A method and system for producing steam for use in heavy hydrocarbon recovery operations. Water, containing impurities, produced from the well is separated from hydrocarbons and other materials, and subsequently directly passed to a produced water boiler with online pigging. The boiler is indirectly heated by means of a hot flue gas, such as a gas turbine exhaust, which produces electricity (for powering a central processing facility, or alternatively a burner to heat the boiler) and exhaust heat for heating the boiler.
PRODUCED WATER STEAM GENERATION PROCESS USING PRODUCED WATER BOILER WITH GAS TURBINE

CROSS-REFERENCE TO RELATED APPLICATION


FIELD OF THE INVENTION

[0002] The invention relates to thermal recovery methods and systems for heavy hydrocarbon deposits, and specifically to such methods and systems requiring steam injection to mobilize the deposits.

BACKGROUND

[0003] In the field of subsurface hydrocarbon production, it is known to employ various stimulation procedures and techniques to enhance production. For example, in the case of heavy oil and bitumen housed in subsurface reservoirs, conventional drive mechanisms may be inadequate to enable production to surface, and it is well known to therefore inject steam or steam-solvent mixtures to make the heavy hydrocarbon more amenable to movement within the reservoir permeability pathways, by heating the hydrocarbon and/or mixing it with lighter hydrocarbons or hot water.

[0004] In steam-assisted gravity drainage ("SAGD") and cyclic steam stimulation ("CSS") hydrocarbon recovery operations, steam is generated at surface by steam generation units and injected downhole into a well, where it is subsequently introduced into an underground hydrocarbon formation in which the well lies, after which the steam warms bitumen and oil within the formation. Thus-warmed hydrocarbon within the formation is mobilized and moves or is drawn toward the well, where it is then collected and produced to surface. The steam, when contacting cooler subterranean bitumen and oil, typically condenses to water, releasing latent heat of condensation and thereby effectively transferring heat to the oil/bitumen.

[0005] Due to the foregoing condensation of injected steam to water, and also by reason that underground formations typically contain amounts of water in the form of brine or the like, water is typically produced to surface with the recovered hydrocarbon and the brine. Because proximate surface sources of water for producing steam for injection downhole are often in very short supply, or their use prevented or limited due to governmental restrictions, it is very desirable to use produced water to generate steam. Not only is such water (although contaminated) available at site, but by generating steam from produced water the disposal costs of such contaminated produced water is reduced.

[0006] Typically, water that is produced to surface with the collected hydrocarbon arrives in the form of free water, suspended water, water-in-oil emulsions and/or oil-in-water reverse emulsions. The produced water must go through a series of processing steps to be useful as conventional boiler feedwater, such as de-oiling and softening, or evaporation. Typical de-oiler systems include a free water knock out ("FWKO") vessel, followed by a skim tank, induced gas flotation and finally an oil removal filter. The de-oiler system is conventionally used at surface to separate the recovered hydrocarbons from the produced water, and the produced water is thereupon recycled to the steam generation unit for re-use in converting same to steam for injection downhole; typically, however, the produced water contains significant impurities in the form of inorganic compounds, such as silica, calcium and magnesium ions, which must be addressed before the de-oiled produced water can be introduced to steam generation units as feedstock.

[0007] Conventional drum boilers operating at circa 2% blowdown cannot typically be used to generate steam from the produced water without using evaporators to generate high purity feedwater due to the concentration of dissolved solids and impurities such as calcium, silica, organics and the like that cause precipitation and thereby scaling within boiler tubes during the boiling of the water, which thereby very quickly renders the boiler ineffective in transferring heat to the water to generate steam and can also rupture boiler tubes due to the generation of hot spots.

[0008] Alternatively, special types of steam generators are commonly used, namely so-called “once-through steam generators” (“OTSG” or “OTSGs”), which can better handle higher amounts of impurities in the produced water feed stream and generate steam ranging from 65% to 90% steam quality (65-90 parts steam vapor, 10-35 parts liquid water containing the impurities). Operating at this steam quality greatly reduces the tendency of the dissolved salts to precipitate and scale the tubes. Nevertheless, produced water pre-conditioning steps are still necessary, such as the conventional warm lime softening ("WLS") or hot lime softening ("HLS") process, which injects lime to reduce water hardness and alkalinity and precipitates silica and carbonate ions out of the water, and in conjunction with a weak acid cation or strong acid cation ion exchange ("WACS" or "SACS") process, removes the calcium and magnesium scale generating ions to acceptable concentrations, thereby reducing build-up of scale in the OTSG. The major bulk chemicals used in these processes are lime (Ca(OH)2), magnesium oxide (MgO), soda ash (Na2CO3), caustic (NaOH), and hydrochloric acid (HCl). Minor amounts of coagulant and polymer are used to aid in solid separation.

