US Patent & Trademark Office
Patent Public Search | Text View

United States Patent	12385380
Kind Code	B1
Date of Patent	August 12, 2025
Inventor(s)	Alkhalifa; Mohammed et al.

Electrical submersible pump concentric tubing completion

Abstract

A system for producing a wellbore fluid from a wellbore includes inner and outer tubing hangers at a surface location and inner and outer production tubing strings suspended from the inner and outer tubing hangers in a wellbore. A packer forms an annular seal around the outer production tubing string and an electrical submersible pump (ESP) is coupled in the inner production tubing string below the packer. A gas/liquid separator is coupled in the inner tubing string and is operable to discharge a liquid component of the wellbore fluid into the inner production tubing string and to discharge a gas component of the wellbore fluid into the lower portion of the wellbore annulus. The gas component may mix with the wellbore fluids in the lower portion of the wellbore annulus and the mixture enters an annular ventilation pathway between the production tubing strings to be vented to the surface location.

Inventors: **Alkhalifa; Mohammed (Dhahran, SA), Alsaleh; Ahmed (Dhahran, SA), Alameer; Mohammed (Dhahran, SA)**

Applicant: **SAUDI ARABIAN OIL COMPANY** (Dhahran, SA)

Family ID: **1000007908765**

Assignee: **SAUDI ARABIAN OIL COMPANY (Dhahran, SA)**

Appl. No.: **18/671864**

Filed: **May 22, 2024**

Publication Classification

Int. Cl.: **E21B43/38** (20060101); **E21B43/12** (20060101); **E21B43/34** (20060101)

U.S. Cl.:

CPC **E21B43/38** (20130101); **E21B43/128** (20130101); **E21B43/34** (20130101);

Field of Classification Search

CPC: E21B (43/38); E21B (43/128)

References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
4366861	12/1982	Milam	N/A	N/A
5271725	12/1992	Freet	417/572	E21B 43/121
6179056	12/2000	Smith	N/A	N/A
6336503	12/2001	Alhanati	166/313	E21B 43/385
6547003	12/2002	Bangash	166/66.4	E21B 43/40
6755250	12/2003	Hall et al.	N/A	N/A
8448699	12/2012	Camilleri et al.	N/A	N/A
2008/0196902	12/2007	Head	166/66.4	F04B 47/06
2008/0245525	12/2007	Rivas et al.	N/A	N/A
2010/0089588	12/2009	Thompson	166/372	E21B 43/38
2010/0258306	12/2009	Camilleri	166/265	E21B 43/128
2013/0068455	12/2012	Brown	166/66.4	E21B 36/006
2016/0084052	12/2015	Armistead	166/62	E21B 43/38
2022/0065090	12/2021	Ejim	N/A	E21B 47/008
2023/0010704	12/2022	Sheth	N/A	E21B 43/38

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
2010118351	12/2009	WO	N/A

Primary Examiner: Carroll; David

Attorney, Agent or Firm: Vorys, Sater, Seymour and Pease LLP

Background/Summary

FIELD OF THE DISCLOSURE

(1) The present disclosure relates generally to wellbore systems including an electrical submersible pump (ESP) and, more particularly, to venting a gas component of a wellbore fluid from a lower portion of a wellbore annulus defined below a packer or another isolation device.

BACKGROUND OF THE DISCLOSURE

(2) In oilfield production operations, valuable hydrocarbon fluids are drawn from subterranean locations to surface facilities or other collection locations through a wellbore. If these fluids do not readily flow to collection locations under existing natural forces, an electrical submersible pump (ESP) system may be installed in the wellbore to artificially lift the fluid. Gas production may generally be avoided by producing above a bubble point pressure. However, gas production may be unavoidable for wellbores producing below the bubble point pressure and should be either separated or handled. In many instances, the formation of free gas at the intake of a submersible pump of the ESP can severely damage the submersible pump or degrade its performance. In some

environments, such wellbores with a high gas to oil ratio (GOR), a gas lockup condition can result in which the submersible pump is unable to deliver enough pressure to maintain continuous pumping.

