(57) Abstract:
An apparatus for hydrocarbon recovery from a production well includes a pump, a motor for driving the pump, and an intake and gas separator between the motor and the pump, in the production well, such that the gas separator is coupled to the pump and is located closer to the wellhead than the motor and the intake is disposed between the gas separator and the motor. A production conduit extends inside the production well casing, from an outlet of the pump to a second end at the wellhead to facilitate pumping of liquid from a discharge outlet of the gas separator, through the production well casing, to the wellhead, and tubing is in fluid communication with a gas outlet of the gas separator and extends to expel gas received from the gas separator, at a location above a liquid level in the production well.
Abstract

An apparatus for hydrocarbon recovery from a production well includes a pump, a motor for driving the pump, and an intake and gas separator between the motor and the pump, in the production well, such that the gas separator is coupled to the pump and is located closer to the wellhead than the motor and the intake is disposed between the gas separator and the motor. A production conduit extends inside the production well casing, from an outlet of the pump to a second end at the wellhead to facilitate pumping of liquid from a discharge outlet of the gas separator, through the production well casing, to the wellhead, and tubing is in fluid communication with a gas outlet of the gas separator and extends to expel gas received from the gas separator, at a location above a liquid level in the production well.
HYDROCARBON PRODUCTION APPARATUS

Technical Field
[0001] The present invention relates to the production of hydrocarbons such as heavy oils and bitumen from underground deposits by artificial lifting of the fluid including the hydrocarbons.

Background
[0002] When a hydrocarbon reservoir lacks sufficient energy for oil, gas, and water to flow from wells at desired rates, supplemental production methods may be utilized. Gas and water injection for pressure support or secondary recovery may be utilized to maintain well productivity. When fluids do not naturally flow to the surface or do not naturally flow at a sufficient rate, a pump or gas lift techniques may be utilized, referred to as artificial lift. Lift processes transfer energy downhole or decrease fluid density in wellbores to reduce the hydrostatic load on formations, and cause inflow. Commercial hydrocarbon volumes can be boosted or displaced to the surface. Artificial lift also improves recovery by reducing the bottomhole pressure at which wells become uneconomic and are abandoned. Also, the development of unconventional resources such as viscous hydrocarbons usually include construction of complex wells, and high hydrocarbon lifting rates are desirable to produce oil quickly and efficiently at low cost.

[0003] Rod pump, gas lift, and electric submersible pumps are the most common artificial lift systems. Hydraulic and progressing cavity pumps are also utilized. Electric submersible systems use multiple centrifugal pump stages mounted in series within a housing, coupled to a submersible electric motor that is connected to surface controls and electric power by an armor-protected cable. Submersible systems have a wide performance range. Standard surface electric drives power outputs from 100 to 30,000 barrels per day and variable-speed drives add pump-rate flexibility. High Gas Oil Ratio (GOR) fluids can be handled. Large gas volumes, however, may lead to a condition known as gas-locking in which the void space in the lower stages of the pump is occupied by gas, inhibiting the electric submersible pump from boosting pressure,
resulting in a drop in flow rate. Submersible pumps may be operated at reservoir temperatures up to 250 °C (482 °F) utilizing special high-temperature motors and cables. High GOR, high-gas environments are now common in electric submersible pump applications. Reliable gas-handling technology is desirable to produce hydrocarbons utilizing pumps.

[0004] Extensive deposits of viscous hydrocarbons exist around the world, including large deposits in the Northern Alberta oil sands that are not susceptible to standard oil well production technologies. One problem associated with producing hydrocarbons from such deposits is that the hydrocarbons are too viscous to flow at commercially relevant rates at the temperatures and pressures present in the reservoir. In some cases, such deposits are mined using open-pit mining techniques to extract hydrocarbon-bearing material for later processing to extract the hydrocarbons. Alternatively, thermal techniques may be used to heat the reservoir to mobilize the hydrocarbons and produce the heated, mobilized hydrocarbons from wells. One such technique for utilizing a horizontal well for injecting heated fluids and producing hydrocarbons is described in U.S. Patent No. 4,116,275, which also describes some of the problems associated with the production of mobilized viscous hydrocarbons from horizontal wells.

[0005] One thermal method of recovering viscous hydrocarbons using spaced horizontal wells is known as steam-assisted gravity drainage (SAGD). Various embodiments of the SAGD process are described in Canadian Patent No. 1,304,287 and corresponding U.S. Patent No. 4,344,485. In the SAGD process, steam is pumped through an upper, horizontal, injection well into a viscous hydrocarbon reservoir while hydrocarbons are produced from a lower, parallel, horizontal, production well that is vertically spaced and near the injection well. The injection and production wells are located close to the bottom of the hydrocarbon deposit to collect the hydrocarbons that flow toward the bottom.

