(54) Titre : SYSTEME INTEGRÉ ET PROCEDE DE PRODUCTION DE PETROLE LOURD A DRAINAGE PAR GRAVITE AU MOYEN DE VAPEUR (DGMV) FAISANT APPEL A DU CARBURANT ET A DE L'EAU DE QUALITES MEDIOCRES

(54) Title: INTEGRATED SYSTEM AND METHOD FOR STEAM-ASSISTED GRAVITY DRAINAGE (SAGD)-HEAVY OIL PRODUCTION USING LOW QUALITY FUEL AND LOW QUALITY WATER

(57) Abrégé/Abstract:
A method and system for producing steam for extraction of heavy bitumen including the steps of mixing carbon or hydrocarbon fuel. The fuel is crude oil, vacuum residue, asphaltin, petcoke or coal. The oxidation gas includes oxygen, oxygen enriched air or air-
(57) Abrégé(suite)/Abstract(continued):
combustion of the mixture under high pressure and high temperature. The fuel is mixed with low quality contaminated water containing organics and inorganics. The liquid phase transferred to a gas phase includes steam and carbon dioxide, 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 water is recycled back for liquids gasification. The super-heated dry steam and gas mixture is send to an enhanced oil recovery facility for injection into an underground reservoir.
ABSTRACT OF THE DISCLOSURE

A method and system for producing steam for extraction of heavy bitumen including the steps of mixing carbon or hydrocarbon fuel. The fuel is crude oil, vacuum residue, asphaltin, petcoke or coal. The oxidation gas includes oxygen, oxygen enriched air or air-combustion of the mixture under high pressure and high temperature. The fuel is mixed with low quality contaminated water containing organics and inorganics. The liquid phase transferred to a gas phase includes steam and carbon dioxide, 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 water is recycled back for liquids gasification. The super-heated dry steam and gas mixture is send to an enhanced oil recovery facility for injection into an underground reservoir.
INTEGRATED SYSTEM AND METHOD FOR STEAM-ASSISTED GRAavity
DRAINAGE (SAGD)-HEAVY OIL PRODUCTION USING LOW QUALITY FUEL AND
LOW QUALITY WATER

Field of the Invention

This application relates to a system and method that improves the Steam-Assisted Gravity
Drainage (SAGD) facility or other Enhanced Oil Recovery (EOR) facilities with a system that
can be integrated into an existing facility or be used as a new stand-alone facility. The present
invention relates to processes for producing steam from low quality rejected water containing
high levels of dissolved and suspended inorganic solids or organics, such as oil.

With its simple direct contact, above ground adiabatic nature, and its high pressure and
temperature solid removal; this invention will minimize the amount of energy used to produce
the mixture of steam and gas injected into the underground formation to recover heavy oil. This
thermal efficiency minimizes the amount of greenhouse gases released into the atmosphere.

This thermal efficiency is achieved due to direct heat exchange. The condensed steam and the
gases that will return back to the surface with the produced bitumen are at the temperature
required for oil recovery, which is no higher than the underground reservoir temperature, which
is no higher than the temperature required for oil recovery. The produced water does not need to
be cooled to be treated in a water treatment facility as the produced hot contaminated water can
be used for steam production without any additional treatment.
The above-mentioned invention also relates to processes for making SAGD facilities or other EOR (Enhanced Oil Recovery) facilities more environmentally friendly by using low quality fuel and reducing the amount of greenhouse gas emissions through thermal efficiency and injecting the CO₂ into the underground formation, where a portion will remain permanently.

BACKGROUND OF THE INVENTION

Steam injection into deep underground formation(s) has proven to be an effective method for EOR facilities producing heavy oil. This is typically done by SAGD or by Cyclic Steam Stimulation (also known as “huff and puff”). In recent years the SAGD method has become more popular, especially for heavy oil sand formations. Presently, steam injection is the only method commercially used on a large scale for recovering oil from oil sands formations.

The invention can be used together with prior art processes being used in upstream and downstream production facilities, (currently in use by the oil Industry); it adds the adiabatic direct contact steam and carbon dioxide generation unit to reduce the disadvantages of the prior art and to allow for expansion with use of a low quality water supply, reject water from existing facilities and the use of low quality fuel supplies. (see “Canadian Oil Sands: Opportunities, Technologies and Challenges”; S. Patel; Hydrocarbon Processing, February 2007, pp. 65-73). Also, there is no need for high quality separation and purification downstream oil removal processes with this invention. The present invention is Zero Liquid Discharged (ZLD) system because solid waste is produced instead of liquid waste.
In the present invention, the exothermic reactions and treatment of the injected gas mixture are done in an adiabatic control area above ground. The underground portion of oil production is very complex, with many unknowns, because the oil formed over millions of years until it reached steady-state equilibrium. As shown in other areas, one way to exploit resources and produce products is by improving processes control. Since underground combustion processes change the chemistry of the reservoir, they further complicate the complex underground reservoirs and are difficult processes to control.

The injection of pure steam, or steam in a mixture with other gases, creates the minimum necessary increase in the underground formation disorder. It does not increase the complexity of the underground reservoir beyond the minimum required to mobilize oil from the sand. This may be the reason why only the processes of steam-injection (or of steam and other gases), are implemented and found to be commercially effective with SAGD.

The present invention is to be used with EOR methods, mainly SAGD. The main disadvantages of existing commercial SAGD(s) are the main drivers of the present invention.

SAGD, CSS and similar EOR facilities consume large quantities of water to extract the heavy oil by using steam. The water-to-oil ratio needed to extract the oil from the ground is about 2-4 barrels of water to one barrel of oil. The current prior-art technologies require relatively high water quality, as required by the Once-Through Steam Generators (OTSGs) or boilers for Scaling prevention. This results in expensive water treatment plants with water de-oiling separation. The operations of such facilities consume chemicals to minimize oil traces in the
recycled water. Reject water is produced and injected into disposal wells. In the case of lime softeners, sludge is produced as well. The purification processes can create sludge (as is the case with lime softeners) and reject wastewater. Where disposal wells are not permitted for environmental reasons, an additional expensive and energy consuming ZLD system is added to evaporate the reject water to produce solid waste. As part of the recycled water treatment, all oil traces must be removed. These stringent requirements are applicable in both prior-art commercial technologies, lime softeners and in evaporator-based facilities. Any oily emulsions must be broken down by chemicals or filters to a very high degree of separation. (see "Zero Liquid Discharge at Macky River"; presented by Gary Giesbrecht at the Canadian Heavy Oil Association (CHOA) in Calgary, Alberta on February 13 2007). The process usually produces a stream of "reject water" from the blow-down that is injected into disposal wells or treated in an additional, expensive and energy consuming ZLD facility, including evaporators and crystallizers. Low quality, high TDS and TSS source water requires an expansive treatment facility and using lime softeners creates large amounts of sludge. As a result the oil producing companies are typically drawing relatively high aquifers to produce the best water quality available from an area, which is much larger than the area in which the oil is produced.

An ongoing portion of the EOR construction and operation costs is the cost of constructing and operating the water treatment plant. At present, the most widespread commercial water treatment process in the SAGD industry is the use of lime softeners. In this process, lime, magnesium oxide and other materials are used to remove dissolved solids from the water in the form of slurry. This process requires constant chemical supply and creates significant amounts of slurry.
waste, resulting in landfill costs and environmental impacts. Different processes include evaporators that require water de-oiling and reject water that must be disposed of in disposal wells, or evaporated and crystallized to produce solid waste in additional ZLD crystallizer facilities. (See "Use of Evaporation for Heavy Oil Produced Water Treatment", by W. Heins and D. Peterson, Journal of Canadian Petroleum Technology, 2005, vol. 44, pp. 26-30.). There is a need for the ability to use oily water and water-oil emulsions in the production of steam so as to reduce the complexity of water treatment and associated capital costs. As well, it is necessary to do so in order to reduce the amount of energy and chemicals used. There is an advantage to producing dry solid waste that is easy to dispose of.