[0009] It is known and generally acknowledged that conventional steam generation technologies suffer from numerous disadvantages. For example, OTSGs still require boiler feedwater pretreatment, require large volumes of feedwater since much of the feed is rejected downhole as blowdown to manage impurities, and can suffer large amounts of downtime to clean boiler tubes (piggling). However, alternative drum boilers require the use of evaporation technology, which adds significant capital expense and requires high energy consumption.

[0010] Indirect fired steam generators have been introduced as a possible alternative to such conventional technologies. Indirect boiling can be used with more contaminated feed water, thus reducing some equipment line-up complexity and capital cost. For example, United States Patent Application Publication No. US 2014/0165928 to Larkin et al. teaches a steam generation system in which solid particulate such as sand is first heated by heat exchange with hot fluids, and then the heated particulate is contacted with the water to be vaporized. As a further example, Hipviap Technologies of Alberta, Canada, is pilot testing an indirect fired steam generation system which uses a forced-circulation heat
exchanger process to recirculate a hot oil fluid in a closed loop to generate steam from produced water.

[0011] However, indirect boiling technologies currently under consideration are often complex and likely relatively expensive to implement as they may contain double the heat transfer surface area than what is required to generate steam alone. It would therefore be desirable to have access to a steam generation system that is relatively simple and inexpensive, while still possessing the advantages of indirect boiling in terms of equipment line-up simplification, moderated, constant and homogeneous heat flux on the tube walls and reduced operating costs.

BRIEF SUMMARY

[0012] The present invention therefore seeks to provide a system for generating steam from produced water with a value-added and simplified line-up that avoids heat transfer surface area duplication and minimizes the need for boiler feedwater treating.

[0013] According to a first aspect of the present invention there is provided a steam generation system for use in thermal hydrocarbon recovery operations, the system comprising a produced water boiler for generating steam, the boiler tubes heated indirectly by means of flue gas, such as a gas turbine exhaust. The gas turbine produces electricity which can be used for powering submersible pumps, and/ or the central processing facility (“CPF”) of the hydrocarbon recovery operation, and/or for powering an electric heater on the surface or subsurface, while exhaust heat from the turbine is used to heat the produced water boiler. The heat supplied by the gas turbine vaporizes a portion of the produced water in the produced water boiler, thus providing steam for injection downhole to enable subsequent hydrocarbon production.

[0014] In some exemplary embodiments of the present invention, mechanical cleaning means, such as but not limited to online “piggling”, is applied to clean build-up from the produced water boiler tube interior.

[0015] A detailed description of exemplary embodiments of the present invention is given in the following. It is to be understood, however, that the invention is not to be construed as being limited to these embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] In the accompanying drawings, which illustrate exemplary embodiments of the present invention:

[0017] FIG. 1A is a simplified schematic view of a conventional prior art process for recycling produced water for steam generation;

[0018] FIG. 1B is a simplified schematic view of a conventional prior art process for recycling produced water for steam generation;

[0019] FIG. 2 is a simplified schematic view of a novel produced water recycling process line-up according to the present invention; and

[0020] FIG. 3 is a schematic view of a first exemplary embodiment of a system and process in accordance with the present invention, wherein electricity produced by the gas turbine is used for powering the central processing facility or electric heaters or submersible pumps, etc.

[0021] Exemplary embodiments of the present invention will now be described with reference to the accompanying drawings.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0022] As mentioned above, conventional produced water steam generation systems involve a number of subsystems to separate and purify the produced water to a state that is acceptable as feedwater for the steam generation equipment. As is shown in FIG. 1A, the subsystems of a conventional prior art system for processing water produced from a wellhead include a gas/oil/free water/solids separation stage 2, a produced water removal stage 3, a produced water treatment impurity removal stage 4 and steam generation 5. The oil/produced water separation stage 2 is designed to remove most of the oil from the water, the oil then being stored or pipelined elsewhere for processing, while the produced water—still somewhat contaminated with minor amounts of oil—must undergo additional processing in the oil removal stage 3 (in which further removed oil is recovered and processed). The produced water treatment impurity removal stage 4, as discussed above, removes various impurities from the de-oiled water that create heat transfer tube surface scaling and fouling to prepare it for introduction to the steam generation stage 5, in which steam is produced for downhole injection at the wellhead 1 (with waste water or blowdown being rejected from the system for impurities buildup management and disposed of as necessary).

