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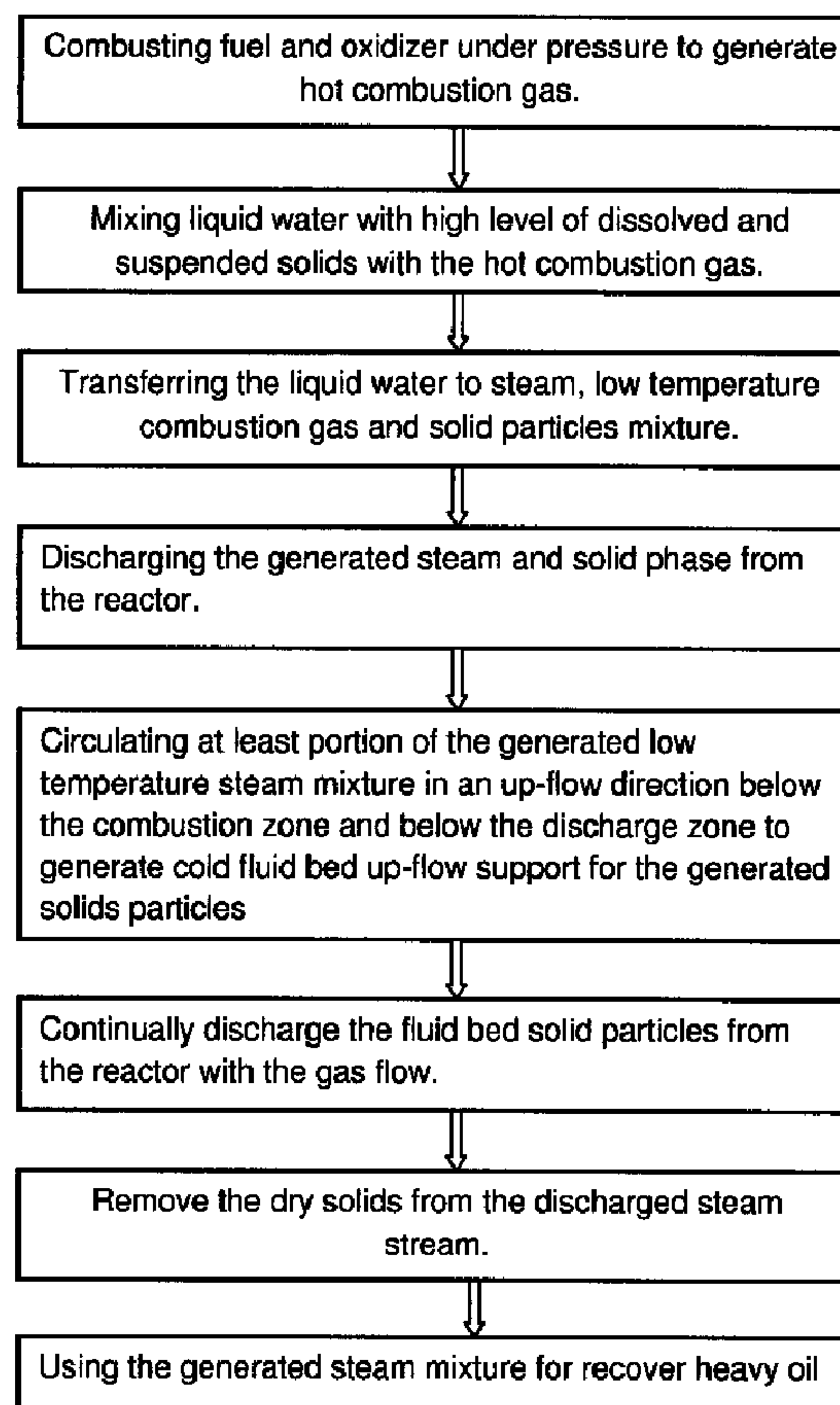
(72) **Inventeur/Inventor:**
BETZER-ZILEVITCH, MAOZ, CA

(73) **Propriétaire/Owner:**
BETZER-ZILEVITCH, MAOZ, CA

(74) **Agent:** NA

(54) **Titre : PROCESSUS ET SYSTEME DE PRODUCTION DE VAPEUR PAR CONTACT DIRECT AVEC LE LIT FLUIDISE**

(54) **Title: FLUID BED DIRECT CONTACT STEAM GENERATOR SYSTEM AND PROCESS**



(57) **Abrégé/Abstract:**

The present invention is a method and system for vertically producing a steam and combustion gas mixture, typically used in enhanced oil recovery processes. The system is a fluid bed up-flow with combustor system, including a vertical vessel with four

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

sections. In a first section, fuel, oxidizer, and possibly water are supplied to the high pressure combustor at a combustion section of a vertical vessel. The combustion gas from the first section flows to a second section for steam generation, where low quality water is injected and turned into steam. Next, the third section is a homogenizer vessel, where any remaining water drops are converted to steam and solid particles and discharged from the vessel. The fourth section located at the bottom of the vessel is a fluid bed, receiving and processing the falling solids from the combustion and the steam generation sections.

ABSTRACT OF THE DISCLOSURE

The present invention is a method and system for vertically producing a steam and combustion gas mixture, typically used in enhanced oil recovery processes. The system is a fluid bed up-flow with combustor system, including a vertical vessel with four sections. In a first section, fuel, oxidizer, and possibly water are supplied to the high pressure combustor at a combustion section of a vertical vessel. The combustion gas from the first section flows to a second section for steam generation, where low quality water is injected and turned into steam. Next, the third section is a homogenizer vessel, where any remaining water drops are converted to steam and solid particles and discharged from the vessel. The fourth section located at the bottom of the vessel is a fluid bed, receiving and processing the falling solids from the combustion and the steam generation sections.

FLUID BED DIRECT CONTACT STEAM GENERATOR SYSTEM AND PROCESS

Field of the Invention

[1] The present invention relates to a steam generating method with an overall process of producing gas mixtures ready for enhanced oil recovery (EOR). In particular, the present invention relates to a direct contact steam generator with a fluid bed at a bottom of the generator vessel.

[2] The fluid bed contains inorganic particle waste resulting from evaporated water or from used solid fuel. The fluid bed does not contain a fuel component, and solids are continually removed from the fluid bed as dry waste. There is no combustion in the fluid bed, but rather above the fluid bed, where the fuel and oxygen-rich gas are mixed.

[3] There are patents issued in the field of the present invention. US patent No. 4,377,066 issued to Dickinson on March 22, 1983 describes a process for the combustion of slurry fuels in an up-flow pressurized fluidized bed. The water supplied with the fuel and the oxidizing gas are further condensed through a series of indirect heat exchangers and used to scrub the combustion solids. The solids are removed from the water. The combustion is done in a typical fluidized bed method where the pressurized oxidizer (air) is injected from below the fluidized bed fuel particles to support combustion. The combustion reaction is carried while the fuel is in the fluidized bed. The present invention includes a cold fluidized bed that does not include the carbonic fuel or support the combustion reaction. The fluid bed of the present invention, will support, solidify and eventually remove the solid particles from the supplied water and to some extent from the fuel. The method eliminates the need for a quenching bath and allows a pure ZLD (Zero Liquid Discharge) system.

[4] US patent No. 5,967,098 issued to Tanca et al. on October 19, 1999 describes a process for fluid bed combustion of fuels, like oil shale in an up-flow atmospheric fluidized bed. Most of the combustion energy is recovered in the form of steam generated in boiler heat exchangers (non-direct steam generation) where there is no mixture of the low pressure flue gas with the steam. In one embodiment, only a portion of the energy is recovered to produce steam in an indirect heat exchanger at the bottom of down-flow combustor where the cold fluid bed is at the bottom of the pressurized vessel and most of the energy is used to generate the steam in a direct contact heat exchange while mixing the liquid water with the combustion gas. In the Tanca invention, all the water used for generating the steam (in the boiler heat exchangers) is treated clean BFW (Boiler Feed Water). The up-flow fluid bed of the Tanca patent is used to support the fuel and oxidizer mixer and combustion. The present invention includes a cold fluidized bed that does not include the carbonic fuel or support the combustion reaction.

BRIEF SUMMARY OF THE INVENTION

[5] The present invention is a method for vertically producing a steam and carbon dioxide mixture, comprising the following 4 sections with 4 steps:

[6] Section A comprises the step of mixing a fossil fuel, including low quality fuel, low quality water, and an oxidation gas that contains oxygen and combusting the mixture under high pressure and temperature. The fuel is selected from a group consisting of coal, pet-coke, asphaltin, vacuum residuals (VR), untreated crude oil in a slurry form or any other available carbon or hydrocarbon fuel. Solid carbon fuel is grinded and mixed with water. There are commercially available packages for grinding, mixing and pumping solid fuels that are used by

the oil industry. The low quality water maybe tailing pond water with high levels of TSS, TDS and organics. It can be brackish water or sewage effluent water. The oxidation gas is selected from a group consisting of oxygen, oxygen-enriched air, and air. The oxidation gas can contain oxygen in stoichiometric ratio for full combustion.

[7] The combustion converts the fuel to a gas and solid byproducts such as slag, fly ash and char. The solid byproducts are in solid, liquid (melted) or sticky (partly melted) form. The combustion section can incorporate a heat exchanger to use up to 45% of the generated combustion heat to generate super-heated steam and gas mixture from saturated steam and gas mixture.