EOR facilities like SAGD consume a large amount of heat energy. In most commercial SAGDs, natural gas is used as the energy source for steam production. Natural gas is a valuable resource. The extensive use of it for producing oil is expensive with significant environmental impacts. In some prior art projects, steam is produced by burning some of the extracted heavy oil for the production of steam. This is a problematic process since there is a need for flue gas treatment to remove the sulfur prior to releasing it into the atmosphere. Another option is to combine upstream and downstream technologies in the form of an SAGD and Upgrader that uses a gasification process to gasify the "barrel bottom" to produce syngas for the production of steam in non-direct steam generators. There is a need to use heavy oil upgrading by-products for steam production.
The use of OTSG, boilers or gas turbines to generate steam causes only a portion of the heat from the burning hydrocarbon to be injected underground into the reservoir. Hot flue gases with carbon dioxide are released to the atmosphere. A typical SAGD that produces 50,000 bitumen barrels per day generates 4,000 ton to 8,000 ton of carbon dioxide per day. There is a need to minimize the carbon dioxide release. This can be achieved by: (1) using less steam; (2) producing the steam in a more efficient manner, (so as to minimize aboveground heat losses); and (3) injecting the carbon dioxide with the produced steam to the reservoir; where some of it will permanently remain. (See “Low Carbon Future”; PTAC (Petroleum Technology Alliance Canada); March 31, 2007; pp. 15-18, 161-170) and PTAC Technology Session; February 1, 2007; pp. 19-23).

Various patents have been issued that are relevant to this invention. For example, U.S. Patent No. 4,498,542, issued on February 12, 1985 to Eisenhawer et al. describes a system for aboveground direct contact steam generation. The method and apparatus produce a high-pressure mixture of steam and combustion gases for thermal stimulation of petroleum wells. The produced mixture of combustion products, (steam and water) is separated to gas and liquid phase in a separator where the gas and steam mixture is injected to create enhanced oil recovery. The liquid water is flashed to produce additional steam. The solids’ concentration increases downstream from the combustion in the separator and flash chamber where they are continually removed with disposed, drained water. The drained water’s heat energy is reused in this process. The generated steam in the saturated condition will create corrosion problems and will require additional steps to be taken.
U.S. Patent No. 4,398,604, issued on August 16, 1983 to Krajicek et al. describes a system for aboveground stationary in direct contact horizontal steam generation. The method and apparatus produce: high pressure, a thermal water vapor stream, and a stream of combustion gases for recovering heavy viscous petroleum from a subterranean formation. These high-pressure combustion gases are directed into a partially water-filled vapor generator vessel used to produce a high-pressure stream of water vapor and combustion gases. The generated solids are continually removed with reject water.

There are also patents related to applications in down-hole heavy oil production. U.S. Patent No. 4,463,803, issued to Wyatt on August 7, 1984 describes a system for down-hole stationary direct contact steam generation for enhanced heavy oil production. The method and apparatus generate high-pressure steam within a well bore. The steam vapor generator is used for receiving and mixing high-pressure water, fuel and oxidant in a down-hole configuration. The produced solids are discharged to the reservoir. Generally, the down-hole direct contact steam generators of the prior art have some debilitating disadvantages. Any maintenance is complicated, and requires the wheel to shut down, while a drilling completion rig is necessary to pull out the equipment. The water and fuel that is used must be of the highest quality so as to prevent the creation of solids that plug up the well over time. Any operation outside of optimal design conditions can lead to corrosion and solid carbon problems.

The prior art methods and systems typically generate reject water that can be either released to a disposal formation or crystallized in a separate facility, where the remaining water is evaporated.

The steam and carbon mixture produced by the prior art can easily lead to corrosion, due to condensation. The prior art also requires a liquid-solid separation process, typically if using low quality water with high solid contaminates, as well as low quality solid fuels, such as petcoke or asphaltin.

It is a goal of the present invention to provide a system and method to improve EOR facilities like SAGD, through a supply of steam and gas mixtures for underground injection wells and also by creating add-ons to existing facilities.

It is another objective of the present invention to provide a system and method that can produce steam from low quality rejected water containing high levels of Total Dissolved Solids and high levels of TSS (Total Suspended Solids) or organics emulsion.

Another objective of the invention is to provide a system and method that utilizes low-grade fuel.

An additional objective of the present invention is to provide a system and method that will remove produced solids by converting the liquids to gas phase under high pressures, which will remove solids from the gas phase.
Furthermore, it is another objective of the present invention to provide a system and method that enhances thermal efficiency as a result of direct heat exchange, which minimizes the amount of energy used to produce the mixture of steam and gas 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 that are released out into the atmosphere.

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 and reducing the harmful effects of greenhouse gases.

An additional goal of the present invention is to provide a system and method, which minimizes water treatment costs.

It is still a further object of the present invention to provide a method for steam production and gas mixing for extraction of heavy bitumen.

It is an object of the present invention to provide a method for producing super-heated, dry, solid- free steam and gas mixture flow being between 800 and 4000 Kpa and in temperature of between 170º C and 450º C.
It is still a further object of the present invention to provide a method that uses disposal water, possibly with oil, clay or silica sand from a SAGD facility.

It is still a further object of the present invention to provide a system for oil recovery using heat injection.

These and other objects and advantages of the present invention will become apparent from a reading of the attached specification and appended claims.

BRIEF SUMMARY OF THE INVENTION

The method and system of the present invention for steam production for extraction of heavy bitumen includes the following steps: (1) mixing a low quality fuel containing at least heavy bitumen, solid hydrocarbons or carbons emulsion and oxidizing gas like oxygen, enriched air or air; (2) combusting the mixture under high pressure and temperature; and (3) mixing water, possibly with high total dissolved and suspended solids content (like silica, calcium, magnesium, sodium, carbonate or organics) within the combusted mixture so as to control reactor temperature and generate steam.

The method of combustion includes transferring the liquid phase to a gas phase, and separating the solids from the gas phase adiabatically in order to keep the gas at the high temperature. The gas phase contains steam, carbon dioxide and possibly other gases that were present at the oxidizer or generated from the fuel used. The gas and steam are cleaned in a separator and then
they are mixed with liquid water of high saturated temperature and pressure so as to produce saturated clean wet steam, and any remaining solids are scrubbed from the gas. The liquid water is then separated from the gas. In the event that the gas contains sulfur, and in the event that there is a requirement to remove the sulfur in the produce steam and gas mixture prior to the injection to the underground formation, the process can include adding lime, possibly with dolomite, and magnesium oxide during the step of scrubbing and then reacting the lime with the sulfur.

The liquid phase and the remaining solids are recycled and moved back, with liquid water, to the combustion chamber. The liquid phase and remaining solids are heated in the combustion reactor so as to gasify the liquid phase and remove the remaining solids. Corrosive contaminant gases can be removed from the gas phase by commercially available packages designed for specific gas composition on specific locations. The pressure of the clean, saturated wet steam is reduced to an injection pressure that will transfer the steam from a saturated wet phase to a dry phase. Heat can be added to the steam to produce yet a higher temperature of super-heated dry steam and gas mixture. The pressure of the dry steam and gas mixture is between 800 and 4000Kpa. The temperature of the steam and gas mixture will be between 170°C and 300°C. A heat exchanger can be added in-between the hot gases, leaving the combustion chamber and the produced gases for injection. The temperature of the produced super-heated dry steam and gas mixture can be up to 450°C. High temperature is necessary to prevent condensation and corrosion due to the presence of carbon dioxide and other gases like sulfur dioxide in the steam and gas mixture.
The super-heated dry steam and gas mixture can be injected into an underground reservoir through a prior art commercially used EOR facilities like SAGD horizontal injection well, or by CSS vertical injection wells.

The disposed water delivered from an Existing EOR-like SAGD facility can be used as the low quality water needed for the above method. Similarly, the extracted heavy bitumen can be received from the SAGD facility without processing in-between. Fuel for the combustion process can be supplied from a remote Upgrader in the form of slurry, using the Upgrader reject water. The fuel used in this method can be pet coke, untreated “green” pet coke (that is, removed from the delay cokers without any additional processing or asphaltin). Explicitly, this solid fuel is transported in the form of slurry mixed with low quality water. It is pumped into a direct contact steam generator, where it is injected to a combustion chamber along with some of the transportation water. A portion of the water can be recycled, and sent back to be used again as the solid fuel transportation medium, together with fresh, continuously added make-up water.

**BRIEF DESCRIPTION OF THE DRAWINGS**

FIGURE 1 is a schematic view of an illustration of the current invention for Zero Liquid Discharge (ZLD) direct contact steam generation with solids removal.

FIGURE 2 is a schematic view of an illustration of a ZLD direct contact super-heated steam generator, for the production of a super heated steam/gas mixture for heavy oil recovery.
FIGURE 3 is a schematic view of an illustration of a ZLD direct contact super heated steam generator with partial combustion in the steam generation reactor, solids removal from the combusting vessel and two steam generators, solids scrubbing and separation vessels.

FIGURE 4 is a schematic view of an illustration of a ZLD direct contact super-heated vertical steam generator with steam and gas recycle for combustion temperature control.