[0006] The SAGD process is believed to work as follows. The injected steam initially mobilizes the hydrocarbons to create a steam chamber in the reservoir around and above the horizontal injection well. The term steam chamber is utilized to refer to the volume of the reservoir that is saturated with injected steam and from which
mobilized oil has at least partially drained. As the steam chamber expands upwardly and laterally from the injection well, viscous hydrocarbons in the reservoir are heated and mobilized, in particular, at the margins of the steam chamber where the steam condenses and heats the viscous hydrocarbons by thermal conduction. The heated hydrocarbons and aqueous condensate drain, under the effects of gravity, toward the bottom of the steam chamber, where the production well is located. The heated hydrocarbons and aqueous condensate are collected and produced from the production well.

When the pressure in the steam chamber is sufficiently high, the fluids produced, including liquids and gases naturally flow through the production well, to the surface. The gases may include vapor, or water in the form of steam, hydrocarbon gases, and other trace compounds. The liquid may include hydrocarbons, water, and other compounds. Artificial lift may be utilized along with the SAGD process to increase the flow rate from the production well. Electric submersible pumps may be utilized in the production well to facilitate the flow of the fluids to the surface. Such pumps, however, are susceptible to vapor locking, also referred to as air locking or gas locking when the volume of free gas or vapor in the multi-phase fluid is too high at the pump intake.

Improvements in apparatus for use with artificial lift are desirable.

Summary

According to an aspect of an embodiment, an apparatus for hydrocarbon recovery from a production well is provided. The production well includes a production well casing extending from a segment of the hydrocarbon production well to a wellhead. The apparatus includes a pump disposed in the production well, a motor disposed in the segment for driving the pump, and an intake and gas separator disposed in the production well, between the motor and the pump such that the gas separator is coupled to the pump and is located closer to the wellhead than the motor and the intake is disposed between the gas separator and the motor. The apparatus also includes a production conduit extending inside the production well casing from an outlet of the pump to a second end at the wellhead to facilitate pumping of liquid from a discharge
outlet of the gas separator, through the production well casing to the wellhead, and tubing in fluid communication with a gas outlet of the gas separator and extending along the production well to expel gas received from the gas separator into the production well, at a location below the wellhead.

**Brief Description of the Drawings**

[0010] Embodiments of the present invention will be described, by way of example, with reference to the drawings and to the following description, in which:

[0011] FIG. 1 is a sectional view through a reservoir, illustrating a SAGD well pair;

[0012] FIG. 2 is a side view of a hydrocarbon production well of the SAGD well pair of FIG. 1;

[0013] FIG. 3 is a sectional view through a horizontal segment of a hydrocarbon production well including a schematic illustration of an apparatus for use in the well in accordance with an embodiment;

[0014] FIG. 4 is a sectional view through a wellhead including a vertical segment of the hydrocarbon production well of FIG. 3.

**Detailed Description**

[0015] For simplicity and clarity of illustration, reference numerals may be repeated among the figures to indicate corresponding or analogous elements. Numerous details are set forth to provide an understanding of the examples described herein. The examples may be practiced without these details. In other instances, well-known methods, procedures, and components are not described in detail to avoid obscuring the examples described. The description is not to be considered as limited to the scope of the examples described herein.

[0016] The disclosure generally relates to an apparatus for hydrocarbon recovery from a steam assisted gravity drainage production well. The production well includes a production well casing extending from a segment of the hydrocarbon production well to a wellhead. The apparatus includes a pump disposed in the production well, a motor disposed in the segment for driving the pump, and an intake and gas separator.
disposed in the production well, between the motor and the pump such that the gas separator is coupled to the pump and is located closer to the wellhead than the motor and the intake is disposed between the gas separator and the motor. The apparatus also includes a production conduit extending inside the production well casing from an outlet of the pump to a second end at the wellhead to facilitate pumping of liquid from a discharge outlet of the gas separator, through the production well casing to the wellhead, and tubing in fluid communication with a gas outlet of the gas separator and extending along the production well to expel gas received from the gas separator into the production well, at a location below the wellhead.

[0017] As described above, a steam assisted gravity drainage (SAGD) process may be utilized for mobilizing viscous hydrocarbons. In the SAGD process, a well pair, including hydrocarbon production well and a steam injection well are utilized. One example of a well pair is illustrated in FIG. 1 and an example of a hydrocarbon production well 100 is illustrated in FIG. 2. The hydrocarbon production well 100 includes a generally horizontal segment 102 that extends near the base or bottom 104 of the hydrocarbon reservoir 106. The steam injection well 112 also includes a generally horizontal segment that is disposed generally parallel to and is spaced vertically above the horizontal segment 102 of the hydrocarbon production well.

