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(54) Title: SUPERCRITICAL BOILER FOR OIL RECOVERY

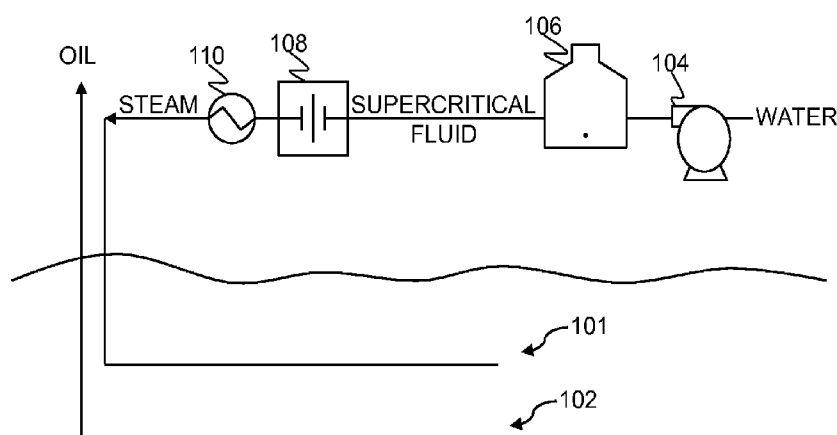


FIG. 1

(57) Abstract: Method and systems relate to generating steam by transitioning water from supercritical conditions and injecting the steam that results into a formation to facilitate recovery of oil. Pressurizing and heating the water forms a supercritical fluid that may solvate impurities in the water and/or oxidize the impurities. Retaining the impurities in solution and/or oxidation of the impurities limits fouling problems associated with generating the steam from water recycled in thermal processes, such as steam assisted gravity drainage (SAGD), for recovering the oil.

SUPERCRITICAL BOILER FOR OIL RECOVERY**STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR
DEVELOPMENT**

[0001] None.

FIELD OF THE INVENTION

[0002] Embodiments of the invention relate to methods and systems for generating steam used in thermal oil recovery processes and that may facilitate water treatment and limit fouling.

BACKGROUND OF THE INVENTION

[0003] Several techniques utilized to recover hydrocarbons in the form of bitumen from oil sands rely on generated steam to heat and lower viscosity of the hydrocarbons when the steam is injected into the oil sands. One common approach for this type of recovery includes steam assisted gravity drainage (SAGD). The hydrocarbons once heated become mobile enough for production along with the condensed steam, which is then recovered and recycled.

[0004] Costs associated with building a complex, large, sophisticated facility to process water and generate steam contributes to economic challenges of oil sands production operations. Such a facility represents much of the capital costs of these operations. Chemical and energy usage of the facility also contribute to operating costs.

[0005] Past approaches rely on once through steam generators (OTSGs) to produce the steam. However, boiler feed water to these steam generators requires expensive de-oiling and treatment to limit boiler fouling problems. Even with this treatment, fouling issues persist and are primarily dealt with through regular pigging of the boilers. This recurring maintenance further increases operating costs and results in a loss of steam production capacity, which translates to an equivalent reduction in bitumen extraction.

[0006] Therefore, a need exists for methods and systems for generating steam that enable efficient hydrocarbon recovery from a formation.

BRIEF SUMMARY OF THE DISCLOSURE

[0007] In one embodiment, a method of generating steam for oil production includes pressurizing and heating water to form a supercritical fluid. At least some of the supercritical fluid transitions to the steam. Injecting the steam into a formation facilitates the oil production.

[0008] According to one embodiment, a steam generating system for oil production includes a pump having a pressurized fluid outlet through which the pump is configured to provide water at above 22 megapascal to a furnace having a heated fluid outlet through which a supercritical fluid is provided by the furnace configured to increase temperature of the water to above 375° C. A letdown device couples to the heated fluid outlet of the furnace to receive the supercritical fluid and is configured to produce steam from pressure reduction of the supercritical fluid. An injection well couples with an outlet of the letdown device for conveying the steam into a formation to facilitate the oil production.

[0009] For one embodiment, a method of generating steam for oil production includes reducing level of fouling precursors in water by oxidation of the fouling precursors in the water at a pressure and temperature above a critical point thereof. Transitioning the water from a supercritical fluid forms the steam. Injecting the steam into a formation facilitates the oil production.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] A more complete understanding of the present invention and benefits thereof may be acquired by referring to the follow description taken in conjunction with the accompanying drawings in which:

[0011] Figure 1 is a schematic of a steam generating system for oil production that relies on transitioning water from supercritical conditions prior to injection of resulting steam, according to one embodiment of the invention.