FIGURE 5 is a block diagram showing the integration of the direct contact super-heated steam generation facility of the present invention with a prior art Upgrader, a co-generation facility, air separation facility and a prior art EOR facility.

FIGURE 6 is a block diagram showing the integration of the direct contact superheated steam generation facility of the present invention, including a prior art “stand alone” SAGD facility where liquid waste produced by the previous art SAGD is consumed by the ZLD direct contact facility.

DETAILED DESCRIPTION OF THE INVENTION

FIGURE 1 shows an embodiment of the current invention. In it, hydrocarbons like untreated, heavy, low-quality crude oil, VR (vacuum residue), coal, asphaltin or petcoke if available from oil upgrading process, are injected together with oxidation gas (oxygen, air or enriched air) to the combustion area of a high-pressure Direct Contact Steam Generator 11. Heat is released from the exothermic reaction. Water is injected to the combustion area 11 to keep the high temperature
under control; this is to prevent damage to the facility while achieving full oxidation reaction of the carbon to minimize the amount of unburned carbon solids. An additional water is injected to produce steam. The amount of water is controlled to produce steam, where all the liquids amid the soluble materials become solids and all liquids evaporate or combust to gas and solid slug and ash. Additional chemical materials can be added to the reaction. For example, limestone can be added to water in a situation where the fuel used is rich in sulfur. The gas and solids move to a high-pressure solid separation block 12 where the solid phase is removed from the gas phase. This can done in a continuous way or at intervals combined with pressure drops.

10 The high pressure, high temperature gas is mixed and washed throughout the water in the partially filled vessel 13 to remove the remaining solids and produce wet steam. The rejected water and solids from the block are injected back into the steam generator 12. In a case where the water or the fuel include a high percentage of impurities that react to produce unacceptable corrosive materials (high chlorine, sulfur etc), an additional reaction block for corrosion control is added. The wet steam is injected to a high-pressure, high-temperature, corrosive gas scrubber.

15 At 14 the water is circulated and re-generated and at 16 the remaining corrosive gases are removed. This exact scrubbing and re-generation of the injected steam-gas mixture is chosen according to the impurities that appear in the water and the oil at the specific site. Those units are commercially available. It is important to emphasize that purification treatment at this stage is not designed to allow the release of the gases to the atmosphere (which requires removal of most contaminants) but only to maintain the corrosive product at an acceptable level relative to the
facility design. For instance, there is no need for a block in a case where stainless steel is being used for piping and casing, even if the fuel and water feeds are heavily polluted. 14.

The steam and gas mixture flows to a high-pressure separator block 15 where the steam and reaction gases are separated from the liquids and readied for injection into the reservoir. The separated liquid phase is injected back to the wet steam production vessel 13 and from it to the steam generator 11.

FIGURE 2 shows a schematic visual illustration of a ZLD direct contact super-heated steam generator for the production of a super-heated steam and gas mixture for oil recovery.

Fuel, possible in slurry form, 21, oxidizer 22, like oxygen enriched air and water 23 are injected to the high-pressure steam generation reactor 24. The pressure in the steam generator reactor is 800kpa-10000kpa, preferably in the range of 3000kpa-4000kpa. The temperature in the combustion reaction area is 900°C-2500°C, preferably in the range of 1100°C-1800°C in most of the reaction area. Low quality water that contains high concentrations of solids can reach beyond 50,000 ppm TDS, TSS (i.e.- silica, sand, clay, CaCO₃, gypsum in slurry form) and organics 212 are injected to the vessel to the boundaries of the combustion reaction zone where they generate steam while reducing the temperature to solidify the created slug, if slug is generated. This low quality water that is injected separately from the burner is not supposed to reduce the combustion zone temperature but should generate steam, protect the structure of the steam generator and prevent melted soot particles from sticking to the internal elements.
The generated gas, steam and solids 25 leave from vessel 24 at a temperature in the range of
300°C-800°C, more preferably in the range of 350°C-600°C. The produced gas and steam flows
through heat exchanger 26 where some of the heat is transferred to the produced flow
superheated dry steam / gas mixture 217. The gas-solids mixture flows through line 27 to solid
separation unit 210. The solid separation is a unit that is commercially available, and can include
cyclonic separators, centrifugal separators, mesh separators or any combination technologies.
(see “Gas-Solid Operations and Equipment”; Perry’s Chemical Engineers’ Handbook; 1999;
Section 17). The solids discharge from separator 210 flows through heat exchange 28 to recover
heat for pre-heated process flows. The solids discharged from the process through line 29 can be
disposed of in a landfill or through any other disposal method. The lean solids gas-steam mixture
211 leaves the separator and is injected into vessel 213. The gas-steam mixture released heat to
the liquid saturated water in the vessel, converts water to steam. Vessel 213 is maintained at high
pressure, about 800kpa-10000kpa, preferably in the range of 3000kpa-4000kpa, (slightly less
than the pressure at the steam reactor). The vessel is partially filled with water at saturated vapor
pressure and temperature. Steam is continually produced in vessel 213 and the remaining solids
are washed form the injected steam and gas mixture 212 by the water. Fresh make-up water 218
is continually injected to the vessel to maintain the scrubbing liquid water level. To increase the
heat transfer and steam generation capacity, saturated liquid water can be circulated 215.
Limestone together with Dolomite, magnesium oxide or other additives 215 can be injected to
vessel 213 in slurry form. Because the solids are water-scrubbed and water continually converted
to steam, solid-rich reject water is continually removed from the bottom of the vessel to control
the solid concentration level in the liquid water of vessel 213. The rejected water 212 that
contains scrubbed fly solids, any remaining Limestone, gypsum (generated from the reaction of the lime with sulfur) and any other dissolve solids are recycled back to steam generation reactor 24. The vessel produces saturated, clean, wet steam and gas mixture 216. The wet steam flows through heat exchanger 26. It is heated by stream flow 25 leaving the reactor 24 and becomes a super-heated dry steam and gas mixture at 217. The pressure of said mixture is in the range of 800kpa-3500kpa depending on the specific EOR facility requirements. The temperature can be in the range of 250°C-450°C. These dry, high temperature and pressure products can be injected into underground formation to enhance oil recovery while minimizing corrosion problems due to condensation in the steel pipes.

FIGURE 3 shows a schematic visual illustration of a ZLD direct contact super heated steam generator for the production of a super-heated steam/gas mixture for oil recovery with partial combustion in the steam generation reactor.

Fuel, possibly in slurry form 32, oxidizer 33, possibly oxygen-enriched air, and water 31 are injected to fluid bed high pressure steam generation reactor 34. The pressure in the steam generator reactor is in the range of 800kpa-10000kpa, preferably in the range of 2000kpa-4000kpa. The temperature in the combustion reaction area is in the range of 600°C-1300°C, preferably in the range of 800°C-1200°C within most of the reaction area. For temperature control and for the production of Syngas Synthesis Gas by-product the reactor can be operated in a partial combustion mode where less heat is generated while generating carbon monoxide and hydrogen that will be combusted later in the process. A possible advantage in using partial
combustion in the invention is a reduction of the heat flex and combustion temperature in the 
combusting reactor 34, while producing Synthesis Gas that part of it 327 can be used for other 
processes (like hydrogen production), after further processing in a commercially-available 
Syngas processing unit. Unfortunately from a practicality standpoint, prior art commercial 
gasifier packages used by the industry for syngas and hydrogen production can not be use with 
the present system. The reasons are that the commercial designs uses water only for hydrogen 
and carbon monoxide generation as part from the produced Syngas. In most prior art gasifiers the 
water is injected to the combustion reaction area as steam. The partial combustion reaction heat 
produced by the gasifiers typically used for steam generation in a non direct heat exchanger that 
requires high water quality typically from a water treatment plant. The produced Syngas is 
typically mixed in direct contact with quenching water for cooling and solids wash. The cooled 
clean Syngas further processed in catalytic reactor or used as an energy source. The quenching 
water does not generate steam - the opposite – any steam presented in the gasifier will 
condensate and removed from the cooled syngas to the quenching water. From practicality 
aspects, it will be possible to modify and use commercially available prior art gasifier 
components like gasifier burners after modifying them with addition water injectors.

Syngas 318, after being cleaned from the fly solids in separator 315, is injected together with the 
oxidizer 33 to vessel 320 while generating additional heat. A possible drawback in the partial 
combustion use is the additional complication and the generation of carbon particle solids, 
especially when the fuel in use is high in minerals coal and the reaction temperature is in the 
lower range. Another disadvantage is toxicity of the produced Syngas, because it contains
Carbon monoxide and Hydrogen sulfide (which are generated from the sulfuric fuel and the oxygen starvation conditions). Toxicity complicates solids removal 317.