[8] Section B comprises the step of injecting and mixing liquid water to the flowing combustion gas. The water can contain high level of suspended and dissolved solids and organics. The amount of injected water is such that all the liquid water is converted into steam. The remaining solid particles are mixed with the gas flow.

[9] Section C is the homogenizing and discharging section that ensures that all the liquids were converted to gas and solids to prevent deposits on the down-flow pipe and equipment and discharge the produced steam, gas and solid mixture.

[10] The temperature of the produced steam, carbon dioxide, nitrogen (if air is used as the oxidizing gas) and dry solids leaving from section C are between 200°C and 800°C and the pressure is between 103 and 10,000 kpa.

[11] Section D is a fluid bed section at the bottom of the vessel. Cold gas is injected and up-flow through the fluid bed section. Solids that were generated by the combustion and from the water turning into steam are cooled by the fluid bed cold gas up-flow and eventually removed by

the solid discharge from the vessel bottom. The cold gas temperature and the temperature of the fluid bed are relative to the combustion section and it is slightly lower than the discharge steam temperature, in the range of 150°C and 500°C. The fluid bed section can also support down-falling liquid water droplets until they fully evaporate.

[12] The invention also describes the integration of the steam generating method with the overall method to produce gas mixtures for EOR. The solids-rich gas leaving the vertical steam generator flows to a cyclone solid separation where the solid lean gas flow recycled and directed back to the fluid bed. The solids-rich flow is processed by a dry solids separation unit, commercially available in package units that may include cyclonic separators, centrifugal separators, mesh separators or different combinations of gas-solid separation technologies. Solids are removed from the gas flow for disposal. The gas, with some solid remains washed by mixing the gas and steam with saturated water of high temperature and pressure, so as to produce a saturated wet steam and gas mixture, scrubbing any remaining solids from the gas, separating the liquid phase from the gas phase, and recycling the water with the scrubbed solids back to the fluid bed steam generation vertical chamber. In the event that the gas contains sulfur, and if there is a need to reduce the amount of sulfur, the process can include adding lime, like in the form of lime stone, to the solid scrubbing, saturated liquid water in the vessel where the lime will react with the sulfur while generating calcium sulfite or gypsum solids.

[13] The saturated steam and gas mixture can be used to heat process water in an oil sand mine or it can be heated in a heat exchanger with the hot gas phase that leaves the combustion chamber. The heated gas product is a solid free, super-heated dry steam and gas mixture, preventing condensation on the pipes of the apparatus.

[14] The pressure of the clean, wet steam is reduced to an injection pressure. The pressure of the dry steam and gas mixture is between 800 and 10,000 kpa. The temperature of the dry steam and gas mixture is between 170°C and 650°C. The super - heated dry steam and gas mixture can be injected into an underground reservoir through a vertical or horizontal injection well, for EOR.

[15] The dry extraction of produced solid waste and the dissolved solids that was brought in with the consumable water is advantageous. This is because it eliminates the need for additional treatment facilities to remove dissolved solids from the supplied water and to treat the quenching water with filter presses, evaporators, crystallizers or any other method.

[16] The present invention is also a system for vertically producing a steam and carbon dioxide mixture, comprising the following 4 sections:

[17] Section A comprises a burner for mixing and combusting a low quality fuel, possibly some low quality water, an oxidation gas that can contains oxygen in stoichiometric ratio, and combusting the mixture under high pressure and temperature. The fuel is selected from a group consisting of coal, pet-coke, asphaltin, VR, untreated crude oil in a slurry form or any available carbon or hydrocarbon fuel. Solid carbon fuel is grinded and mixed with water. There are commercially available packages for grinding, mixing and pumping solid fuels that are used by the oil industry. The low quality water maybe tailing pond water with high levels of TSS, TDS and organics. It can be brackish water or sewage effluent water. The oxidation gas is selected from a group consisting of oxygen, oxygen-enriched air, and air.

[18] The combustion converts the fuel to a gas and solid byproducts such as slag, fly ash and char. The solid byproducts are in solid, liquid (melted) or sticky (partly melted) form.

The combustion section includes a heat exchanger to use portion of the generated combustion heat to generate super-heated steam and gas mixture from saturated steam and gas mixture.

[19] Section B is adjusted to section A. It includes low quality water injectors that inject liquid water to the flowing combustion gas. The water can contain high levels of suspended and dissolved solids and organics, like MFT (Mature Fine Tailing). The amount of injected water is such that all the liquid water is converted into steam.

[20] Section C is adjusted to section B. It includes a vertical vessel with flow deflectors that ensure flow mixture and prevents any liquids remains or large, possible sticky, solids particles from flowing with the produced steam, gas and solid mixture and deposit on the down-flow pipe and equipment.

[21] Section D is a fluid bed section at the bottom of the vessel. It includes cold gas injector and dispenser. The fluid bed section contains solids that were generated from the fuel and from the water turning into steam. The fluid bed solids are maintained at relatively cold temperature by the cold gas up-flow. The solids eventually removed from the system by the solid discharge from the vessel bottom. The cold gas temperature and the temperature of the fluid bed are close to the discharge steam temperature, in the range of 150°C and 500°C.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[22] FIGURE 1 is a schematic view of the fluid bed with an up-flow combustor for the direct contact steam generator of the present invention.

[23] FIGURE 2 is a schematic view of another embodiment of the fluid bed with down-flow combustor integrated with internal heat exchanger and water injection for direct contact steam generator and bottom solid discharged of the present invention.

[24] FIGURE 3 is a diagrammatic illustration of the process of the present invention.

[25] FIGURE 4 is another schematic view of the vertical up-flow fluid bed direct contact steam generator with produced gas circulation through the fluid bed and solids removal.

[26] FIGURE 5 is another schematic view of the vertical up-flow fluid bed direct contact steam generator with produced gas circulation and chain internals to improve the heat transfer and remove solids build-ups.

[27] FIGURE 6 is another schematic view of the vertical down-flow fluidized bed direct contact steam generator with combustion heat exchanger and produced gas circulation through the fluidize bed with solids removal.

[28] FIGURE 7 is schematic view of the integration of vertical down-flow fluidize bed direct contact steam generator with saturated steam generator and solids scrubber for the production of solid free steam and gas mixture for EOR.

[29] FIGURE 8 is schematic view of integrated down-flow combustion unit with MFT (Mature Fine Tailing) water injection for steam generation, up-flow fluid bed, dry solids separation and direct contact heating of oils and open mine process water for bitumen extraction.

DETAILED DESCRIPTION OF THE INVENTION

[30] FIGURE 1 shows is a schematic view of the four steps of the fluid bed up-flow combustor of the present invention. Fuel 1, oxidizer 2, and water 3 are supplied to a high pressure combustor 6 at section A which is located at the lower section of the vertical vessel. The fuel 1 may be coal slurry, petcoke slurry, hydrocarbons such as untreated heavy low quality crude oil, VR (vacuum residuals), asphaltin, or any available carbon fuel. The oxidizer gas 2 can

be oxygen, enriched air or oxygen. The combustion is stoichiometric, and the amount of heat energy generated is greater than in partial combustion, resulting in extremely high temperatures. The temperature is controlled by the water injected to the combustor 3. The water can be supplied with the fuel in a slurry form. The combustion gas flows upward to steam generation section B where low quality water 7 is injected into the up-flow combustion gas. All of the liquid water turns into steam, leaving the water TSS and TDS solids mixed with the up-flow gas flow. Large solid particles remaining from the water fall down by gravity to the fluid bed in section D. The produced steam, gas and solid mixture flow to the homogenizer section C at the top of the vessel, where any remaining water drops are converted to steam and discharged from the upper vessel section 8. Section D located at the bottom of the vessel includes a fluid bed where cold gas 4 is injected and suspends the solids particles. The temperature of the injected cold gas is at the range of the discharged gas temperature 8. Melted or semi-melted slag in a sticky form is cooled down by the relatively cooled gas 4 and become non-sticky solid particles. An outline of the method of the present invention is shown in Figure 3.

[31] FIGURE 2 is a schematic view of another embodiment of a fluid bed with a down-flow combustor integrated with internal heat exchanger and water injection for direct contact steam generator and bottom with solids discharge of the present invention. Fuel 1, oxidizer 2, and water 3 are supplied to a high pressure combustor 6 at section A, which is located at the top of the vertical vessel. The fuel 1 may be coal slurry, petcoke slurry, hydrocarbons, such as untreated heavy low quality crude oil, VR (vacuum residuals), asphaltin, or any available carbon or hydrocarbon fuel. The oxidizer gas 2 can be oxygen, enriched air or oxygen. The combustion is stoichiometric, and the amount of heat energy generated is greater than in partial combustion,

resulting in extremely high temperatures especially if oxygen is used as the oxidizer. The temperature is controlled by the water injected to the combustor 3. The water can be supplied with the fuel in a slurry form. The combustion section can include a radial heat exchanger 9 that is located near the vessel wall. The heat exchanger heats a saturated, solid free steam and gas flow 10 to generate a dry, super heated steam and gas flow or generate high pressure pure steam from treated BFW (Boiler Feed Water) ready for injection for EOR. The combustion gas with the generated solids, possibly in liquid form (like melted slag) flows downward to the direct contact steam generation section B. In this section low quality water 7 are injected and disperse into the down flowing gas flow.