DETAILED DESCRIPTION

[0012] Method and systems relate to generating steam by transitioning water from supercritical conditions and injecting the steam that results into a formation to facilitate recovery of oil. Pressurizing and heating the water forms a supercritical fluid that may

solvate impurities in the water and/or oxidize the impurities. Retaining the impurities in solution and/or oxidation of the impurities limits fouling problems associated with generating the steam from water recycled in thermal processes, such as steam assisted gravity drainage (SAGD), for recovering the oil.

[0013] Turning now to the detailed description of the preferred arrangement or arrangements of the present invention, it should be understood that the inventive features and concepts may be manifested in other arrangements and that the scope of the invention is not limited to the embodiments described or illustrated. The scope of the invention is intended only to be limited by the scope of the claims that follow.

[0014] Figure 1 illustrates an exemplary system that includes an injection well 101, a production well 102, a pump 104, a furnace 106, and a letdown device for converting a supercritical fluid exiting the furnace 106 into steam and including at least one of a pressure reducer 108 and a cooler 110. While illustrated in an exemplary SAGD configuration, other techniques, such as cyclic steam stimulation, solvent assisted SAGD, steam drive or huff and puff, may employ the steam generated as described herein. The injection well 101 extends in a horizontal direction and above the production well 102 also extending in the horizontal direction.

[0015] In operation, the steam enters the formation along the injection well 101 forming a steam chamber with heat transferred from the steam to the oil or bitumen in the formation. The oil once heated becomes less viscous and mobile enough for flowing by gravity along with condensate of the steam to the production well 102. A mixture of the condensate and oil collected in the production well 102 flows to surface where the oil to be sold is separated from the condensate, which is treated and recycled for generating additional steam to sustain steam injection.

[0016] With respect to generating the steam, the pump 104 increases pressure of water, including the condensate recycled, to above 22 megapascal (MPa). The furnace 106 then increases temperature of the water to above 375° C. This temperature and pressure at which the water is heated and pumped forms a supercritical fluid as a result of being above a critical point of the water.

[0017] In some embodiments, impurities or fouling precursors in the water react within the supercritical fluid to form products that do not form solids upon generation of

the steam. These impurities may include dissolved organic compounds that react with available oxygen from the water under supercritical conditions. Products of this reaction include carbon dioxide.

[0018] The carbon dioxide may pass with the steam into the formation through the injection well 101 and may facilitate production of the oil due to such influences as dissolution into the oil or thermal insulating. Further, removal of the dissolved organic compounds by this conversion to the carbon dioxide treats the water avoiding buildup of these compounds in the water as the water is recycled. According to some embodiments, these reactions result in at least a 50 percent reduction in total organic carbon content by mass in the water.

[0019] For some embodiments, the impurities remain solvated by the supercritical fluid without fouling tube walls of the furnace 106. The pressure ensures that transition from a liquid phase is to the supercritical fluid rather than a gas phase that is distinct and may permit solids to come out of solution. Such solids can cause the fouling if not kept in solution by the supercritical fluid.

[0020] The supercritical fluid then flows from the furnace 106 to the pressure reducer 108, such as any flow controller including an orifice plate or a valve. In some embodiments, the pressure reducer 108 drops the pressure to between 3 and 10 MPa or between 9 and 10 MPa, depending on desired pressures for injection of the steam into the formation. Such pressure reduction may also occur proximate a well pad (e.g., within 1 kilometer (km) of the injection well 101) to limit distance for conveying the steam or at a central processing facility that may be located 5 to 10 km or more away from the injection well.

[0021] In some embodiments, transitioning the supercritical fluid to the steam relies on the pressure reducer 108 without further temperature adjustment other than any line losses. For example, the pressure reducer 108 may drop the pressure to provide the steam that is superheated. Use of the steam that is superheated avoids condensation and hence steam loss in transfer lines to the injection well 101 and may also facilitate vaporization of solvents as may be desired for injection with the steam.

[0022] For some embodiments, the cooler 110 further contributes to altering conditions of the supercritical fluid in order to generate the steam. In some embodiments,

the supercritical fluid passes through the cooler 110 before the pressure reducer 108. The cooler 110 may inject water into the steam that is superheated in order to lower the temperature of the steam to a saturation temperature of the steam or may integrate with other heating needs, such as being used as a heat exchanger to preheat the water supplied to the furnace 106 while reducing temperature of the supercritical fluid.

[0023] The supercritical fluid may transition to the steam that is wet (e.g., between 80 and 100 percent quality steam) based on conditions caused by the cooler 110 and/or the pressure reducer 108 being below a saturated state of the steam. At least some of the impurities may remain in a liquid phase when the steam is wet to facilitate removal of the impurities. For example, a vapor-liquid separator may divide the steam for injection from liquids for further treatment or disposal.