[0023] FIG. 1B provides further details regarding a conventional prior art OTSG system for recycling produced water to generate steam. Again, material from the reservoir (along with condensed water from previously injected steam) is produced at the wellhead 1, and a water-oil mixture is sent to the FWKO unit 6 to separate the oil and produced water (this is the oil/water separation stage 2 shown in FIG. 1A). The de-oiled produced water is then sent to one or more skim tanks 7, and then to an induced gas flotation (“IGF”) unit 8, the oil froth being removed and then cleaned water being sent to the next stage in the process. To remove various inorganic impurities, the cleaned water stream is pumped to a WLS unit 9, through a series of afterfilters 10, and then to an ion exchange unit 11 such as WACs. At this stage the treated water is of sufficient purity to be fed into an OTSG 12, producing waste/lowdown and steam for downhole injection.

[0024] The above description is simplified and does not include all of the equipment or additives that might be required under the conventional OTSG system, and thus it would be clear to those skilled in the art that such a system is complex, capital-intensive and relatively expensive to operate.

[0025] Turning now to FIGS. 2 to 3, exemplary embodiments of the present invention are illustrated. The exemplary embodiments are presented for the purpose of illustrating the principles of the present invention, and are not intended to be limiting in any way.

[0026] FIG. 2 illustrates, in a simplified schematic view, the basic stages of produced water processing according to the present invention. Materials including gas, solids, oil/bitumen and water are produced at the wellhead 20, and subsequently separated into various desired components at the separator 22. Gas would normally be piped to the boiler burners, and may or may not need to be processed for sulphur removal in a sulphur recovery unit, while solids are landfilled. The separated oil can be diluted with a diluent for pipelining if necessary, or it may be subjected to partial upgrading on-site in a manner known to those skilled in the art.
The separated water is then sent to an impurity containing produced water boiler with on line pigging unit 24, and again numerous types of produced water boiler technologies may be useful with the present invention so long as they enable a heat exchange to heat the water pumped through the impurity containing produced water boiler with on line pigging 24 to its boiling point. The impurity containing produced water boiler with on line pigging 24 is heated by means of the hot exhaust of a gas turbine 26, which turbine 26 can be powered by either fresh gas or a mixture of fresh gas and produced gas separated by the separator 22, as would be clear to those skilled in the art. Once the water is heated to boiling in the impurity containing produced water boiler with on line pigging 24, steam is generated for downhole injection at the wellhead 20 and the remaining concentrate can be disposed of as waste/blowdown in a conventional manner.

Turning now to FIG. 3, a first embodiment of the present invention is illustrated. As with FIG. 2, materials produced at the wellhead 20 are pumped to the separator 22 for separation into the four main components. FIG. 3 illustrates that separated gas may or may not be re-used as part of the feedstock for the gas turbine 26. Separated water is pumped into the impurity containing produced water boiler with on line pigging 24, which in this case is a heat exchanger.

The gas turbine unit 26 comprises an upstream compressor 28 coupled to a downstream turbine 30; although not shown in this simplified illustration, there is a combustion chamber between the compressor 28 and turbine 30, in a manner well known to those skilled in the art. The gas is fed into the compressor 28, which increases the pressure of the gas, and then into the combustion chamber, and then fuel is fed into the combustion chamber and ignited, resulting in a high-temperature gas flow that enters the turbine 30. The heated gas flow expands in the turbine 30, producing shaft work output. This work output is illustrated as creating electricity, which would be achieved by the shaft driving an electricity generator in a conventional manner. In this embodiment, the created electricity would be used to power the submersible pumps, the central processing facility or “CPF” of the hydrocarbon recovery operation, or electric heaters.

The gas turbine 26 operation described above also produces exhaust heat. While heat from a turbine can be rejected as waste, or recovered through a heat recovery steam generator, or through a once through steam generator lacking on-line pigging and fed with impurity removed boiler feedwater, in the present case the exhaust heat is used to heat the untreated produced water boiler 24 that has online pigging. In a heat exchanger arrangement, the exhaust heat would indirectly heat the water that is pumped through the impurity containing produced water boiler with on line pigging 24, and at least some of the water would be converted to steam as a result, which can then be used for downhole injection as part of the thermal hydrocarbon recovery operation. Any water not converted to steam would be rejected from the impurity containing produced water boiler with on line pigging 24 as waste or blowdown and can be disposed of by conventional means. Online pigging or other conventional cleaning techniques can be used to clean the impurity containing produced water boiler with on line pigging 24 internals.

Unlike other prior art indirect boiling systems, which use energy simply to power steam generation, the use of a turbine allows for both the production of heat for the impurity containing produced water boiler with on line pigging and useful electricity for the hydrocarbon recovery operation.

As can be readily seen, then, there are numerous advantages provided by the present invention. In addition to the simplified equipment line-up, which can in appropriate circumstances eliminate or reduce the need for de-oiling or water treatment stages such as the IGF, ORF, warm line sooter, after filters, and ion exchange, chemical additive requirements can be reduced. In addition to this potential reduction in capital and operating costs, recovering what would have been waste heat helps to reduce energy consumption when compared to indirect fired steam generation systems, and the turbine-generated electricity can be used to either power the CPF or even supplement the exhaust heat that is used to boil produced water in the impurity containing produced water boiler with on line pigging unit.