[32] The water converted to gas leaves the solids in a dry particle form mixed with the gas. The low quality water can contain high levels of TDS, TSS and organics contaminations. The gas and solids flow to the discharge section, located low at the vessel. In this section, the gas flow is deflected and forces a change direction to improve the mixture and to prevent large solid particles, possible in a sticky form and possible liquid droplets from discharging with the gas flow out from the system where it can settle in down-flow pipe and equipment. At the bottom of the vessel, there is the fluid bed section D where cold gas 4 circulates and flows upwards to suspend the solids bed. Solids are discharged from the bottom of the vessel 5 to maintain the bottom fluid bed solids level. The up-flow velocity above flow 4 in section D and below discharge flow 8 in section C, is in the range of 0.2m/sec to 6m/sec to support the upward carry-on solids particle size of up to 1.2 mm. An outline of the method of the present invention is shown in Figure 3.

[33] FIGURE 3 is a diagrammatic outline of the method of the present invention.

[34] FIGURE 4 shows a view of the four steps of the fluid bed up-flow combustor of the present invention. Fuel 1, oxidizer 2, and water 3 are supplied to a high pressure combustor 6 located at section A, which is located at the lower section of the vertical vessel. The combustion gas flows upward to steam generation section B where low quality water 7 is injected into the up-flow combustion gas. All the liquid water turn into steam leaving the water TSS and TDS solids mixed with the up-flow gas flow. Large solid particles remaining from the water can fall down by gravity to the fluid bed in section D. The produced steam, gas and solids discharged from the top of the vessel 8. Portions of the produced gas 8 are recycled back 12 and injected upwards through the fluid bed at the vessel bottom to generate the cold bed bottom effect. Some cold oxidizer 2, can be injected with the recycled gas 12 to the fluid bed section D to further lower the temperature of the up-flowing recycled gas 12 and support the combustion at section A. Solids are continually removed from the vessel 5 through a solid separation unit 15. The lean solid gas flow 14 recycled back to line 12. The solids are removed from the solid separation unit in a dry form, where it can be discharged in a landfill. The up-flow velocity above flow 12 in section D is in the range of 0.2m/sec to 3m/sec to support the carry-on solids.

[35] FIGURE 5 shows a view of the four steps of the fluid bed up-flow combustor of the present invention as described in Fig. 4 with modified steam generation section B. The heat transfer in section B is improved by the use of chains 19 that enhanced the direct contact heat transfer sufficiency of the flowing combustion gas and the injected water. Low quality water 7 injected all around the vessel wall through circular injector 20. The chain improved the heat transfer between the flowing combustion gas and the water. Solids generated by the evaporated water will settle on the chains 19. Because the chains are made from links that are free to move,

the relative movement of the links will break-off solids that have built-up. To enhance this self-cleaning behavior the chains can move mechanically through sealed rotating shaft 18 that can continually move or move in intervals.

[36] FIGURE 6 is a schematic view of another embodiment of a fluid bed with a down-flow combustor integrated with internal heat exchanger and water injection for direct contact steam generator. Fuel 1, oxidizer 2, and possibly water 3 are supplied to a high pressure combustor at section A which is located at the top of the vertical vessel. The combustion is stoichiometric, and the amount of heat energy generated is greater than in partial combustion, resulting in extremely high temperatures. The temperature is controlled by the water injected to the combustor 3. If the fuel is in a slurry form, or if the oxidizer is air, then water 3 is not required. The combustion section includes a radial heat exchanger 9 located near the vessel wall to minimize its contact with the melted solids, like slag generated by the combustion. The heat exchanger is using radiation as the heat exchange method. It is important to minimize the physical contact with the melted solid particles generated by the combustor. The energy recovered through this heat exchanger is relatively small (up to maximum of 45% of the combustion energy, and typically not more than 25% of the energy). Most of the combustion heat energy is used to generate steam from the water 3 in a direct contact heat exchange and not through the non-direct radiation based heat exchanger 9. Boiler feed water or saturated steam and gas mixture 6 flows through this heat exchanger to produce super-heated dry steam and gas mixture 7 ready for EOR.

[37] Then, the combustion gas flows downwards to the direct contact steam generation section 10, where low quality water 3 is injected to the gas flow where the liquid water turns to

steam and fly solid particles. The temperature in the combustion area, that is in the range of 1200°C - 2000°C most of the solids like the slag, are in a liquid state. The direct contact water injection 3 immediately reduces the temperature to 350°C - 500°C where the melted and sticky solids particles turn to solid and flow with the gas stream. To protect the structure from the high combustion temperature refractory insulation might be used 16. After the water injection section 3 the vessel wall is covered with free moving bodies like chains. Because the free movement between the chain link prevents the solids build-up on the wall and improved the direct contact heat transfer in the steam generation section 10.

[38] The gas and solid particles flow to the discharge section 13. This section includes the gas discharge 8. The gas discharge 8 includes change in the down flow direction to ensure that large solid particles and possibly water droplet remains will not flow with the discharged gas mixture. The fluid bed section located at the bottom of the vessel 14. Heavy solid particles and other solid that were not removed with the discharged gas 8 are suspended at the fluid bed. Some of the discharged gas recycles back to the fluid bed and flows upward to create the fluid bed solid suspension effect. The up-flow gas cooled down any melted solid particles and any liquid droplets are converted to gas and solids remaining. To maintain the fluid bed solids level, dry solids are discharged from the vessel bottom 5 for disposal while most of the fine solid particles discharged at 11 and removed through gas-solid separator (not described). The generated gas temperature and pressure 11 is according to the particular heavy oil EOR requirements, typically in the range of 250°C- 400°C and the pressure of 10bar- 40bar.

[39] FIGURE 7 shows the integration of vertical down-flow fluid bed direct contact steam generator with a saturated steam generator and solids scrubber for the production of solid

free steam and gas mixture for EOR. Fuel 5, oxidizer 6, and possibly water 7 (as part from the fuel, if the fuel is in the form of slurry) are supplied to a high pressure combustor 13 located at the top of the vertical vessel. The combustion is stoichiometric, and the amount of heat energy generated is greater than in partial combustion, resulting in high temperatures. The temperature is controlled by the water injected to the combustor 3.

[40] The combustion section includes a radial heat exchanger 9 located near the vessel wall to minimize its contact with the melted solids, like slag generated by the combustion. Saturated steam and gas mixture 16 flows through this heat exchanger to produce super-heated dry steam and gas mixture 10 ready for EOR. The combustion gas flow downwards to the direct contact steam generation section where it is contacted with low quality water 14 injected to the gas flow where the liquid water turns to steam and fly solid particles. The steam, gas and solid particles discharge through a change in the down flow direction 8 to ensure that large solid particles and possibly liquid droplet remains will not flow with the discharged gas mixture. The discharged gas and solid mixture separate to solid rich gas flow and solid lean gas flow 4. The solid lean gas flow 12 recycled back and injected to the vessel bottom 12 to support the fluid bed. Heavy solid particles and other solids that were not removed with the discharged gas 8 are suspended at the fluid bed. The up-flow gas 12 cooled down any melted solid particles and any liquid droplets are converted to gas and solids remaining.

[41] Large solid particles that were not supported in the fluid bed can be discharged from the vessel bottom 11 for disposal, however most of the solids carried by the fluid bed and discharged with the produced gas 8. The solid rich steam and gas flow from separator 4 flows to a high efficiency separator 2. This separator removes the solids 15 with minimal discharge gas. Such

dry gas-solid separators packages are commercially available. The solids are then disposed. The solid lean gas flow 17 flows to a wet solid scrubber and saturated steam generator 3. Water 7 is continually added to vessel 3 to maintain the liquid water level and to compensate for the water converted to steam and discharged 14.

[42] Additional chemical materials can be added to the injected water 7. For example, if there is a need to remove sulfur oxides from the produced steam-gas mixture limestone slurry can be added to the low quality water 7. The generated calcium sulfite and calcium sulfate solids will be converted to solid particles and removed in way similar to the removal of slag and other carry-on solids that by-pass the solid separator 2. Liquid water is pumped and sprayed 18 to improve the solid scrubbing and the steam generation. Vessel 3 generates saturate solid free steam 16. This saturated steam flows through heat exchanger 9 to generate dry, superheated steam and gas mixture 10 at temperature in the range of 250°C- 400°C and the pressure of 8bar-40bar. Water with the scrubbed solids 14 from vessel 3 is recycled back to the vertical steam generator 1 where the water is converting to gas and the solids removed in a dry form. The superheated steam and gas mixture 10 injected into injection well 20 for EOR.

[43] FIG. 8 is a schematic view of integrated down-flow combustion unit with cold fluid bed support for generating steam from MFT, recover the water and the heat from the produced gas mixture for heating the process water for bitumen extracting in an open mine oils and facility. Fuel 1, oxidizer 2, and possibly water 3 (if required to generate fuel slurry or to reduce the combustion temperature) are supplied to a high pressure combustor 6 at section A, which is located at the top of the vertical vessel. The fuel 1 may be any available carbon or hydrocarbon fuel. The oxidizer gas 2 can be oxygen, enriched air or oxygen. The combustion is

stoichiometric. The combustion section may include a radial heat exchanger 9 that is located near the vessel wall. The combustion gas with the generated solids, possibly in liquid form (like melted slag) flows downward to the direct contact steam generation section B. In this section, MFT 7 is injected and disperse into the down flowing hot combustion gas flow. The water in the MFT converted to steam gas, leaves the solids in a dry particle form mixed with the gas.