The gases and fly solids flow from the top of vessel 37. The discharge temperature is in the range of 350°C-700°C, preferably in the range of 400°C-500°C. Solids can be discharged from the bottom of reaction vessel 34 through de-pressurizing containers and the valve system at 35.

The produced gas and steam flows through heat exchanger 38, where some heat is transferred to produce superheated dry steam / gas mixture for injection 39. The gas-solids flow to an additional heat exchanger 312 where they are deliver heat to pre-heat the supplied water. The heated supplied water 311 injected to vessel 320. The steam and gas mixture 313 temperature drops to approximately 250°C-400°C. Stream 313 flows to a solid separation unit 315, a commercially available package unit that can include cyclonic separators, centrifugal separators, mesh separators or any combination of gas-solid separation technologies. The solids discharged from separator 315 are discharged through a system of at least two vessels and valves in row 316 to de-pressurize the solids discharged. The solids 317 can be disposed in a landfill or through other disposal methods. The lean solids gas-steam mixture 318 leaves the separator from the upper section and is injected into the first scrubbing and steam generation vessel 320. Vessel 320 is maintained at high pressure 800kpa-10000kpa, preferably in the range of 2000kpa-4000kpa, slightly less than the pressure of the steam reactor. The vessel is partially filled with water at the saturated vapor temperature and temperature. The water washes the remaining solids. Steam is continually produced in vessel 320. Pre-heated, fresh, make-up water 314 is continually injected
to vessel 320 to maintain the scrubbing liquid level. Chemicals like Limestone, magnesium oxide or other materials 321 can be injected to vessel 320 in slurry form. Because water scrubbed the solids and continually converted to steam, solid-concentrated reject water 319 is continually removed from the bottom of vessel 320. The rejected water 319 Containing scrubbed fly solids, Limestone, generated gypsum and any other dissolve solids is recycled back to steam generation reactor 34. The vessel produces a saturated, clean, wet, steam and gas mixture 322. The wet steam flows to vessel 323 where additional scrubbing water and slurry like Limestone, magnesium oxide or other materials can be injected 324. The saturated steam and gas phase is separated from the liquid phase. The water with remaining materials recycled from the bottom of vessel 323 to the previous vessel 320. The saturated wet steam and gas mixture 325 is separated and released from the top of vessel 323. The wet saturated gas and vapor mixture 325 is heated in heat exchanger 38 by stream 37, leaving reactor 34 to become a super-heated, dry steam and gas mixture 39. These dry, high temperature and pressure products can be injected into underground formation for enhanced oil recovery while minimizing the problems of corrosion.

FIGURE 4 shows a schematic visual illustration of a ZLD direct contact super-heated vertical steam generator with gas recycle for combustion temperature control for the production of steam and gas mixture for oil recovery. Fuel, possibly in slurry form, 41, oxidizer 42, like oxygen, oxygen-enriched air, or air and water 43 are injected to high-pressure vertical steam generation reactor 44. The pressure in the steam generator reactor is in the range of 800kpa-10000kpa, preferably in the range of 2000kpa-4000kpa. The temperature in the combustion reaction area is in the range of 900°C-2500°C, preferably in the range of 1100°C-1800°C within most of the
combustion reaction area. Low quality water, possibly with organics and inorganic contamination 43 is injected to the vessel to generate steam while controlling the internal temperature.

The gases and solids are discharged from the opposite side of the vessel 45. The discharge temperature is in the range of 300°C-800°C, more preferably in the range of 350°C-600°C.

The produced gas and steam flows through heat exchanger 46 where some of the heat is transferred to the stream of the solids free gas and saturated steam 47. The temperature of the steam and gas mixture 49 dropped to 300°C-450°C. For combustion temperature control in the steam generation reactor 44, portion of the produced steam and gas mixture 49 can be recycled back 423 and circulated in reactor 44. Stream 49 flows to a solid separation unit 410. The rich solid discharge from separator 410 flows through heat exchanged 420 to recover heat, in order to pre-heat the water supplied to process 422. The discharged solids 419, flow to an additional gas-solid separator 417. The lean solids gas stream flows back to separator 410 and the solids 418 are removed for disposal in a land-fill or through other disposal methods. The lean solid gas-steam mixture 411 flows from the upper section of separator 410 and is injected into solid scrubbing and steam generator vessel 412. Vessel 412 is maintained at high pressure of 800kpa-10000kpa, preferably at 3000kpa-4000kpa; at a pressure slightly less than the pressure of the steam reactor 44. The vessel is partially filled with liquid water at the saturated vapor temperature. Steam is continually produced in vessel 412, where the remaining solids are washed by the water phase. Pre-heated, fresh, make-up water 415 is continually injected to vessel 412 to maintain scrubbing
liquid level. Chemicals like limestone, magnesium oxide or other materials 413 can be injected to the vessel 412 in slurry form. Because water scrubbed the solids and continually converted to steam, reject water rich in solids 414 is continually discharged from the bottom of vessel 412. The rejected water at 414 contains scrubbed fly solids, remaining limestone, generated gypsum and other dissolve solids. This is recycled back to steam generation reactor 44. Vessel 412 produces a saturated, clean, wet steam and gas mixture 47. The wet saturated gas and vapor stream 47 is then heated in heat exchanger 46 by stream 45, leaving reactor 44 to become superheated dry steam and gas mixture 48 in a temperature of 200°C-300°C and injection pressure. This dry, high temperature and pressure product can be injected into underground formation for enhanced oil recovery while minimizing corrosion problems.

FIGURE 5 is a block diagram showing the integration of the ZLD direct contact super-heated steam generator, described previously in figures 1-4, with an Upgrader, a co-generation facility, air separation facility and EOR facility that includes a water treatment plant with indirect steam generation equipment like OTSG. The method described in Fig. 5 can also be applied to a facility that does not include prior art indirect steam generation or Co-gen as a power source for an air separation unit.

An Upgrader 53 produces solid fuel that has minimal or no commercial value, like "green" pet coke from delay cokers. Any other type of carbon fuel like pet coke, asphaltin and similar by-products can be used as well. The Upgrader produces waste water contaminated with fine inorganic materials like silica sand, clay, dissolved salts, metals and also organic contaminants.
The Upgrader's wastewater is maintained in tailing pond 56. The solid fuel waste produced by the Upgrader is ground to grains less than six millimeters in size. These are then mixed with the low quality tailing water. Next, the slurry mixture is pumped through a pipeline, to a ZLD direct-contact super heated steam generator 58 where it is injected to the direct-contact high-pressure steam generator, along with oxygen or enriched air as previously described in figures 1-4.

The method includes an air separation unit 55. To supply energy to the air separation unit and prevent the grid electricity supply dependency, the system can include a co-generator facility 54. The co-gen unit produces energy for the air separation unit and, with the turbine tailing hot gases; it produces steam in an indirect exchanger from high quality treated water. The water can be provided from the water treatment plant of an existing prior art EOR facility 57, like SAGD. An air separation facility 55 produces oxygen or enriched air for direct contact reactor 58.

The oxygen or enriched air is injected into high-pressure direct contact steam generator 58, together with water and fuel. The low-quality water contains a residual bitumen emulsion that needs no further treatment. This prevents the need for use of expensive chemicals and facilities for the water purification emulsion separation process as used in the prior-art EOR water treatment plant.

The direct contact steam generation facility 58 is constructed in close proximity to an EOR facility 57, like a SAGD facility that includes a water treatment plant for non-direct steam generation equipment (like OTSG). The reject water from the prior art EOR facility is consumed
without additional treatment at the new facility 58. The water treatment requirements for the existing prior art EOR water treatment facility can be simplified because the new facility 58 is able to consume oily water, often with an oil emulsion instead of being treated with chemicals to separate the remaining oil (as required for disposal, both by injection wells or by ZLD evaporation facilities).

Facility 58 can also be connected in close proximity to a new EOR facility that does not include: a water treatment plant, prior art steam generation facilities or CO-GEN that required treated water. In that case, the steam produced in facility 58 will be the only steam injected throughout the EOR facility. There will not be a flow of blowdown reject water from EOR facility 57 to facility 58. However, there will be a flow of oily bitumen water rejected from the EOR facility during the oil-water separation process. (see "Ford, GM, Chrysler or Import: Choosing the ideal design for specific oil treating applications"; presented by Mark N. Smithdorf at the Canadian Heavy Oil Association (CHOA) in Calgary, Alberta on January 16 2007).