[0024] The following examples of certain embodiments of the invention are given. Each example is provided by way of explanation of the invention, one of many embodiments of the invention, and the following examples should not be read to limit, or define, the scope of the invention.

Example 1:

[0025] A sample of produced water from an oil sands formation contained an initial total organic carbon (TOC) content by mass of 3,250 parts per million (ppm) and total inorganic carbon (TIC) content by mass of 66 ppm. The produced water was heated and pressurized to supercritical conditions. Then, the water was brought back to ambient conditions with resulting steam in such process being condensed and collected to form treated water.

[0026] The treated water contained only 1,140 ppm of TOC and 825 ppm of TIC representing a reduction in TOC from the produced water. The TIC increased in the treated water and included bicarbonates dissolved in the treated water due to oxidation of the organics. This example thus illustrates effectiveness of removing dissolved organics from water to limit fouling issues in steam generation processes.

[0027] In closing, it should be noted that the discussion of any reference is not an admission that it is prior art to the present invention, especially any reference that may have a publication date after the priority date of this application. At the same time, each

and every claim below is hereby incorporated into this detailed description or specification as additional embodiments of the present invention.

[0028] Although the systems and processes described herein have been described in detail, it should be understood that various changes, substitutions, and alterations can be made without departing from the spirit and scope of the invention as defined by the following claims. Those skilled in the art may be able to study the preferred embodiments and identify other ways to practice the invention that are not exactly as described herein. It is the intent of the inventors that variations and equivalents of the invention are within the scope of the claims while the description, abstract and drawings are not to be used to limit the scope of the invention. The invention is specifically intended to be as broad as the claims below and their equivalents.

WHAT IS CLAIMED IS:

1. A method of generating steam for oil production, comprising:
pressurizing and heating water to form a supercritical fluid;
converting at least some of the supercritical fluid to the steam; and
injecting the steam into a formation to facilitate the oil production.
2. The method according to claim 1, wherein impurities in the water react within the supercritical fluid to form products that do not form solids upon generation of the steam.
3. The method according to claim 1, wherein dissolved organic compounds in the water react within the supercritical fluid to form carbon dioxide that is injected with the steam.
4. The method according to claim 1, wherein dissolved organic compounds in the water react within the supercritical fluid resulting in at least a 50 percent reduction in total organic carbon content by mass in the water.
5. The method according to claim 1, wherein the supercritical fluid is converted to steam that is superheated.
6. The method according to claim 1, wherein impurities in the water remain solvated within the supercritical fluid during the heating.
7. The method according to claim 1, wherein the supercritical fluid is converted to the steam at conditions below a saturated state to generate the steam that is wet.
8. The method according to claim 1, wherein impurities in the water remain solvated within the supercritical fluid during the heating and the supercritical fluid is then converted to the steam at conditions below a saturated state to generate the steam that is wet with the impurities remaining in a liquid phase.

9. The method according to claim 1, wherein the converting at least some of the supercritical fluid to steam includes reducing pressure of the supercritical fluid to between 9 and 10 megapascals.

10. The method according to claim 1, wherein the converting at least some of the supercritical fluid to steam includes reducing pressure of the supercritical fluid from above 22 megapascals to between 3 and 10 megapascals.

11. The method according to claim 1, wherein the injecting of the steam is into a horizontal well disposed in fluid communication with a horizontal producer well for steam assisted gravity drainage production.

12. The method according to claim 1, wherein the water is pumped to a pressure above 22 megapascals to provide pressurized water that is then heated to above 375° C to provide the supercritical fluid.

13. A steam generating system for oil production, comprising:

- a pump having a pressurized fluid outlet through which the pump is configured to provide water at above 22 megapascal;

- a furnace coupled to receive the water from the pressurized outlet of the pump and having a heated fluid outlet through which a supercritical fluid is provided by the furnace configured to increase temperature of the water to above 375° C;

- a letdown device coupled to the heated fluid outlet of the furnace to receive the supercritical fluid and configured to produce steam from pressure reduction of the supercritical fluid; and

- an injection well coupled with an outlet of the letdown device for conveying the steam into a formation to facilitate the oil production.

14. The system according to claim 13, wherein the letdown device further includes a heat exchanger for cooling the supercritical fluid.

15. The system according to claim 13, wherein the letdown device includes a flow restrictor for the pressure reduction of the supercritical fluid.
16. The system according to claim 13, wherein the injection well is horizontal and disposed in fluid communication with a horizontal producer well for steam assisted gravity drainage production.
17. The system according to claim 13, wherein the letdown device is configured to produce the steam that is superheated.
18. A method of generating steam for oil production, comprising:
 - reducing level of fouling precursors in water by oxidation of the fouling precursors in the water at a pressure and temperature above a critical point thereof;
 - transitioning the water from supercritical conditions above the critical point to below the critical point for generation of the steam; and
 - injecting the steam into a formation to facilitate the oil production.
19. The method according to claim 18, wherein the fouling precursors include dissolved organics converted to carbon dioxide for injecting with the steam.
20. The method according to claim 18, wherein the reducing the level of fouling precursors includes at least a 50 percent reduction in total organic carbon content by mass in the water.