[44] The gas and solids flow to the discharge section C, located low at the vessel. In this section, the gas flow is deflected and forces a change direction to improve the mixture and to prevent large solid particles, possible in a sticky form and possible liquid droplets from discharging with the gas 8 flow out from the system where it can settled in down-flow pipe and equipment.

[45] At the bottom of the vessel, there is the fluid bed section D where cold gas 4 circulates and flows upwards to support the fluid bed. Most of the solids discharged with the produced gas 8 due to the fluid bed circulation. Solids, which were not supported by the fluid bed, can be discharged from the bottom of the vessel 5 to maintain the bottom fluid bed solids level. The generated steam, combustion gas and solid mixture 8 flow to solid separation unit 13. The solids 15 are recovered in a dry form using commercial available gas-solid separation unit 13 where solids 15 in dry form removed from the process and can be trucked back to the oils and mine for disposal in landfill. The steam and NCG (None Condensable Gas) mixture 14 flows to the direct contact heating vessel 23 where the steam and gas flow upwards and the process water flows downwards to condense the steam in flow 14 and recover the condensing steam and NCG for heating the process water. The steam generated from the MFT is condensed and become part from the process water.

[46] The tailing water from the oils and 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 and the Froth Treatment Tailings. A Sand dyke 44 contains tailing pond. The sand separates from the tailing and generates a sand beach 45. Fine tailings 46 are put above the sand beach at the middle-low section of the tailing pond. Some fine tailings are trapped in the sand beach 45. On top of the fine tailing is the recycled water layer 47. 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 process water 27 is pumped from a location close to the surface of the tailing pond, (typically from a floating barge). The fine tailings are pumped from the deep areas of the fine tailings 46. MFT (Mature Fine Tailing) 33 is pumped from the lower section of the tailing pond and is then directed to the fluid bed direct contact steam generation vessel where it is continuously recycled and injected 7 to the up-flow combustion gas.

[47] Under the heat and pressure inside the vessel, the MFT turn into gas and solids, as the water converts to steam. The steam and NCG (Non Condensable Gas) flow 14 is used to heat the process water. The process water 27 is pumped from the upper level of the tailing pond 47 or from other separation units (not shown). The process water is injected to the upper section of vertical direct contact heat exchanger vessel 23 where it is mixed and heated by direct contact with the up-flow condensing steam and combustion NCG 14. The heated process water is

discharged from the vessel bottom at temperature of 70°C- 90°C as required by the oil sand extraction facility. The pressure in the system can be at the range of 1bar-50bar, most preferably at the range of 3bar-10bar. Most of the steam generated from the MFT is condensed during the process of heating the process water 27. The cooled NCG 26 discharged from the upper section of vessel 23. The hot process water is mixed with the crushed solid oils and 40 and separate at the extraction facility 42 to produced bitumen, sand and water 43. The sand and water 43 discharged back to the tailing pond.

[48] EXAMPLE 1: The following flow table is a simulation of a direct - contact steam generation process, as described in FIG. 7. The simulation was done for 3 different pressures as described in the following table. The heat source is petcoke internally combusted. The fuel that was used for the simulation was a high sulfur petroleum coke with 7% sulfur. The water source was disposal water with high solids content that includes, as example, some hot lime softeners sludge or fine tailing pond water. The combustion occurred in the high pressure direct contact steam generator 1 and the water mixed with the combustion gases. The combustion pressures were 1500kpa (kilopascals), 200kpa, and 103kpa. The solids introduced mostly from the water were removed in a solid separator 2, which can use a cyclone design. The gas at a temperature of 280°C- 300°C, with carry-on solids was scrubbed in the solids scrubber and wet steam generator 3 to generate saturated (“wet”) steam product 16. The water in scrubber 3 includes lime stone slurry to react with the SO₂. The generated Calcium Sulfite and sulfate recycled back with the scrubbed solids and removed by the solid separator 2 with the other solids in a dry form. To replace the water converted to steam, make-up water 7 is continually supplied to vessel 3. The simplified analysis result is described in the following table.

Process pressure: 103kpa

	Flow 6	Flow 5	Combustion flow 13	Flow 8	Flow 7	Flow 16
T, C	25.00	25.00	1507.23	285.85	25.00	96.76
P, bar	103.00	103.00	103.00	103.00	103.00	103.00
Vapor Fraction	0.37	0.00	1.00	0.97	0.00	1.00
Enthalpy, MJ/h	-48993.34	-15890.46	-66883.84	-178003.40	-29353.13	-199426.30
Mass Flowrate, kg/h	6362.13	2070.00	8432.14	15937.52	1850.00	16527.80
H2O	3000.00	1000.00	3998.55	10624.38	1850.00	12474.38
C	0.00	1000.00	0.00	0.00	0.00	0.00
CO	0.00	0.00	3.26	0.00	0.00	0.00
CO2	0.00	0.00	3659.02	3760.23	0.00	3760.23
O2	2879.91	0.00	149.05	110.97	0.00	110.97
Ar	182.22	0.00	182.22	182.22	0.00	182.22
Solids	300.00	0.00	300.00	961.00	0.00	0.00
S	0.00	70.00	0.00	0.00	0.00	0.00
SO2	0.00	0.00	139.88	0.00	0.00	0.00
CaCO3	0.00	0.00	0.00	1.47	0.00	0.00
CaSO4	0.00	0.00	0.00	297.25	0.00	0.00
H2	0.00	0.00	0.16	0.00	0.00	0.00

Process pressure: 200kpa

	Flow 6	Flow 5	Combustion flow 13	Flow 8	Flow 7	Flow 16
T, C	25.00	25.00	1504.53	285.03	25.00	116.27
P, bar	200.00	200.00	200.00	200.00	200.00	200.00
Vapor Fraction	0.36	0.00	1.00	0.97	0.00	1.00
Enthalpy, MJ/h	-49059.23	-15890.46	-66949.48	-178375.30	-26338.49	-196268.30
Mass Flowrate, kg/h	6362.13	2070.00	8432.14	16028.98	1660.00	16323.26
H2O	3000.00	1000.00	3998.98	10609.84	1660.00	12269.84
C	0.00	1000.00	0.00	0.00	0.00	0.00
CO	0.00	0.00	2.28	0.00	0.00	0.00
CO2	0.00	0.00	3660.56	3760.23	0.00	3760.23
O2	2879.91	0.00	148.11	110.97	0.00	110.97
Ar	182.22	0.00	182.22	182.22	0.00	182.22
Solids	300.00	0.00	300.00	1067.00	0.00	0.00
S	0.00	70.00	0.00	0.00	0.00	0.00
SO2	0.00	0.00	139.88	0.00	0.00	0.00
CaCO3	0.00	0.00	0.00	1.47	0.00	0.00
CaSO4	0.00	0.00	0.00	297.25	0.00	0.00
H2	0.00	0.00	0.11	0.00	0.00	0.00

Process pressure: 1500kpa

	Flow 6	Flow 5	Combustion flow 13	Flow 8	Flow 7	Flow 16
T, C	25.00	25.00	1871.76	289.39	25.00	192.23
P, bar	1500.00	1500.00	1500.00	1500.00	1500.00	1500.00
Vapor Fraction	0.45	0.00	0.99	0.97	0.00	1.00
Enthalpy, MJ/h	-32752.59	-15890.46	-50643.00	-178942.00	-17215.22	-188187.80
Mass Flowrate, kg/h	5262.13	2070.00	7332.14	15992.22	1085.00	15811.50
H2O	2000.00	1000.00	2995.57	10673.08	1085.00	11758.08
C	0.00	1000.00	0.00	0.00	0.00	0.00
CO	0.00	0.00	18.41	0.00	0.00	0.00
CO2	0.00	0.00	3635.21	3760.23	0.00	3760.23
O2	2879.91	0.00	160.35	110.97	0.00	110.97
Ar	182.22	0.00	182.22	182.22	0.00	182.22
Solids	200.00	0.00	200.00	967.00	0.00	0.00
S	0.00	70.00	0.00	0.00	0.00	0.00
SO2	0.00	0.00	139.88	0.00	0.00	0.00
CaCO3	0.00	0.00	0.00	1.47	0.00	0.00
CaSO4	0.00	0.00	0.00	297.25	0.00	0.00
H2	0.00	0.00	0.50	0.00	0.00	0.00

[49] The preceding disclosure and description of the invention is illustrative and explanatory thereof. Various changes in the details of the illustrated construction may be made within the scope of the appended claims, without departing from the true intent of the invention. The invention should only be limited by the following claims and their legal equivalents.

