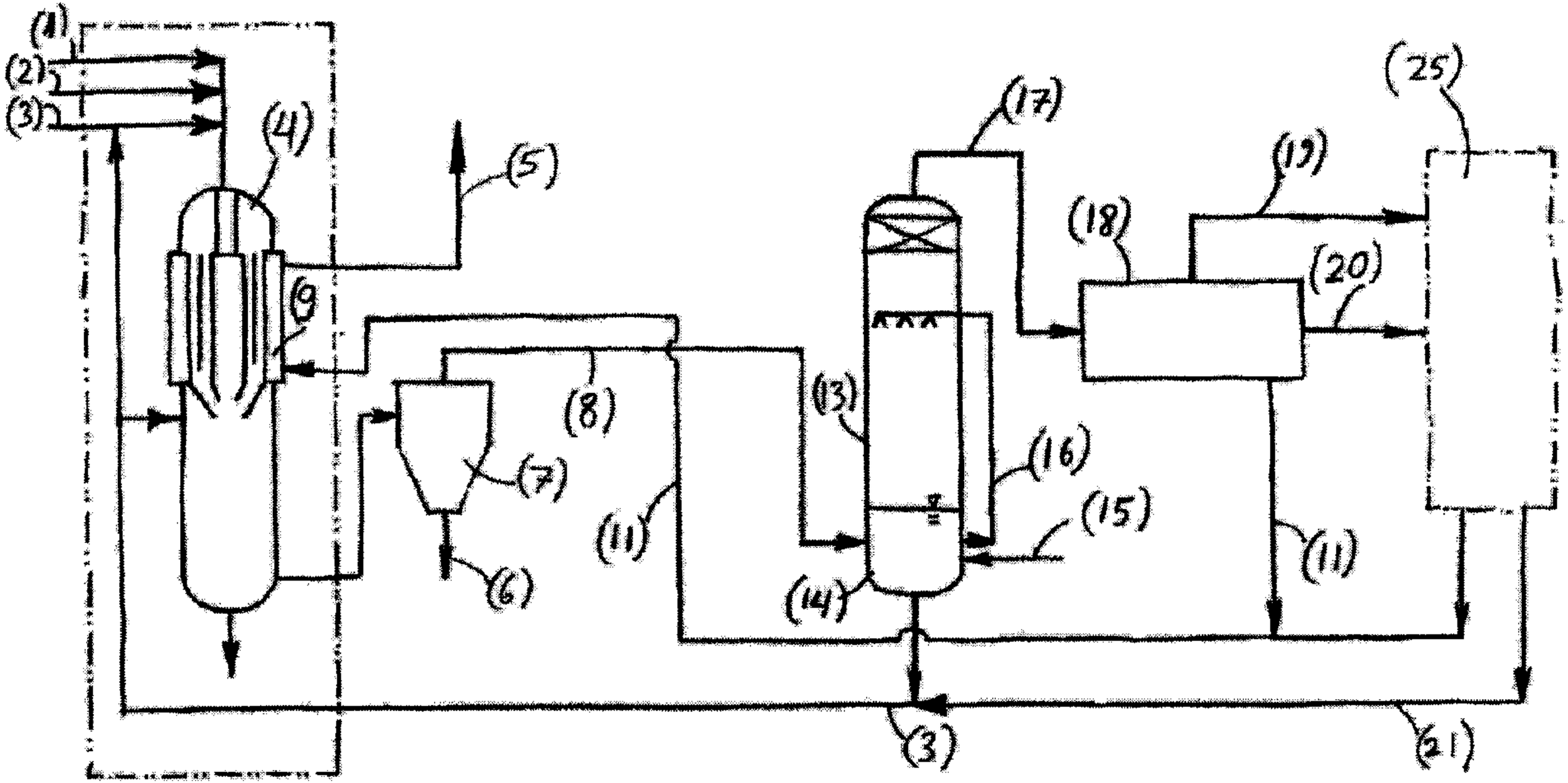
FIG. 7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