In areas where availability of carbon-based fuel from an Upgrader or other sources like coal is limited, the fuel used can be substituted by unprocessed bitumen produced by the EOR facility. It is alright for the bitumen to have water and sand impurities.

The waste from ZLD Direct contact steam generator 58 will be in a solid form suitable for landfill disposal; preventing the need for disposal wells or an additional ZLD facility, combined with the prior art EOR facility. Another advantage is that carbon dioxide released to the
atmosphere due to ZLD direct contact facility 58 will be minimal because the oil to water ratio is reduced, because of the high thermal efficiency of the process and also because most of the carbon dioxide will be injected directly into the reservoir, where some of it permanently stays underground.

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FIGURE 6 is a block diagram showing the direct contact superheated steam generation facility of the present invention 61 as well as a possible integration of the new facility 61 with a prior art EOR like SAGD facility. Liquid waste produced by the SAGD is consumed by the present invention’s direct contact process, so the integration becomes a ZLD as a whole. Unit 61 is described by the embodiments in the previous figures 1-4. For better understanding of FIG. 6, independent, possibly “stand-alone” ZLD direct contact facility portions are marked by a diagonally patterned background; whereas existing prior art EOR facilities have a blank background.

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The direct contact ZLD super heated steam generation facility 61 produces a super-heated dry steam and gas mixture for downhole injection for EOR. Oxygen or enriched air 624 is supplied to steam generation unit 61 from an air separation unit. Energy for the air separation unit can be supplied from the grid or any other source. The fuel source for the direct contact steam generator 61 can be liquid hydrocarbon fuel like heavy oil, VR or any available carbon like Petcoke, asphaltin or coal slurry 623. The mixture produced at the EOR production well 65 is separated into gas (mainly carbon dioxide and natural gas), oil and water. The produced water contains heavy oil remains, dissolve minerals, sand and clay. The separated low quality produced water
64 is used for steam generation 61 without any additional treatment. The ability of steam production facility 61 to use such highly contaminated water with no additional treatment is a significant advantage when compared to prior art, as it simplifies the whole process.

Additional sources of make-up water can be sewage effluent 67, brackish water and Upgrader tailing water 68. The waste produced by Unit 61 is in a dry solid form suitable for disposal in a landfill. The separated water can include oil, sand and clay impurities and their temperature may be similar to the well discharge temperature, typically in the range of 150°C. There is no need for cooling the water for further treatment (as in the prior art technologies) thus preventing the heat loss. The produced oil and gas are delivered for further treatment in any type of prior art EOR facility like SAGD or directly to an upgrading facility.

The advantage in integrated facility that includes the direct contact facility and a prior art EOR facility like SAGD is greater than when the two facilities work separately in parallel. The advantage lies in the fact that the new direct contact ZLD facility 61 will simplify the requirements of water treatment plant 62 of the prior art. As well, it will eliminate wastewater discharge, while maintaining the advantages of stand-alone, new, direct-contact steam generation like reduction in CO2 emissions.

The produced water, oil and gas that produced from production well 65, are separated at the water-oil and gas separation unit 64, de-oiled water 620 being supplied to the lime softeners 618 for further treatment. Both prior art water treatment technologies, the softening and the
evaporating, require full removal of residual oil. Oily water that might contain sand and clay
contaminations is delivered directly, without additional treatment, to ZLD direct contact steam
generator 61. As a result, the prior art SAGD water treatment plant will be simplified and will
require less chemicals and filters. The de-oiled water at 620 is pumped to the prior art lime
softeners at 618, where most of the dissolved solids are removed as sludge 617. The soft water is
pumped through filters 621. The filtered water is treated in an ion-exchange system 625, where
additional waste is generated 614. The treated water is used for generating steam in OTSG or a
COGEN 615. Typically, an 80% steam is produced. This wet steam is separated in steam
separator 612 to produce 100% steam for downhole injection 611. The liquid blow-down is
recycled without additional treatment in the new direct contact steam generator 61. The waste
discharge 61 is in a dry solid form suitable for landfill disposal as previously described in figures
1-4.

[1]One advantage is the GHG emissions; there will be a reduction in CO₂ emissions due to high
thermal efficiency. Heat efficiency of the injection is maximized, compared to indirect steam
generation methods, because the heat transfer occurs through direct contact and also the
combustion gases transfer most of the thermal energy to the formation. The formation acts as a
heat exchanger in relation to the combustion gases. This result in higher heat efficiency
compared to prior art above-ground, indirect steam production where heat in the combusted
gases gets released into the atmosphere.

Another advantage is the reduction of the steam to oil ratio, because of the chemistry of the CO₂
in the reservoir. This results in less water and fuel used for generating the heavy oil. This characteristic is well known in oil industry publications and in prior art. For example, US 4565249 Pebdani et al issued Jan 21 1986 and US 5020595 Van Slyke et al issued June 4 1991.

Another advantage is that a portion of the CO2 injected into the formation will remain there permanently.

A further environmental advantage is the use of available low quality wastewater and the use of the prior art reject and oily water. It allows for reduction in the requirements for water-oil separation, as oily water emulsion is used as a water source in a direct contact. There will be no release of reject oily water to the environment or injection into underground water injection wells. The generation of dry solid waste (a "zero" liquid discharged system) can be easily discharged in landfill.

Another advantage is the use of available low quality fuel, especially the use of pet coke as a fuel. There is a financial advantage in the cost of fuel and an environmental advantage in eliminating the use of natural gas.

For further understanding, the following is an example for the possible implementation of the present invention: An existing prior art SAGD facility produces heavy oil from the tar-sand. Pipelines transfer the produced bitumen to an Upgrader. The SAGD uses water from local water wells (with a water treatment facility based on lime softeners or evaporators). The Upgrader
produces significant amounts of solid petcoke, with no commercial value. The SAGD rejects approximately 10% of low-quality water back to an underground formation through a pipe system and disposal wells. In the Upgrader area there are wastewater tanks and tailing ponds that are used for holding process water, mostly water with fine clay particles and oil contaminations that cannot be separated or re-used prior to long settling periods.

A possible economic and environmentally-friendly expansion with the present invention can be constructed in two stages.

The first stage will include a direct contact steam generator as described in Figs 1-4, which will be built at the SAGD area, together with an air separation unit. This direct contact steam generator will use oxygen or enriched air from the air separation unit. The feed to this system will be low-quality water, including untreated oily water from the existing SAGD facility (as described in Fig. 6) or other available source. The fuel can be any locally-available bitumen produced by the SAGD. The waste from the steam generation process will be in the form of dry solids. The injected product will end up as a mixture of superheated steam, CO2 and other gases at temperatures and pressures similar to those within the existing facility, which is in the range of 250°C and 2000 Kpa at the wellhead.

The second stage will include integration with the Upgrader as described in Fig. 6. To minimize dependence on electric supply, a co-generator can be constructed to provide the energy for the air separation unit. The fuel used in the process may be petcoke from the Upgrader where the
produced bitumen from the SAGD facility is treated. Because the pet coke material is located near the upgrader, and not near to the SAGD facility, the pet coke will be ground and mixed with wastewater from the upgrading process, settlement pond water or any other source. The slurry mixture will be transported using pipes to the direct contact steam generator (See Figs. 1-4), where the slurry will be injected to react with the oxygen/enriched air to produce steam. Some of the transportation water that was not used for the steam production can recycled and pumped back to the upgrader for re-use as transportation water.

The present invention is a system and method for steam production and its integration into a EOR facility, like SAGD to produce hot, dry steam and gas for down well use. The method is adiabatic; the produced gases maintain most of their pressure and thermal energy throughout the process, up to the point at which they are injected into the reservoir. As result of the low quality water and fuel used, the direct contact steam generation process creates solid waste. The high temperature, pressure separation and removal of solids are important factors for continuous operation. Separation is done when the liquids have already been transferred to gas, so that it is done mainly between the solid phase and the gas phase. It can be continual, or at intervals with pressure drops, to increase evaporation and reduce moisture in the solid waste. The steam and gas purification stages (i.e.-scrubbing remaining solids and corrosive gases) are done in liquid phase under high temperature and pressure; additional water is converted into steam. It is important to minimize the corrosive effects of CO2 in the injection gas and also to minimize the requirements for special corrosion-resistant steel for deep, high-pressure wells. Therefore, the gas mixture is further heated to a temperature in which the steam is in "dry" super-heated state.
This goes down the whole way into the underground formation like, for example, through the horizontal perforated underground SAGD injection pipe. The steam condensates in the formation, outside of the injection pipe.