CLAIMS

I claim:

1. A method for vertically producing a steam and combustion gas mixture, the method comprising:

mixing fuel selected from a group containing carbon or hydrocarbon and an oxidation gas containing oxygen;

combusting the mixture at a controllable pressure and temperature so as to generate heat and combustion gas;

mixing liquid water with said combustion gas, said liquid water having solids and being mixed to transfer liquid water into steam while reducing the combustion gas temperature and generating produced gas;

injecting a portion of said produced gas at a temperature lower than the combustion temperature below said generated combustion gas; and

discharging said produced gas.

2. The method of claim 1, wherein said liquid water is selected from a group consisting of tailing pond water, fine tailings, mature fine tailings, disposal water, lime softener sludge, brackish water, and sewage effluent water; and

wherein said oxidation gas is selected from a group consisting of oxygen, oxygen-enriched air and air.

3. The method of any one of claims 1-2, wherein said fuel is selected from a group consisting of carbon and hydrocarbon fuel.

4. The method of any one of claims 1-3, wherein the produced gas injected below said combustion gas is at a temperature range of between 150°C. and 500°C.

5. The method of any one of claims 1-4, further comprising a heat exchanger to use up to 45% of said combustion heat to generate a super-heated steam and gas mixture from said produced gas.

6. The method of any one of claims 1-5, wherein the pressure of said produced gas being between 103 kpa and 10,000kpa.

7. The method of any one of claims 1-6, wherein an up-flow velocity of the produced gas injected below said combustion gas is in a range of between 0.2 m/s and 6 m/s.

8. The method of any one of claims 1-7, further comprising:

flowing the discharged produced gas to a cyclone; and

separating solids from said produced gas flow so as to produce a solids lean produced gas flow.

9. The method of claim 8, further comprising recycling at least a portion of said solids lean produced gas flow below the combustion gas.
10. The method of any one of claims 1-9, wherein the solid mixture is processed by a dry solids separation unit, the method further comprising removing solids from the gas flow.
11. The method of any one of claims 1-10, the method further comprising washing the produced gas by mixing the produced gas with saturated water of a saturated temperature so as to scrub any remaining solids from the gas, and separating a liquid phase from the gas phase.
12. The method of claim 11 further comprising recycling water of the liquid phase with the scrubbed solids and mixed them with said combustion gas.
13. The method of any one of claims 8-12, further comprising adding limestone slurry to the liquid water to remove sulfur contaminates.
14. A method for producing steam mixture for oil recovery comprising:
 - combusting a mixture of fuel and oxidation gas to generate combustion gases;
 - mixing said combustion gases with liquid water having solids in a vertical vessel to directly generate a mixture of combustion gas and steam from said liquid water;
 - evaporating at least a portion of said liquid water with said combustion gas ;
 - recycling a portion of said generated combustion gas and steam mixture to the bottom of said vertical vessel to generate gas up- flow;
 - transferring said combustion gases mixture to a solids separator unit; and
 - removing solids from said solids separator unit.
15. The method of claim 14, wherein said combustion gases pressure being between 103 kpa and 10,000kpa.
16. The method of any one of claims 14 and 15, further comprising:
 - washing the combustion gas mixture with liquid water at a saturated temperature and pressure;
 - and
 - scrubbing any remaining solids from the combustion gas mixture to form a clean steam and gas mixture.
17. The method of any one of claims 14-16, further comprising:
 - transferring the combustion gas mixture to a counter flow direct contact vessel; and
 - mixing the combustion gas mixture with process water;

18. The method of any one of claims 14-17, further comprising recovering heat from the combustion gas mixture and condensing steam to liquid while heating the liquid water to a temperature between 70°C.-90°C. for an oil recovery.

19. A system for vertically producing a steam and combustion gas mixture, the system comprising:

a first section being comprised of a burner means for combusting fuel selected from a group containing carbon or hydrocarbon with oxidation gas containing oxygen;

a second section being adjustably engaged to said first section and being comprised of a means for injecting low quality liquid water to flowing combustion gas, said low quality water containing levels of solids where said low quality water evaporates to generate a mixture of steam and combustion gas;

a third section being adjustable engaged to said second section being comprised of discharge means for discharging said produced steam and combustion gas mixture; and

a fourth section being at the bottom of the vessel, said forth section having a gas injector and containing solids generated from said evaporated water, the forth section includes a solids discharge means located at the bottom of the vessel.

20. The system for vertically producing a steam and combustion gas mixture of claim 19, further comprising recycled portion of said mixture of steam and combustion gas produced at said second section to said forth section.

21. The system for vertically producing a steam and combustion gas mixture of any one of claims 19 and 20, further comprising a flow deflector adjusted to said third section discharge means for reducing liquid remains and heavy solid particles from flowing with said produced steam and combustion gas mixture.

22. The system of any one of claims 19-21, further comprising an apparatus recycling portion of said steam and combustion gas fluidly connected to said forth section to generate gas up- flow.

23. The system of any one of claims 19-22, further comprising a separator separating solids from said mixture of steam and combustion gas.

24. The system of any one of claims 19-23, further comprising an injection well fluidly connected to said system for injecting said steam to recover oil.

25. The system of any one of claims 19-24, further comprising a heat exchanger means recovering combustion heat to generate a super-heated steam and gas mixture from saturated steam and gas mixture.

26. The system of any one of claims 19-25, wherein said fourth section injected gas temperature is in the range of 150°C and 500°C.

27. The system of any one of claims 19-26, further comprising means for generating recyclable gas flow for said forth section, the means for generating being comprised of a cyclone solid separator.

28. The system of any one of claims 19-27, further comprising means for maintaining an up-flow gas velocity in a range of 0.2m/s and 6m/s.

29. The system of any one of claims 19-28, further comprising means for using the produced steam and combustion gas for bitumen recovery.

30. The system of any one of claims 19-17, further comprising an apparatus fluidly connected to said discharge means in said third section for extracting heat and water from said produced steam and combustion gas mixture for an oil recovery.