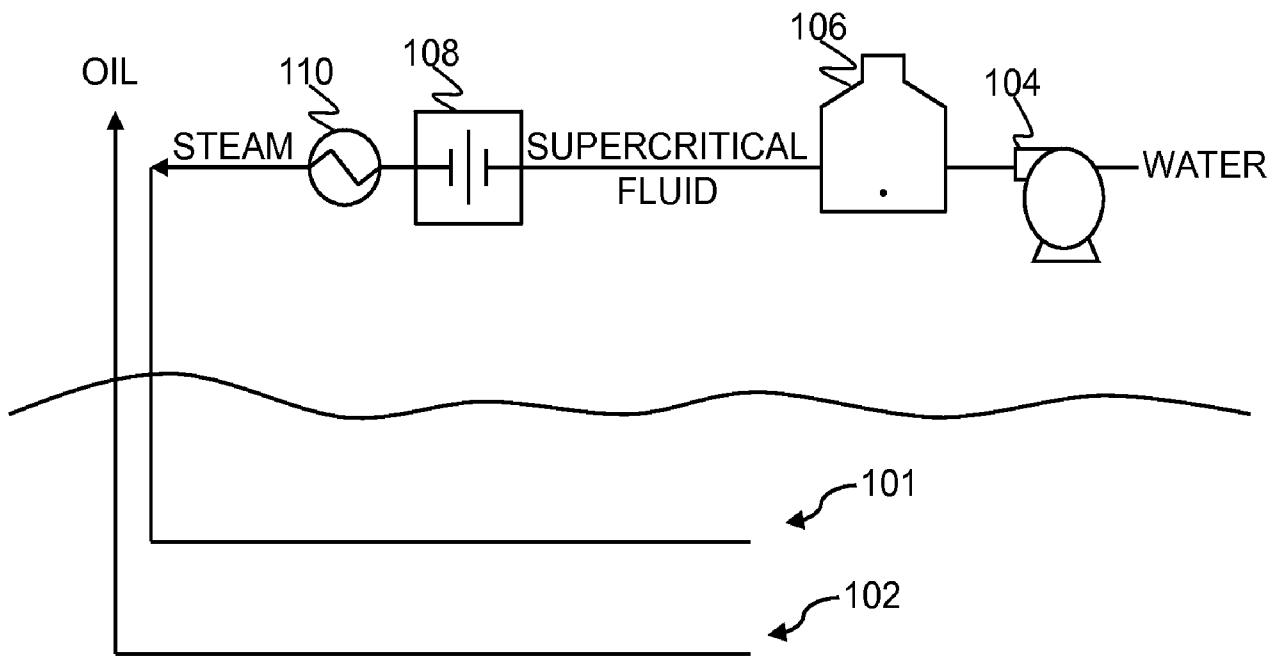


FIG. 1

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - E21B 43/24 (2014.01)

USPC - 166/272.3

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) - C10G 1/00, 1/04; E21B 36/00, 43/16, 43/24 (2014.01)

USPC - 166/50, 272.1, 272.3, 302, 303

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
CPC - C10G 1/065, 2300/805; E21B 36/02, 43/24, 43/2406 (2014.02)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Orbit, Google Patents, Google Scholar

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011/0198085 A1 (O'BRIEN) 18 August 2011 (18.08.2011) entire document	1
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Y		2-20
Y	US 2012/0061294 A1 (CHOI et al) 15 March 2012 (15.03.2012) entire document	2, 14, 15
Y	US 2005/0006317 A1 (LEE et al) 13 January 2005 (13.01.2005) entire document	3, 4, 6-8, 19, 20
Y	US 2010/0189610 A1 (ALLAM) 29 July 2010 (29.07.2010) entire document	5, 9, 10, 12-17
Y	US 2010/0288555 A1 (FOPPE) 18 November 2010 (18.11.2010) entire document	11, 16
Y	US 5,888,389 A (GRIFFITH et al) 30 March 1999 (30.03.1999) entire document	18-20
X, P	WO 2013/050075 A1 (JOHNSEN et al) 11 April 2013 (11.04.2013) entire document	1-20
Y, P	US 2013/0140214 A1 (CHOI) 06 June 2013 (06.06.2013) entire document	1-20

☐ Further documents are listed in the continuation of Box C.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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