The present invention is intended to work with commercially proven underground EOR technologies like SAGD that are commercially proven to be an effective method for the use of steam and stimulating gases (e.g., hydrocarbons, CO₂), to recover the bitumen. Since the present invention does not deal directly with subsurface formation, it can be developed further, engineered and tested remotely away from an oil sand projects. The risk involved in implementing the new technology decreases as the underground portion of the method is developed and proven.

The abovementioned disclosure and description of the invention is illustrative and explanatory thereof. Various changes in the details of the illustrated construction can be made within the scope of appended claims without departing from the essence of the invention. The present invention should only be limited by the following claims and their legal equivalents.
What is claimed is:

1. A method for producing steam and gas mixtures for extracting heavy bitumen, the method comprising the steps of:

   mixing fuel with oxidation gases, said fuel being selected from a group consisting of coal, crude oil, vacuum residue, asphaltin and petroleum coke, said oxidation gases being selected from a group consisting of oxygen, oxygen-enriched air, and air;

   combusting the mixture in a pressure and temperature controlled environment;

   mixing liquid phase water containing organic or inorganic materials;

   generating a steam and gas mixture under a controlled temperature by direct contact heat exchange between the combusted mixture and said liquid phase water; and

   transferring a liquid phase of the combusted mixture and said liquid phase water to a gas phase and a solid phase, said gas phase being comprised of steam, carbon dioxide, said solid phase being particles.

2. The method for producing steam and gas mixtures of Claim 1, further comprising:

   separating said solid phase from said gas phase.

3. The method for producing steam and gas mixtures of Claim 2, further comprising:

   mixing said gas phase with water of saturated temperature and pressure, directly transferring heat of said gas phase to the water to produce a saturated clean wet steam and gas mixture; and

   scrubbing any remaining solids from said gas phase into the water.
4. The method for producing steam and gas mixtures of Claim 3, further comprising:
   separating the saturated water from said gas phase to produce a
   saturated solid-free steam and gas mixture; and
   adding water to the saturate water to maintain the saturated water level.

5. The method for producing steam and gas mixtures of Claim 4, further comprising:
   sending recycled water with the scrubbed solids and dissolved
   solids back to the step of mixing liquid phase water containing organic or
   inorganic materials, the saturated water carrying the solids being converted to
   gas.

6. The method for producing steam and gas mixtures of Claim 4, further comprising:
   heating the solid-free saturated steam and gas mixture through
   heat exchange with combustion heat so as to produce a super heated dry, solids
   free steam and gas mixture flow.

7. The method for producing steam and gas mixtures of Claim 4, further comprising:
   reducing adiabatically pressure of flow of said gas phase to an
   injection pressure, in order to produce dry steam for injection.

8. The method for producing steam and gas mixtures of Claim 5, wherein said gas phase contains
   sulfur, the method further comprising:
   adding lime stone slurry to the water during said step of solids
   scrubbing;
   reacting lime with the sulfur; and
   continuously recycling generated solids back to the step of sending
   recycled water with the scrubbed solids and dissolved solids.
9. The method for producing steam and gas mixtures of Claim 6, wherein pressure of said superheated dry, solid-free steam and gas mixture flow is between 800 and 4000 Kpa.

10. The method for producing steam and gas mixtures of Claim 6, wherein temperature of said superheated dry, solid-free steam and gas mixture flow is between 170°C and 450°C.

11. The method for producing steam and gas mixtures of Claim 6, further comprising:
   injecting said superheated dry, solid-free steam and gas mixture flow into an underground reservoir through a vertical or horizontal injection well.

12. The method for producing steam and gas mixtures of Claim 1, wherein said liquid phase water is comprised of disposal water, said disposal water being comprised of oil, clay or sand from an oil and water separation facility of a steam-assisted gravity drainage (SAGD) facility; and said method further comprises mixing heavy bitumen from the SAGD facility without processing inbetween.

13. The method for producing steam and gas mixtures of Claim 1, said step of combusting the mixture, further comprising:
   supplying fuel from a remote upgrader in the form of a slurry, said fuel being solid petroleum coke or asphaltin;
   grinding and mixing said fuel with water to form a pumpable slurry;
   pumping the slurry through a pipeline to a direct contact steam generator;
   recycling a portion of the water thereof; and
   combusting the fuel slurry through the step of combusting.

14. The method for producing steam and gas mixtures of Claim 1, further comprising:
   producing energy and steam by a cogeneration steam plant; and
   using energy from the cogeneration steam plant to operate an air separation unit, so as to generate oxygen or oxygen enriched air as the oxidation.
gas for use in the step of combusting; and

using rejected blow-down water from the cogeneration steam plant
as a water source for the direct contact heat exchange.

15. A method for producing a steam and gas mixture for extraction of heavy bitumen, the method
comprising the steps of:

mixing a fuel with an oxidation gas to form a mixture, said fuel
being selected from a group consisting of coal, crude oil, vacuum residue,
asphaltin and petroleum coke, said oxidation gas being selected from a group
consisting of oxygen, oxygen-enriched air, and air;

partially combusting the mixture in a pressure and temperature
controlled environment;

mixing liquid phase water containing organic or inorganic materials;

generating a steam and gas mixture under a controlled temperature
by direct contact heat exchange between the combusted mixture and said liquid
phase water;

transferring a whole liquid phase of the mixed and combusted
mixture to a syngas and solid phase, said syngas phase being comprised of
steam, carbon monoxide, hydrogen and solid particles generated from the step of
partially combusting, producing a solid-rich gas phase flow; and

separating the solids from the gas phase flow.

16. The method for producing steam and gas mixtures of Claim 15, further comprising:

mixing the gas phase with an oxidation gas, said gas being
selected from a group consisting of oxygen, oxygen-enriched air, and air,
hydrogen and carbon monoxide converting to carbon dioxide and water while
producing heat; and

mixing the gas phase with water of saturated temperature and
pressure, heat of said gas phase flow to the water producing a saturated, clean,
wet, steam and gas mixture.
17. A system for oil recovery using heat injection, comprising:
    a direct-contact steam generator operating on low quality fuel,
oxidation gas, and water, said fuel being selected from a group consisting of
coal, crude oil, vacuum residue, asphaltin and petroleum coke, said oxidation gas
being selected from a group consisting of oxygen, oxygen-enriched air, or air,
said water containing organic and inorganic materials, said direct-contact steam
generator producing a dry hot mixture of steam, carbon dioxide, flying solids and
possibly other gases by direct contact heat exchange between the combusted
mixture and the water; and
    a solid-gas separation removal means to remove solids
from said steam generator.

18. The system for oil recovery of Claim 17, further comprising:
    a wet scrubber means for cleaning the gas and steam by mixture
with water and scrubbing remaining fine solids particles from said gas flow,
wherein saturated solid-free wet steam and a gas mixture are produced;
    a bottom vessel collect and pump system, recycling concentrated
solid rich water from the bottom of the wet scrubber means back to the
direct-contact steam generator; and
    a lime slurry injection system incorporated into the wet scrubber means, the steam
generator or both.

19. The system for oil recovery of Claim 17, the dry hot mixture leaving the direct contact steam
generator being at a temperature of 200-550°C and pressure of 800 and 4000 Kpa, the solid-free
wet steam and gas mixture being at a temperature of 150-450°C and pressure of 800 and 3800
Kpa.

20. The system for oil recovery of Claim 18, further comprising:
an injection well means for injecting the super-heated dry steam and gas mixture into an underground reservoir.

21. A process for producing steam for extracting heavy bitumen, the process comprising the steps of:
   mixing a fuel with an oxidation gas, the fuel having carbon or hydrocarbon;
   combusting the mixture in a pressure and temperature controlled environment, wherein combustion pressure is similar to pressure of a produced steam and gas mixture;
   mixing liquid phase water containing organic or inorganic materials;
   and
   generating steam by direct contact heat exchange between the combusted mixture and said liquid phase water.

22. The process for producing steam of Claim 21, said step of mixing liquid phase water comprising:
   transferring the liquid phase water from a liquid phase to a gas phase, said gas phase containing steam and combustion gases; and
   separating said gas phase from the solids.

23. The process for producing steam of Claim 21, further comprising:
   mixing water with fuel prior to or during the step of combusting the mixture in a pressure and temperature controlled environment.
   controlling combustion reaction temperature and to generate steam.

24. The process for producing steam of Claim 21, further comprising:
   producing energy and steam from high quality water by a cogeneration steam plant;
   using the energy from the cogeneration steam plant to produce said
oxidation gas for use in the combustion chamber; and
using blowdown water from the cogeneration steam plant as said
liquid phase water containing organic or inorganic materials, being placed in a
direct contact steam generator combustion chamber.