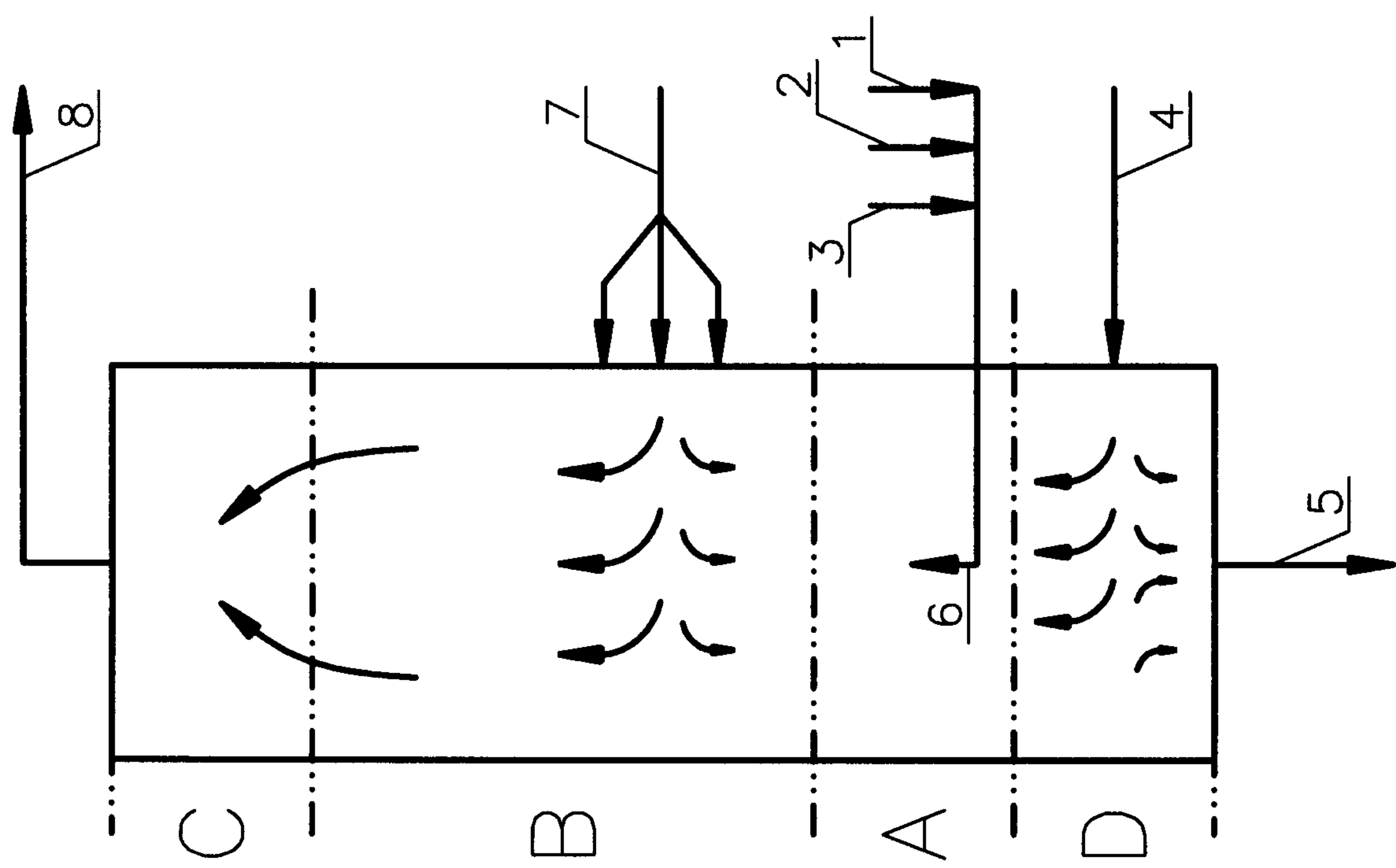


FIG.1

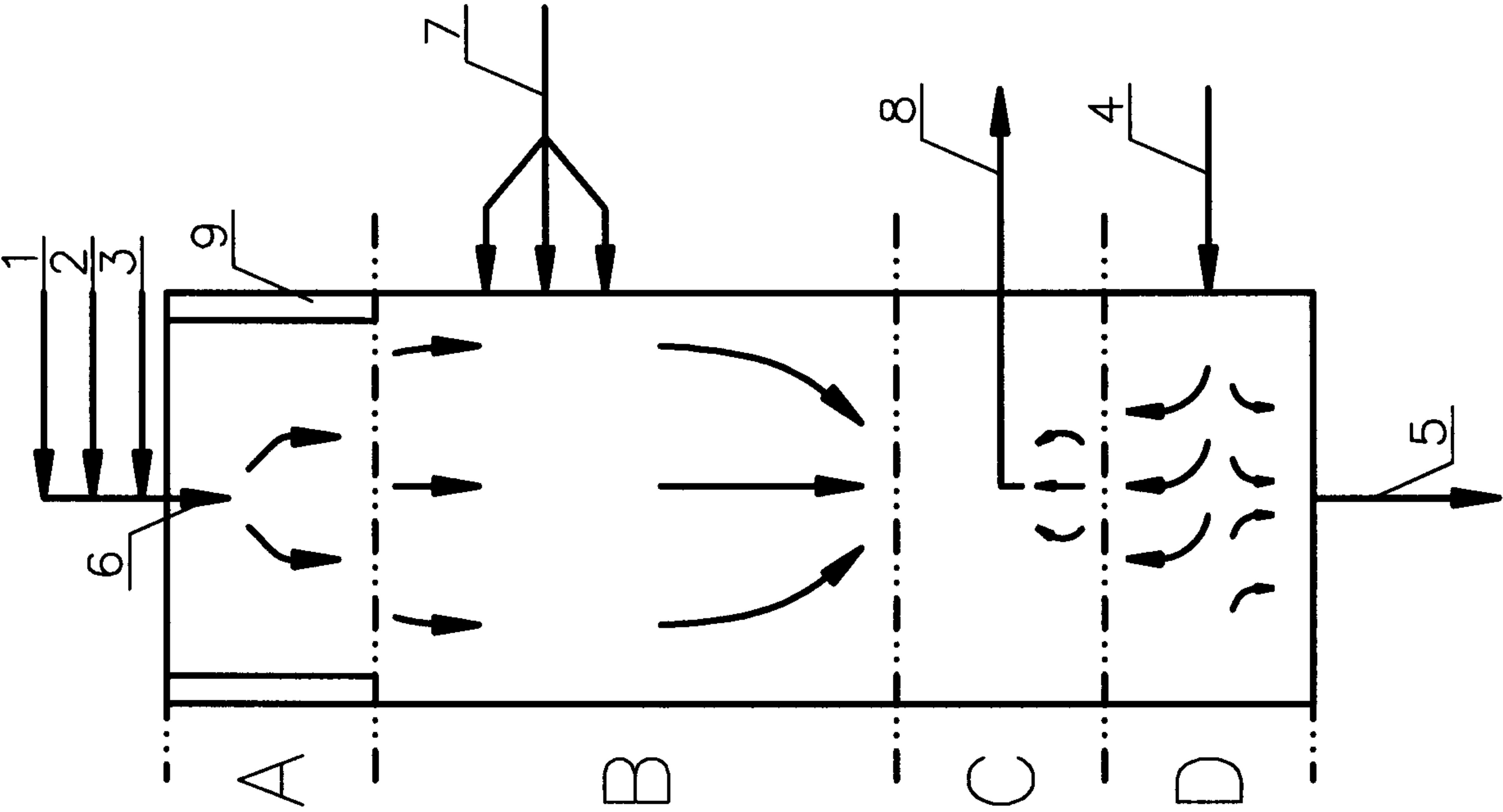


FIG.2