[0018] During SAGD, steam is injected into the steam injection well to mobilize the hydrocarbons and create a steam chamber in the reservoir 106, around and above the generally horizontal segment 112. In addition to steam injection into the steam injection well, light hydrocarbons, such as ethane, propane or butane may optionally be injected with the steam. The volume of light hydrocarbons that are injected is relatively small compared to the volume of steam injected. The addition of light hydrocarbons is referred to as a solvent-assisted process (SAP). Viscous hydrocarbons in the reservoir are heated and mobilized and the mobilized hydrocarbons drain, under the effects of gravity. Fluids, including the mobilized hydrocarbons along with aqueous condensate, are collected in the generally horizontal segment 102. The fluids may also include gases such as steam and production gases from the SAGD process.

[0019] Artificial lift may be utilized to facilitate the flow of the heated hydrocarbons and aqueous condensate to the surface, for example, when the SAGD operation is
carried out at sufficiently low pressure that artificial lift is required to recover mobilized hydrocarbon at the surface, or when increased rate of movement of the fluid from the well is desirable.

[0020] An embodiment of an apparatus 200 for use with a hydrocarbon production well, such as the hydrocarbon production well 100 illustrated in FIG. 2, is illustrated in FIG. 3 and FIG. 4. The hydrocarbon production well 100 includes the generally horizontal segment 102, which is a pipe, also referred to as a slotted liner that is coupled to a production well casing 108, for example, by a liner hanger 116. The production well casing 108 extends from the generally horizontal segment 102 to the wellhead 110.

[0021] The apparatus 200 includes a production conduit 202 that extends inside the production well casing 108, from a first end 204 located within the hydrocarbon production well 100, near the liner hanger 116, to a second end 206 at the wellhead 110. The production conduit 202 is tubular and may extend generally concentrically with the production well casing 108.

[0022] The apparatus 200 also includes an electric submersible pump 208 that includes a motor 210, a seal 216, an intake 218, a rotary gas separator 212, and a pump 214. The electric submersible pump 208 is located in or near the horizontal segment 102 into which fluid flows during the SAGD process.

[0023] The motor 210 is disposed in the hydrocarbon production well 100 and, of the elements of the apparatus 200, is located farthest from the wellhead 110. The motor 210 is utilized to rotate a drive shaft 220 that drives the rotary gas separator 212 and the pump 214 that receives liquid from a discharge outlet of the rotary gas separator 212. In this example, the motor is a three-phase AC motor.

[0024] The motor 210 is coupled to the seal 216 that is located between the motor 210 and the intake 218 of the rotary gas separator 212. The seal 216 is utilized to balance internal motor pressure, absorb axial thrust in the drive shaft 220, and facilitate the connection of the motor 210 to the intake 218 while inhibiting or reducing the chance of wellbore fluid contaminating the motor 210. The motor 210 rotates the drive shaft 220 that may include two or more shafts coupled together. The drive shaft
220 extends through the seal 216 to drive the rotary gas separator 212 and the pump 214.

[0025] On the outside of the production conduit 202 and inside the well casing 108, an armoured, insulated, three-phase electrical cable 221 extends and couples the motor 210 to a power supply.

[0026] The intake 218 is coupled to the seal 216 and to a housing 222 of the gas separator 212 such that the intake 218 is disposed between the seal 216 and the housing 222. The intake 218 includes openings 223 through which the fluid enters the gas separator 212. The housing 222 is generally cylindrical and includes functional components such as rotary blades or elements (not shown) of the rotary gas separator 212 to receive fluid from the intake 218, and to separate gas from liquid by centrifugal force that results in liquid being directed to an outer annular space in the housing 222 and to an inlet of the pump 214. Gas is directed to an inner annular space in the housing 222 and is pushed toward ports 224 in a head of the housing 222. The ports 224 act as outlets through which the gas is expelled from the gas separator 212.

[0027] A gas collection manifold 230 extends around the head of the housing and receives the gas expelled through the ports 224. The gas collection manifold 230 is coupled to a tube 228 that is in fluid communication with the gas collection manifold 230 through a port in the gas collection manifold 230 to receive the gas therefrom. The tube 228 extends along the well casing 108, away from the intake 218 of the gas separator 212. In this example, the tube is ½ inch external diameter (1.27 cm) and the length of the tube is dependent on the production well. The tube 228 is tied or mechanically coupled to, for example, the cable 221 on the outside of the production conduit 202 to facilitate placement or location of the tube 228 in the production well casing 108. For example, the tube 228 may be clamped to the cable 221 and to the production conduit 202 by clamps 232. The tube 228 is open-ended and extends inside the production well casing 108, to a location below the wellhead 110 to expel the gas at location below the wellhead.