25. A method for producing steam and gas mixtures for extracting heavy bitumen, the method
comprising the steps of:
mixing fuel with oxidation gases, said fuel being selected from a group consisting of coal,
crude oil, vacuum residue, asphaltin and petroleum coke, said oxidation gases being selected
from a group consisting of oxygen, oxygen-enriched air, and air;
combusting the mixture in a pressure and temperature controlled environment;
mixing liquid phase water containing organic or inorganic materials;
generating a steam and gas mixture under a controlled temperature by direct contact heat
exchange between the combusted mixture and said liquid phase water; and
transferring a liquid phase of the combusted mixture and said liquid phase water to a gas
phase and a solid phase, said gas phase being comprised of steam, carbon dioxide, said solid
phase being particles, wherein said step of combusting is comprised of a partial combustion,
generating synthetic gas.

26. A system for oil recovery using heat injection, comprising:
a direct-contact steam generator operating on low quality fuel, oxidation gas, and water,
said fuel being selected from a group consisting of coal, crude oil, vacuum residue, asphaltin and
petroleum coke, said oxidation gas being selected from a group consisting of oxygen, oxygen-
enriched air, or air, said water containing organic and inorganic materials, said direct-contact
steam generator producing a dry hot mixture of steam, carbon dioxide, flying solids and possibly
other gases by direct contact heat exchange between the combusted mixture and the water; and
a solid-gas separation means to separate solids from gas flow using cyclonic separation,
centrifugal separation, mesh separation or combinations thereof, wherein said direct-contact
steam generator is comprised of a partial combustion gasifier operating on low quality fuel,
oxidation gas, and water, said
fuel being selected from a group consisting of coal, crude oil, vacuum residue, asphaltin and petroleum coke, said oxidation gas being selected from a group consisting of oxygen, oxygen-enriched air, or air, said water containing organic and inorganic materials, said partial combustion gasifier producing a dry hot mixture of steam, synthetic gas mainly composed from carbon monoxide, flying solids and possibly other gases by direct contact heat exchange between the combusted mixture and the water.

27. A process for producing steam for extracting heavy bitumen, the process comprising the steps of:
   mixing a fuel with an oxidation gas, the fuel having carbon or hydrocarbon;
   combusting the mixture in a pressure and temperature controlled environment, wherein combustion pressure is similar to pressure of a produced steam and gas mixture;
   mixing water with the combustion gas during or after the step of combusting to generate steam, the water containing organic or inorganic materials; and
   generating steam by direct contact heat exchange between the combusted mixture and said liquid phase water.

28. A process for producing steam for extracting heavy bitumen, the process comprising the steps of:
   mixing a fuel with an oxidation gas, the fuel having carbon or hydrocarbon, said fuel containing sulfur;
   combusting the mixture in a pressure and temperature controlled environment, wherein combustion pressure is similar to pressure of a produced steam and gas mixture;
   mixing liquid phase water containing organic or inorganic materials;
   generating steam by direct contact heat exchange between the combusted mixture and said liquid phase water;
   adding alkaline material during the step of combusting, the step of mixing liquid phase water mixing or both steps, said alkaline material being comprised of calcium; and
reacting the calcium with the sulfur.

29. A process for producing steam for extracting heavy bitumen, the process comprising the steps of:
   mixing a fuel with an oxidation gas, the fuel having carbon or hydrocarbon;
   combusting the mixture in a pressure and temperature controlled environment, wherein combustion pressure is similar to pressure of a produced steam and gas mixture;
   mixing liquid phase water containing organic or inorganic materials;
   generating steam by direct contact heat exchange between the combusted mixture and said liquid phase water,
   wherein said step of mixing liquid phase water comprises:
   transferring the liquid phase water from a liquid phase to a gas phase, said gas phase containing steam and combustion gases;
   separating said gas phase from the solids; and
   adding heat to the steam and carbon dioxide so as to produce a superheated dry steam and gas mixture.

30. The process for producing steam of Claim 29, further comprising:
   injecting the superheated dry steam and gas mixture into an underground reservoir through an injection well.

31. The method of claims 2, 4, and 15 further comprising:
   removing corrosive contaminating gas from said gas phase; and
   injecting additives to said gas phase so as to protect the pipe from corrosion.

32. The method of claims 2, 4, and 15 further comprising: adding heat to the steam and carbon dioxide so as to produce a superheated dry steam and gas mixture.

33. The method of claims 32, said step of adding heat comprising: directly contacting and reacting hydrocarbon gas and oxygen to produce heat so as to elevate the temperature of the dry
steam and gas mixture to up to 400 degree C. without a pressure drop.

34. The method of claims 2, 4, and 15, further comprising: injecting the superheated dry steam and gas mixture into an underground reservoir through a vertical or horizontal injection well.

35. The method of claims 1, 4, and 15 wherein said liquid phase water is comprised of disposal water from a steam-assisted gravity drainage (SAGD) facility.

36. The method of claims 1 and 15 further comprising: mixing heavy bitumen from a SAGD facility without processing therebetween.

37. The method of claims 1 and 15, said step of combusting comprising: supplying fuel from a remote upgrader in the form of a slurry.

38. The method of claim 37, the fuel being solid petroleum coke or asphaltin, the process further comprising: grinding and mixing the fuel with waste water so as to form a pumpable slurry.

39. The method of claim 38 further comprising: pumping the slurry through a pipeline to a direct contact steam generator; recycling a portion of the water therefrom; and injecting the fuel slurry to the combustion chamber.

40. The method of claims 1 and 15, said oxidation gas being air, the process further comprising: using the air as a combustion oxidizer in the combustion chamber; adding additional relief wells so as to relive the non-dissolved and non-condensed gases to the surface; treating the non-dissolved and non-condensed gases at a surface location; and releasing the treated gases to the atmosphere.

41. The process of claims 21, 22, 27, 28 and 29 further comprising: removing corrosive contaminating gas from said gas phase; and injecting additives to said gas phase so as to protect the pipe from corrosion.

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42. The process of claims 21, 22, 27, 28 and 29 further comprising: adding heat to the steam and carbon dioxide so as to produce a superheated dry steam and gas mixture.

43. The process of claims 42 said step of adding heat comprising: directly contacting and reacting hydrocarbon gas and oxygen to produce heat so as to elevate the temperature of the dry steam and gas mixture to up to 400 degree. C. without a pressure drop.

44. The process of claims 22, 27, 28 and 29 further comprising: injecting the superheated dry steam and gas mixture into an underground reservoir through a vertical or horizontal injection well.

45. The process of claims 21, 27, 28 and 29 wherein said liquid phase water is comprised of disposal water from a steam-assisted gravity drainage (SAGD) facility.

46. The process of claims 21, 27, 28 and 29, further comprising: mixing heavy bitumen from a SAGD facility without processing therebetween.

47. The process of claims 21, 27, 28 and 29, said step of combusting comprising: supplying fuel from a remote upgrader in the form of a slurry.

48. The process of claim 37, the fuel being solid petroleum coke or asphaltin, the process further comprising: grinding and mixing the fuel with waste water so as to form a pumpable slurry.

49. The process of claim 48 further comprising: pumping the slurry through a pipeline to a direct contact steam generator; recycling a portion of the water therefrom; and injecting the fuel slurry to the combustion chamber.

50. The process of claims 21, 27, 28 and 29, said oxidation gas being air, the process further comprising:
using the air as a combustion oxidizer in the combustion chamber; adding additional
relief wells so as to relive the non-dissolved and non-condensed gases to the surface;
treating the non-dissolved and non-condensed gases at a surface location; and
releasing the treated gases to the atmosphere.

51. The method according to claims 1 and 15 wherein the steps of combustion and at least one
step of steam generation is executed in distinguish zones that are fluidly connected.

52. The method according to claim 51, where the temperature in the combustion zone is higher
than the temperature in the steam generation zone.

53. The system according to claims 17 and 18 wherein:
said direct contact steam generator comprising; a first zone for combustion of a fuel in
the presence of an oxidant and some water to create an elevated temperature and pressure
combustion products flow;
the first zone having inputs for fuel, oxidant and possibly water; and
the first zone is fluidly connected to a second zone for mixing water, possibly with high level of
contaminates, with said products of combustion to generate steam and products of combustion
mixture at elevated temperature and pressure, wherein the second steam generation zone
includes or is fluidly connected to solid removal means.

54. The system of claim 53 further includes output means for connecting the second steam
generation zone to hydrocarbon bearing matrix for delivery the substantially solids steam and
products of combustion mixture, thereby condensing steam while heating and mobilizing a
portion of hydrocarbons.