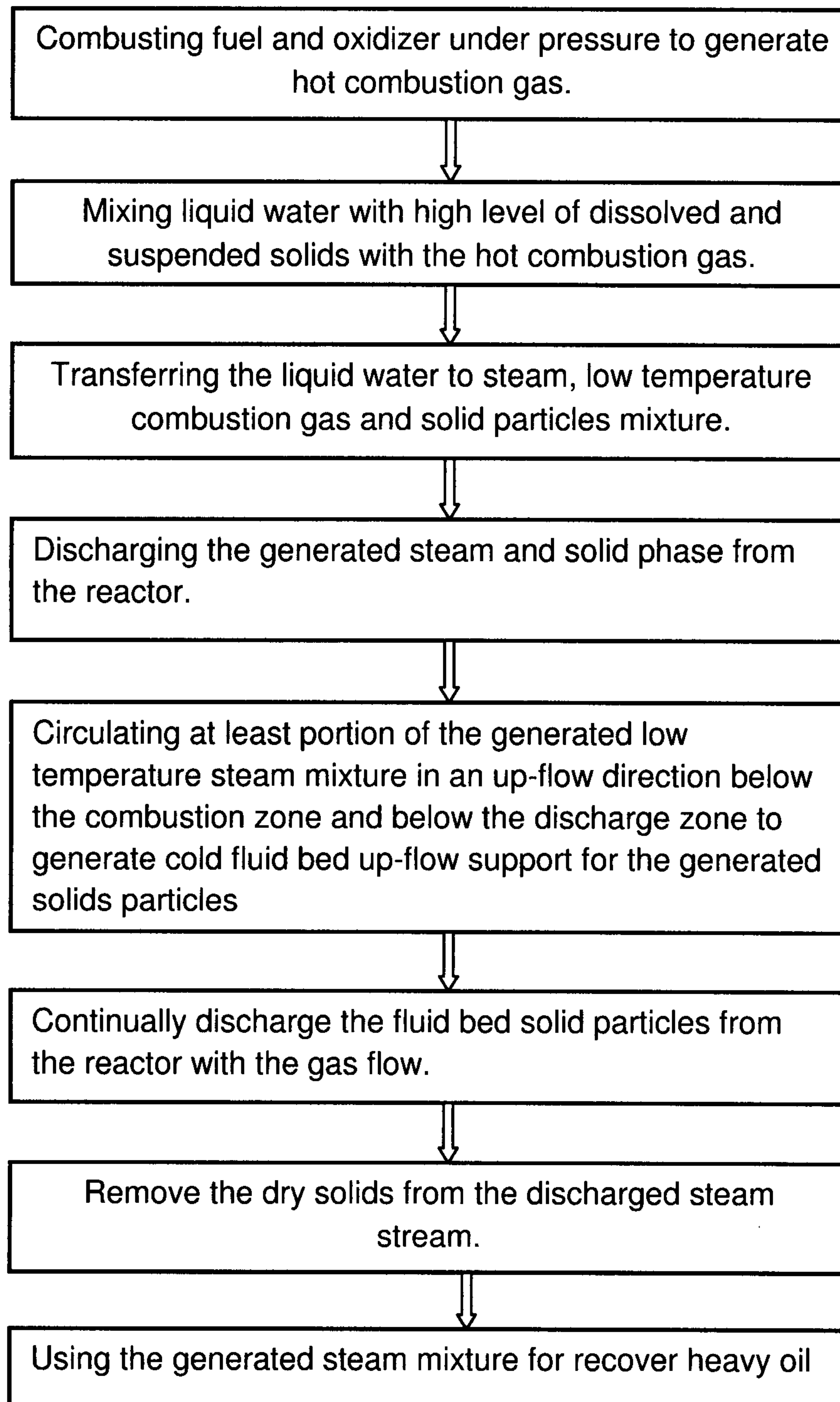


FIG. 3

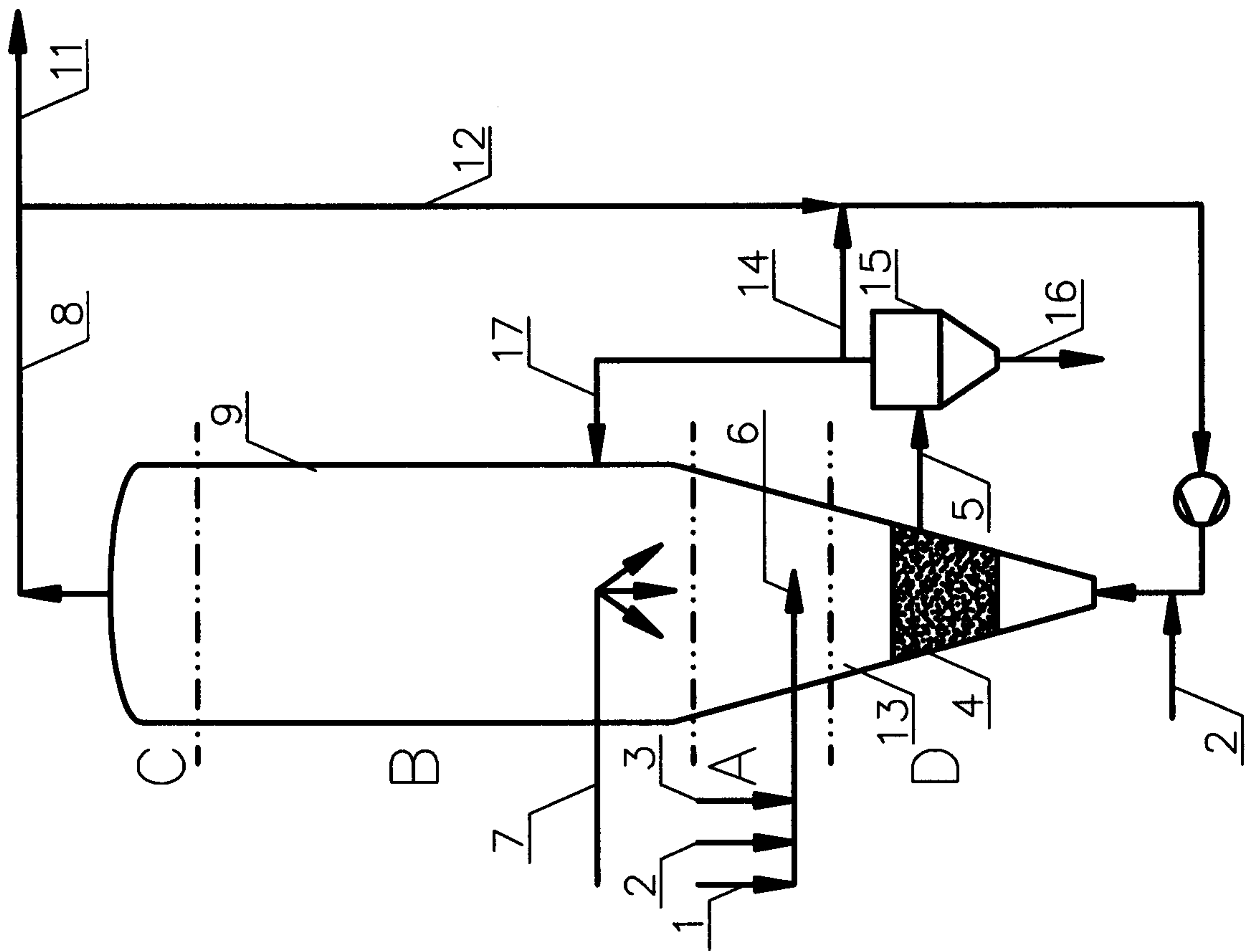
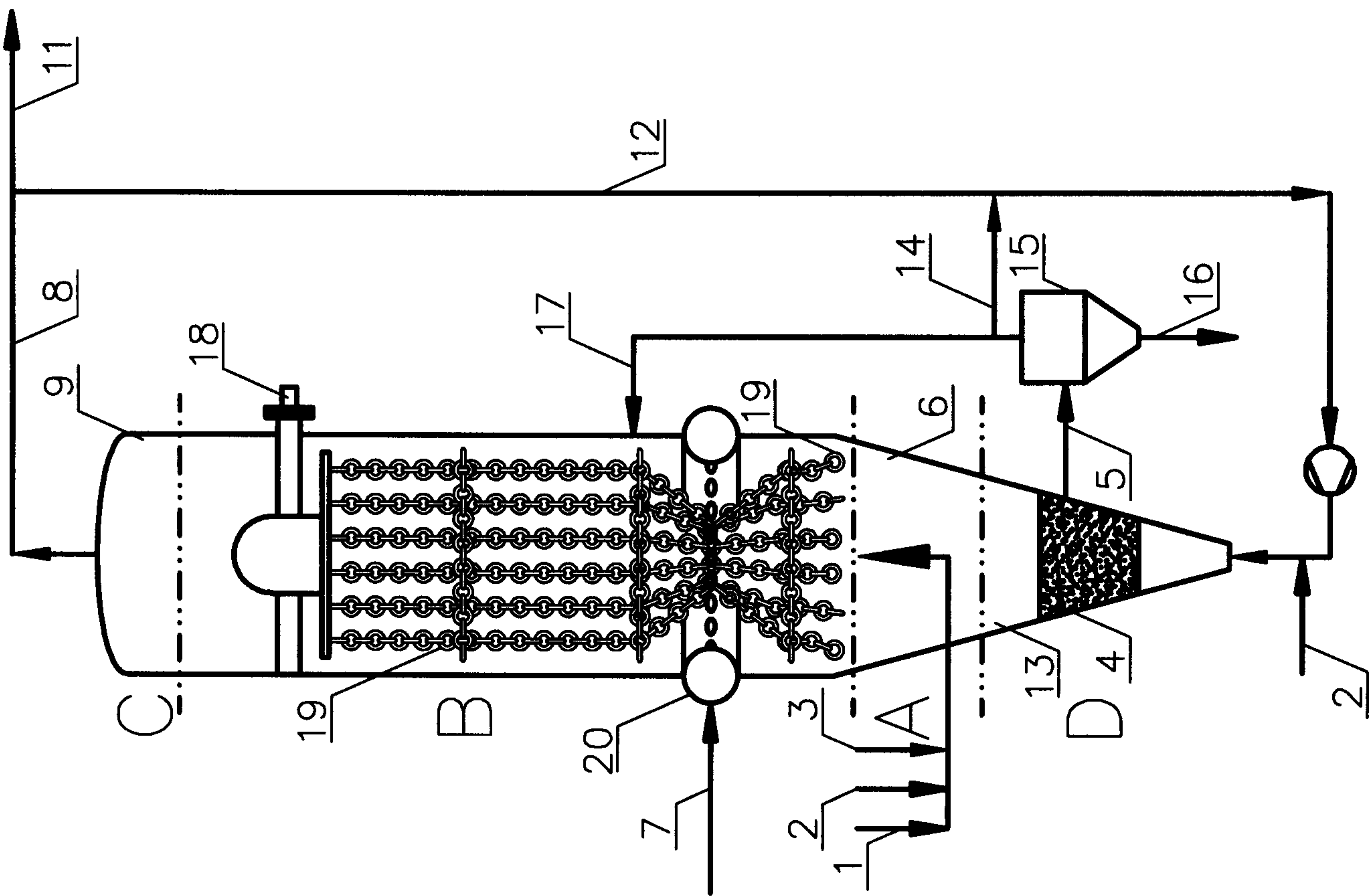