The foregoing is considered as illustrative only of the principles of the invention. Thus, while certain aspects and embodiments of the invention have been described, these have been presented by way of example only and are not intended to limit the scope of the invention. The scope of the claims should not be limited by the exemplary embodiments set forth in the foregoing, but should be given the broadest interpretation consistent with the specification as a whole.

What is claimed is:

1. A method for generating steam for use in a thermal hydrocarbon recovery operation, the operation comprising at least one hydrocarbon recovery well, the method comprising the steps of:

   producing produced materials from the at least one hydrocarbon recovery well;

   treating the produced materials to separate water from the produced materials;

   feeding the water into steam generation means;

   providing a heat source;

   providing heat exchange means between the heat source and the steam generation means;

   transferring heat from the heat source to the steam generation means via the heat exchange means;

   allowing the heat to increase the temperature of the steam generation means; and

   heating at least a portion of the water in the steam generation means to or above the water’s boiling point to generate steam.

2. The method of claim 1 further comprising the step of treating the produced materials to separate gas and/or solids and/or hydrocarbon from the produced materials.

3. The method of claim 2, wherein the gas is separated, further comprising the step of treating the gas by using gas treating means.

4. The method of claim 3 wherein treating the gas comprises reducing sulphur content of the gas.

5. The method of claim 2, wherein the hydrocarbon is separated, further comprising the step of diluting the hydrocarbon with a diluent for transport of the hydrocarbon.

6. The method of claim 1 further comprising the step of injecting the steam into the at least one hydrocarbon recovery well.

7. The method of claim 2, wherein the gas is separated, further comprising the steps of feeding the gas to the heat source and using the gas to at least partially fuel the heat source.
8. The method of claim 1 further comprising the step of injecting the steam into the at least one hydrocarbon recovery well.

9. The method of claim 1 wherein the heat source is waste heat from a machine.

10. The method of claim 9 wherein the machine is an electricity generator.

11. The method of claim 1 wherein the steam generation means are a produced water boiler.

12. The method of claim 1 further comprising the step of cleaning build-up from the steam generation means via mechanical cleaning means.

13. The method of claim 10 wherein gas is separated from the produced materials, the electricity generator is a gas turbine unit, and the gas is used to at least partially fuel the gas turbine unit, the waste heat comprising heated exhaust produced by the gas turbine unit.

14. The method of claim 12 wherein the mechanical cleaning means comprise on-line pigging.

15. The method of claim 2, wherein the hydrocarbon is separated, further comprising the step of partially upgrading the hydrocarbon.

16. A steam generation system for use in thermal hydrocarbon recovery operations wherein the operations comprise at least one hydrocarbon recovery well, the system comprising:

- produced materials treatment means configured to separate water from produced materials produced from the at least one hydrocarbon recovery well;
- feeding means for feeding the water to steam generation means;
- a heat source; and
- heat exchange means between the heat source and the steam generation means for transferring heat from the heat source to the steam generation means, allowing heat to increase the temperature of the steam generation means and heating at least a portion of the water in the steam generation means to or above the water’s boiling point to generate steam from the water.

17. The system of claim 16 wherein the produced materials treatment means are configured to separate gas and/or solids and/or hydrocarbon from the produced materials.

18. The system of claim 17 wherein the produced materials treatment means are configured to separate the gas from the produced materials, further comprising gas treating means for treating the gas.

19. The system of claim 18 wherein the gas treating means are for reducing sulphur content of the gas.

20. The system of claim 17 wherein the produced materials treatment means are configured to separate the hydrocarbon from the produced materials, further comprising a diluent source for diluting the hydrocarbon with a diluent for transport of the hydrocarbon.

21. The system of claim 16 further comprising steam injection means for injecting the steam into the at least one hydrocarbon recovery well.

22. The system of claim 16 wherein the heat source is waste heat from a machine.

23. The system of claim 22 wherein the machine is an electricity generator.

24. The system of claim 16 wherein the steam generation means are a produced water boiler.

25. The system of claim 16 further comprising mechanical cleaning means for cleaning build-up inside the steam generation means.

26. The system of claim 23 wherein the produced materials treatment means are configured to separate the gas from the produced materials, the electricity generator is a gas turbine unit, and the gas is used to at least partially fuel the gas turbine unit, the waste heat comprising heated exhaust produced by the gas turbine unit.

27. The system of claim 25 wherein the mechanical cleaning means comprise on-line pigging.

28. The system of claim 17 wherein the produced materials treatment means are configured to separate the hydrocarbon from the produced materials, further comprising partial upgrading means for partially upgrading the hydrocarbon.

* * * * *