55. The system of claim 26 wherein:
said direct contact steam generator comprising: a first zone for combustion of a fuel in
the presence of an oxidant and some water to create an elevated temperature and pressure
combustion products flow;
the first zone having inputs for fuel, oxidant and possibly water; and
the first zone is fluidly connected to a second zone for mixing water, possibly with high level of
contaminates, with said products of combustion to generate steam and products of combustion
mixture at elevated temperature and pressure, wherein the second steam generation zone
includes or is fluidly connected to solid removal means.

56. The system of claim 55 further includes output means for connecting the second steam
generation zone to hydrocarbon bearing matrix for delivery the substantially solids steam and
products of combustion mixture, thereby condensing steam while heating and mobilizing a
portion of hydrocarbons.

57. The method of claims 1 and 15 wherein said combustion gas comprises products of
combustion and steam, having a temperature between 600 and 1300 degree. C.; wherein the
temperature of combustion gas and steam after mixing the second portion of low quality liquid
water to form a gas flow with additional steam, having a temperature between 350 and
700. degree. C.;

58. The process of claims 21, 25, 27, 28 and 29 wherein said combustion gas comprises products
of combustion and steam, having a temperature between 600 and 1300 degree. C.; wherein the
temperature of combustion gas and steam after mixing the second portion of low quality liquid
water to form a gas flow with additional steam, having a temperature between 350 and
700. degree. C.;
59. The method according to claims 1, 2, 15, and 16 wherein the mixed liquid phase water comprises one or more of dissolved material, suspended solids like particulate material, hydrocarbons and bituminous.

60. The process according to claims 21, 25, 27, 28 and 29 wherein the mixed liquid phase water comprises one or more of dissolved material, suspended solids like particulate material, hydrocarbons and bituminous.

61. The method according to claims 1, 3, 15, and 16, wherein said water feed mixed with the fuel prior to the combustion contains less solids impurities than the low quality water mixed with the combustion gas during or after the step of combustion.

62. The process according to claims 21, 25, 27, and 29, wherein said water feed mixed with the fuel prior to the combustion contains less solids impurities than the low quality water mixed with the combustion gas during or after the step of combustion.

63. The method according to claims 1, 15, and 16, where a system used to execute said method includes a direct steam generator includes a combustion chamber with a combustor to mix the fuel and oxygen streams and a first water feed and a mixing region downstream of the combustion chamber with inputs to mix a second low quality water feed containing more impurities than the first water feed into the output stream downstream of the combustion chamber.

64. The process according to claims 21, 23, 25, 27, 28 and 29 where a system used to execute said method includes a direct steam generator includes a combustion chamber with a combustor to mix the fuel and oxygen streams and a first water feed and a mixing region downstream of the combustion chamber with inputs to mix a second low quality water feed containing more
impurities than the first water feed into the output stream downstream of the combustion chamber.

65. A system according to claims 17 and 18, wherein the direct steam generator includes a combustion chamber with a burner to mix the fuel and oxygen streams and a first water feed and a mixing region downstream of the combustion chamber with inputs to mix a second low quality water feed containing more impurities than the first water feed into the output stream downstream of the combustion chamber.

66. A system according to claim 26, wherein the direct steam generator includes a combustion chamber with a burner to mix the fuel and oxygen streams and a first water feed and a mixing region downstream of the combustion chamber with inputs to mix a second low quality water feed containing more impurities than the first water feed into the output stream downstream of the combustion chamber.

67. The method according to claims 1, 2, 15, and 16 further comprising mixing said products of combustion and steam with liquid water, evaporating a portion of the liquid water to form steam, and accumulating a reservoir of unevaporated water at the bottom.

68. The method according to claim 67, wherein when said accumulated water comprises solids, evaporating a portion thereby generating steam, and concentrating solids in the accumulated water.

69. The method or process according to claim 67, comprising delivering a portion of the accumulated water back to the combustor.

70. The process according to claims 21, 25, 27, 28 and 29 further comprising mixing said products of combustion and steam with liquid water, evaporating a portion of the liquid water to form steam, and accumulating a reservoir of unevaporated water at the bottom.
71. The process according to claim 70, wherein when said accumulated water comprises solids, evaporating a portion thereby generating steam, and concentrating solids in the accumulated water.

72. The process according to claim 70, comprising delivering a portion of the accumulated water back to the combustor.

73. The system of claims 17, 18 and 26, the system further comprising:
   an evaporation and scrubbing zone for contacting water with said generate steam and products of combustion mixture at elevated temperature and pressure, thereby evaporating a portion of the water to produce a pressurized products of combustion and saturated steam;
   the evaporation zone being coupled to a separation zone for accumulating liquid water comprising unevaporated water from the evaporation zone with a liquid sump means at its bottom for recovering solids scrubbed from the condensates; and
   means for delivering at least portion of liquid water, from the evaporation zone sump, to at least one of the combustion zone or evaporation zone, to provide at least a portion of the water feed.

74. A method according to claims 1 and 15 wherein portion of the combustion gas together with the generated steam is recycled back to the stage of combustion to control the combustion temperature.

75. A process according to claims 21, 25, 27, 28 and 29 wherein portion of the combustion gas together with the generated steam is recycled back to the stage of combustion to control the combustion temperature.
76. The system of claims 17, 18 and 26 wherein said steam generator is fluidly connected to an injector well configured to convey the output stream into a formation to contact and heat hydrocarbons in the formation, and a recovery system to produce the hydrocarbons that are heated.

77. The method of claims 2, 15, and 16 further comprising:
   delivering the steam and combustion gas mixture to a heavy hydrocarbon bearing material;
   recovering a produced hydrocarbon fluid comprising hydrocarbon, water, and gas;
   separating the produced hydrocarbon fluid into a hydrocarbon fluid, produced water, and gas; and
   recycle at least a portion of the produced water comprising solids and hydrocarbons contaminates to the stage of mixing them with the combustion gas.

78. The process of claims 21, 25, 27, 28 and 29 further comprising:
   delivering the steam and combustion gas mixture to a heavy hydrocarbon bearing material;
   recovering a produced hydrocarbon fluid comprising hydrocarbon, water, and gas;
   separating the produced hydrocarbon fluid into a hydrocarbon fluid, produced water, and gas; and
   recycle at least a portion of the produced water comprising solids and hydrocarbons contaminates to the stage of mixing them with the combustion gas.

79. A method according to claims 2, 15, 16 further comprising:
   delivering the compound heat medium at pressure to the hydrocarbon bearing matrix material thereby condensing steam and heating and mobilizing a portion of hydrocarbons;
recovering under pressure a mobilized portion comprising water, hydrocarbons, and gas; and removing gas contaminations from the mobilized portion.

80. A process according to claims 21, 25, 27, 28 and 29 further comprising:
   delivering the compound heat medium at pressure to the hydrocarbon bearing matrix material thereby condensing steam and heating and mobilizing a portion of hydrocarbons;
   recovering under pressure a mobilized portion comprising water, hydrocarbons, and gas; and removing gas contaminations from the mobilized portion.

81. The method according to claims 1, 15, 16, wherein enriched air or oxygen is supplied from a commercially available air separation unit like cryogenic air separation unit that uses energy to separate oxygen stream with a limited content of non-condensable gases.

82. The process according to claims 21, 23, 25, 27, 28 and 29, wherein enriched air or oxygen is supplied from a commercially available air separation unit like cryogenic air separation unit that uses energy to separate oxygen stream with a limited content of non-condensable gases.

83. The method of claims 2 and 16, wherein said direct contact steam generation method is integrated with a non-direct contact steam generation facility, wherein:
   at least portion of the contaminated water from produced oil and water separation process is directed to the direct contact steam generator for steam generation; and
   at least a portion of the steam and CO2 mixture generated by the direct contact steam generator is supplied to SAGD injection pads where said mixture is injected to the underground formation.

84. The process of claims 21, 22, 27, 28 and 29 where said direct contact steam generation method is integrated with a non-direct contact steam generation facility, wherein:
at least portion of the contaminated water from produced oil and water separation process is directed to the direct contact steam generator for steam generation; and at least a portion of the steam and CO2 mixture generated by the direct contact steam generator is supplied to SAGD injection pads where said mixture is injected to the underground formation.

85. The process according to claims 21, 25, 27, 28 and 29 wherein the steps of combustion and at least one step of steam generation is executed in distinguish zones that are fluidly connected.

86. The process according to claim 85, where the temperature in the combustion zone is higher than the temperature in the steam generation zone.