[0028] The pump 214 is coupled to the gas separator 212 and receives the fluid from the gas separator 212, after separation of at least some of the gases therefrom. As described above, the pump 214 is also driven by the drive shaft 220, which is rotated
by the motor 210. In this example, the pump is a multi-stage centrifugal pump that adds cumulative head to the fluid for each stage. The fluid exits the pump discharge 234 at a higher pressure than the fluid that entered the intake 218 and flows up the production conduit 202 to and through the wellhead 110.

[0029] Thus, the gas-to-liquid ratio of the fluid that travels through the pump and is pumped through the production conduit 202 is significantly lower than the gas-to-liquid ratio of the fluid surrounding the motor 210 and the fluid that enters the intake 218. The tube 228 directs separated gas away from the intake 218, to a location above the liquid level in the production well 100, to reduce the amount of the separated gas that is expelled into the fluid and mixes again with the fluid.

[0030] During the production of hydrocarbons, the fluid, including hydrocarbons along with aqueous condensate, flows into the generally horizontal segment 102 of the hydrocarbon production well 100. The motor 210 is located further from the wellhead 110 of the hydrocarbon production well 100 than the pump 214 or the intake 218 and the rotary gas separator 212 such that the fluid flows around and passes the motor 210. Heat exchange with the fluid cools the high temperature motor 210, which helps to increase the lifespan of the motor 210. The heat generated by the motor 210 also heats the gases in the fluid that includes dissolved gases, which assists in expelling the dissolved gases from the fluid.

[0031] The fluid enters the intake 218 and gas is separated from the fluid in the gas separator 212. The separated gas is expelled through the tube 228, at a location below the wellhead 110 in the production conduit 202. Thus, gas is separated to reduce the gas-to-liquid ratio of the fluid before the fluid enters the pump 214. The liquid is pumped to the wellhead 110 through the production conduit 202.

[0032] The apparatus of the present disclosure may be utilized to enhance separation of gases and liquids in fluids before the fluid reaches the pump 214 and to inhibit or reduce the chance that the gas is mixed again with the fluid near the intake 218 of the gas separator 212.

[0033] The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the claims should not be limited by the preferred embodiments set forth in the examples, but should be given the broadest
interpretation consistent with the description as a whole. All changes that come with meaning and range of equivalency of the claims are to be embraced within their scope.
Claims

1. An apparatus for hydrocarbon recovery from a production well that includes a production well casing extending from a segment of the hydrocarbon production well to a wellhead, the apparatus comprising:

   a pump disposed in the production well;

   a motor disposed in the segment for driving the pump;

   an intake and gas separator disposed in the production well, between the motor and the pump such that the gas separator is coupled to the pump and is located closer to the wellhead than the motor and the intake is disposed between the gas separator and the motor;

   a production conduit extending inside the production well casing from an outlet of the pump to a second end at the wellhead to facilitate pumping of liquid from a discharge outlet of the gas separator, through the production well casing to the wellhead;

   tubing in fluid communication with a gas outlet of the gas separator and extending along the production well to expel gas received from the gas separator into the production well, at a location below the wellhead.

2. The apparatus according to claim 1, wherein the pump, the motor, and the intake are disposed in a generally horizontal segment of the production well.

3. The apparatus according to claim 1, comprising a seal disposed between the motor and the intake.
4. The apparatus according to claim 3, wherein the seal inhibits wellbore fluid from contaminating the motor.

5. The apparatus according to claim 3, wherein the seal absorbs axial thrust from a drive shaft from the motor.

6. The apparatus according to claim 3, comprising an electric submersible pump that includes the motor, the seal, the intake, the gas separator, and the pump.

7. The apparatus according to claim 1, wherein the gas separator comprises a rotary gas separator.

8. The apparatus according to claim 7, wherein the motor drives the rotary gas separator and the pump.

9. The apparatus according to claim 1, comprising a gas collection manifold extending around a head of the gas separator to receive gas expelled from at least one port of the gas separator.

10. The apparatus according to claim 9, wherein the tubing is coupled to the gas collection manifold.

11. The apparatus according to claim 1, wherein the gas to liquid ratio of fluid that travels through the pump is lower than a gas to liquid ratio of fluid around the motor.

12. The apparatus according to claim 1, wherein the tubing is about 0.5 inches (1.27 cm) external diameter.

13. The apparatus according to claim 1, wherein the tubing is coupled to a cable that couples the motor to a power supply.
14. The apparatus according to claim 1, wherein the tubing expels gas received from the gas separator, at a location above a liquid level in the production well.