FIG.4



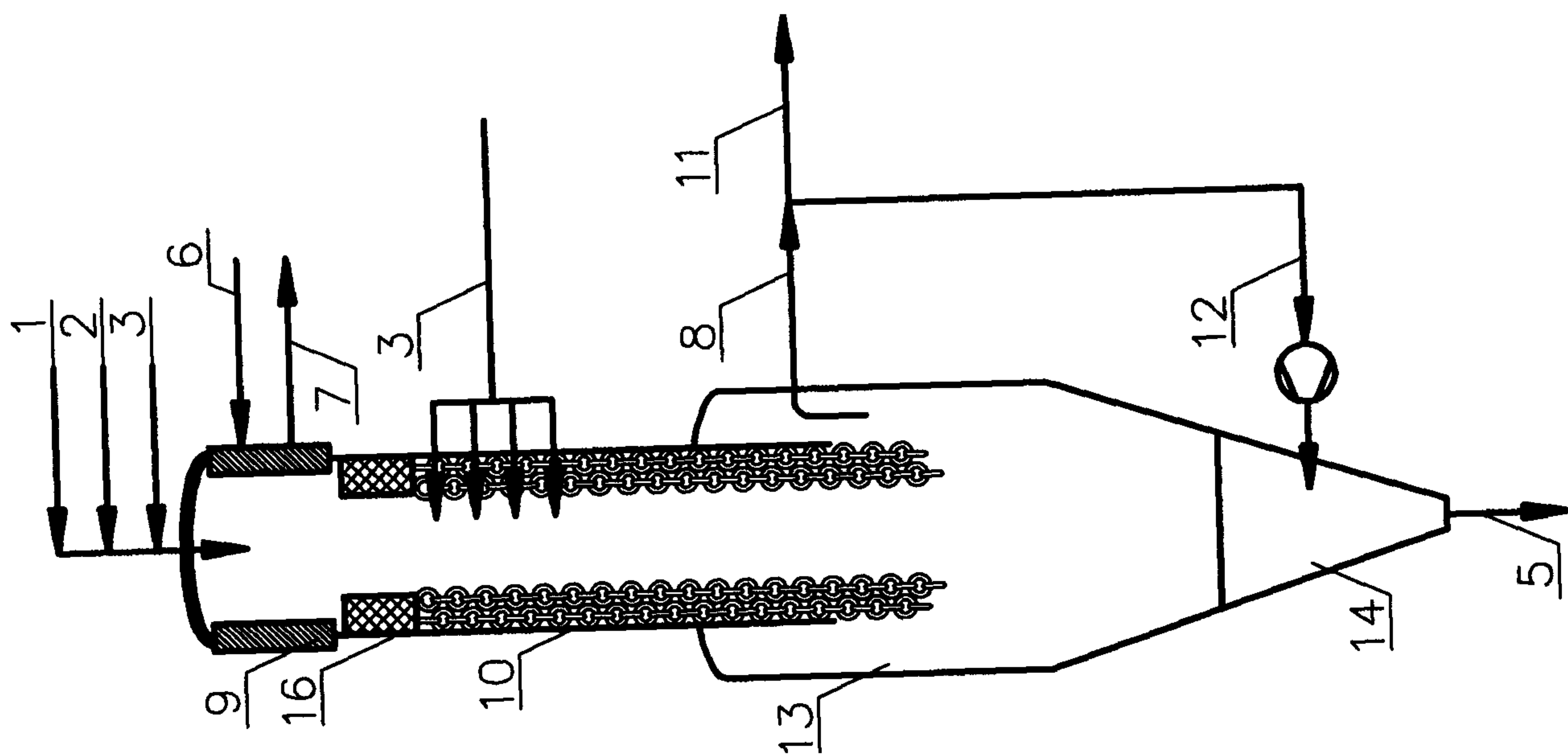


FIG.6

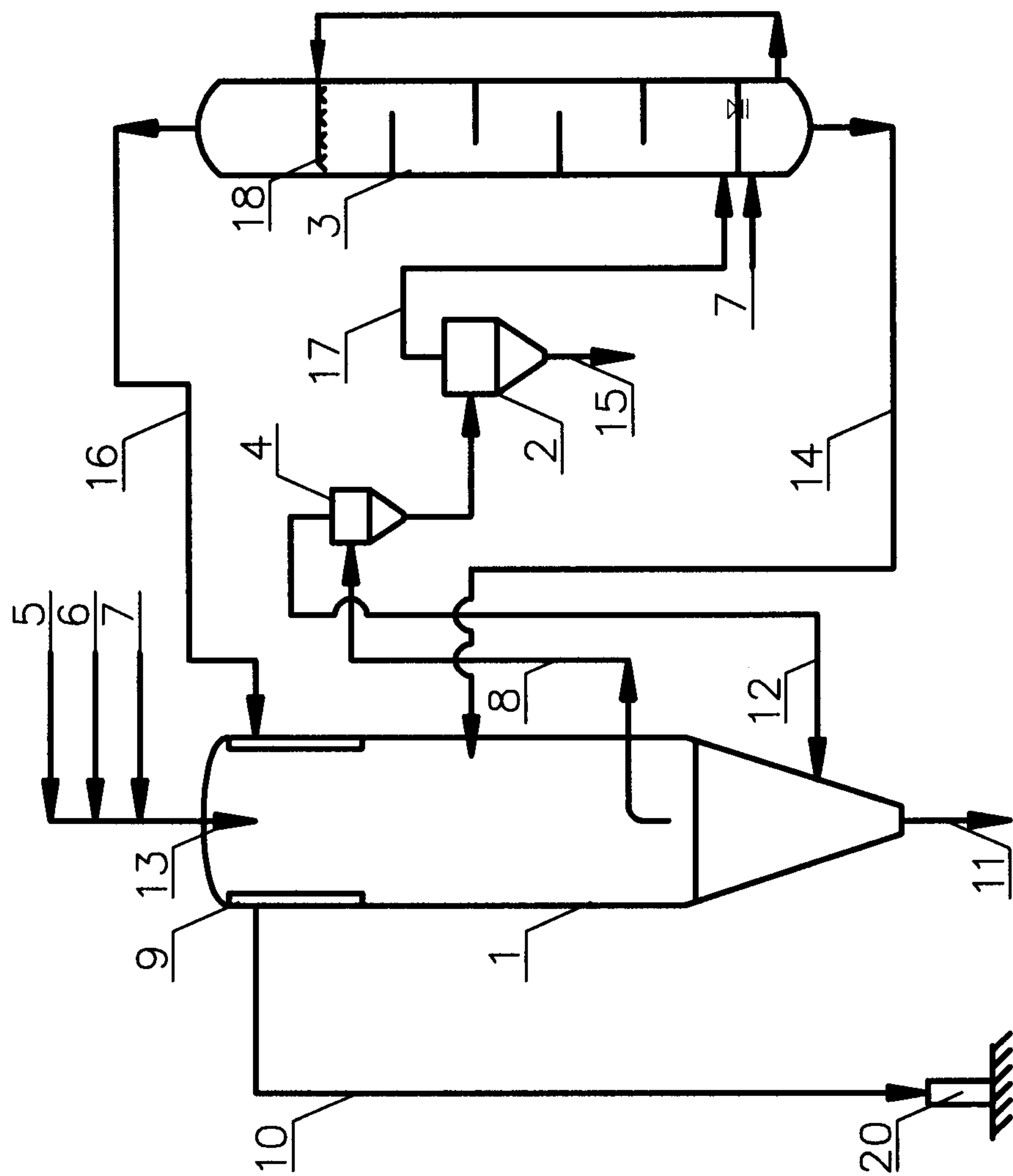


FIG. 7

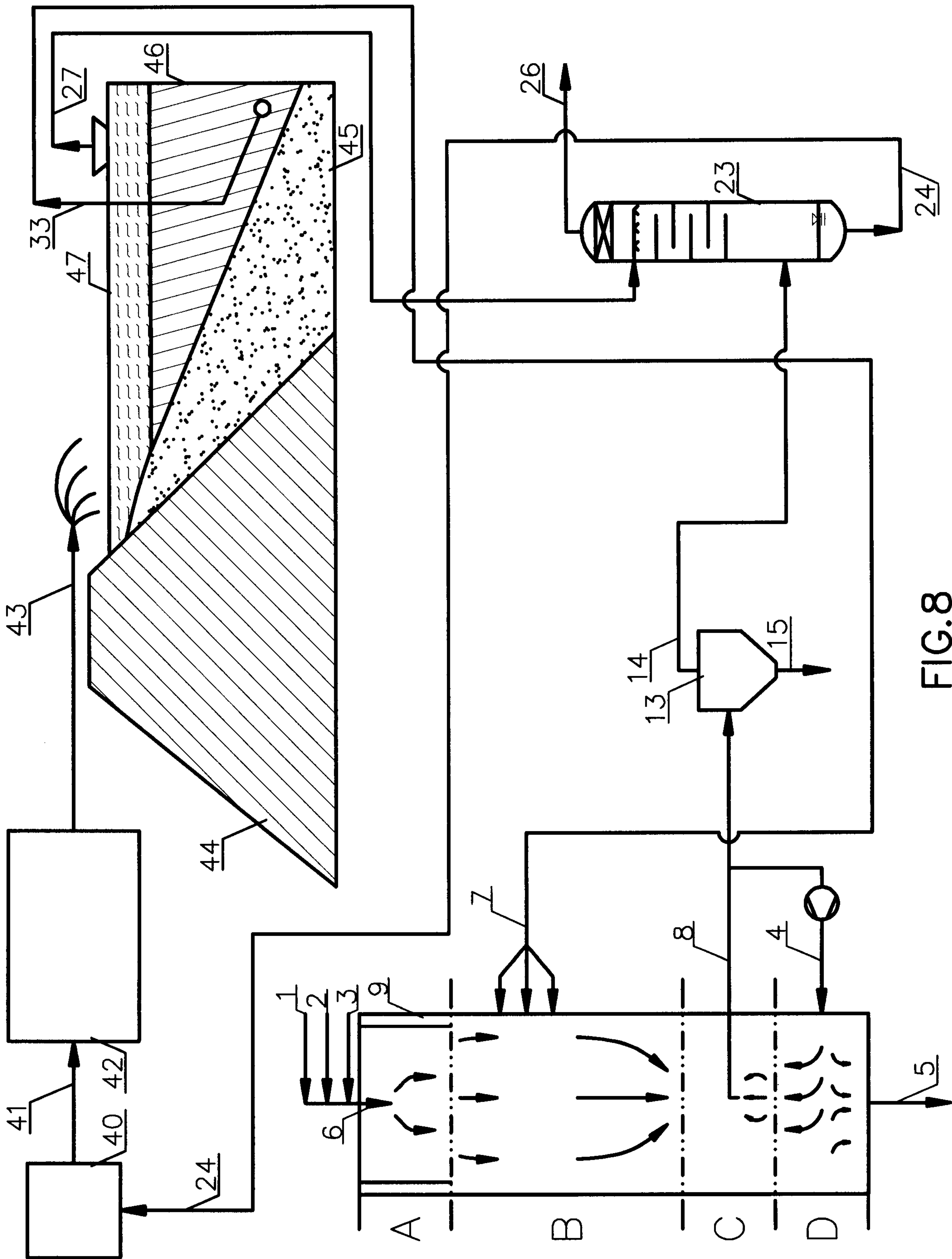


FIG. 8

Combusting fuel and oxidizer under pressure to generate hot combustion gas.



Mixing liquid water with high level of dissolved and suspended solids with the hot combustion gas.



Transferring the liquid water to steam, low temperature combustion gas and solid particles mixture.



Discharging the generated steam and solid phase from the reactor.



Circulating at least portion of the generated low temperature steam mixture in an up-flow direction below the combustion zone and below the discharge zone to generate cold fluid bed up-flow support for the generated solids particles



Continually discharge the fluid bed solid particles from the reactor with the gas flow.



Remove the dry solids from the discharged steam stream.



Using the generated steam mixture for recover heavy oil