(3) When a packer is used above the submersible pump, free gas often accumulates below the packer and eventually creates a gas pocket that reaches the intake of the submersible pump. The free gas must be vented from the wellbore, or the gas lockup condition may be triggered. Without sufficient removal of the accumulated gas, the submersible pump can be exposed to free gas which reduces pumping efficiency and increases the possibility of reaching the gas lockup condition.

SUMMARY OF THE DISCLOSURE

(4) Various details of the present disclosure are hereinafter summarized to provide a basic understanding. This summary is not an extensive overview of the disclosure and is neither intended to identify certain elements of the disclosure, nor to delineate the scope thereof. Rather, the primary purpose of this summary is to present some concepts of the disclosure in a simplified form prior to the more detailed description that is presented hereinafter.

(5) According to an embodiment consistent with the present disclosure, a system for producing a wellbore fluid from a wellbore includes an inner tubing hanger and an outer tubing hanger disposed at a surface location and defining an annular chamber therebetween. An inner production tubing string is suspended from the inner tubing hanger and an outer production tubing string is suspended from the outer tubing hanger. The inner and outer production tubing strings extend into the wellbore and define an annular ventilation pathway therebetween in fluid communication with the annular chamber. A packer forms an annular seal around the outer production tubing string and fluidly isolates an upper portion from a lower portion of a wellbore annulus around the outer production tubing string. An electrical submersible pump (ESP) is coupled in the inner production tubing string and is operable to propel the wellbore fluid through the inner tubing string to the surface location. A gas/liquid separator is coupled in the inner production tubing string. The gas/liquid separator is operable to discharge a liquid component of the wellbore fluid into the inner production tubing string and to discharge a gas component of the wellbore fluid into the lower portion of the wellbore annulus. An opening to the annular ventilation pathway is defined in the lower portion of the wellbore annulus through which a mixture of the gas component within the wellbore fluid may enter the ventilation pathway.

(6) According to another example embodiment consistent with the present disclosure, a method for producing a wellbore fluid from a wellbore includes (a) operating a submersible pump to draw a wellbore fluid from a lower portion of a wellbore annulus into a gas/liquid separator, (b) separating a gas component from a liquid component of the wellbore fluid with the gas/liquid separator, (c) discharging the gas component from the gas/liquid separator into the lower portion of the wellbore annulus, (d) pumping the liquid component from the gas/liquid separator to a surface location through an inner production tubing string suspended from an inner tubing hanger at the surface location, and (e) venting a mixture of the gas component within the wellbore fluid through an annular ventilation pathway defined between the inner production tubing string and an outer production tubing string suspended from an outer tubing hanger at the surface location.

(7) According to still another embodiment consistent with the present disclosure, a system for producing a wellbore fluid from a wellbore includes an inner tubing hanger and an outer tubing hanger disposed at a surface location and defining an annular chamber therebetween. An inner production tubing string is suspended from the inner tubing hanger and an outer production tubing string is suspended from the outer tubing hanger. The inner and outer production tubing strings extend into the wellbore and define an annular ventilation pathway therebetween in fluid communication with the annular chamber. A packer forms an annular seal around an exterior surface of the outer production tubing string and fluidly isolates an upper portion of a wellbore annulus around the outer production tubing string from a lower portion of the wellbore annulus. An electrical submersible pump (ESP) is coupled to the inner production tubing string below the

packer and is operable to propel the wellbore fluid through the inner production tubing string to the surface location. A gas/liquid separator is coupled in the inner production tubing string below the packer, and the gas/liquid separator is operable to discharge a liquid component of the wellbore fluid into the inner production tubing string and to discharge a gas component of the wellbore fluid into the annular ventilation pathway through the lower portion of the wellbore annulus. An electrical cable extends through the annular ventilation pathway and is electrically coupled to the ESP.

(8) Any combinations of the various embodiments and implementations disclosed herein can be used in a further embodiment, consistent with the disclosure. These and other aspects and features can be appreciated from the following description of certain embodiments presented herein in accordance with the disclosure and the accompanying drawings and claims.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** is a cross-sectional view of an example wellbore system including an ESP system deployed in a production tubing string below a packer.

(2) FIG. **2** is a cross-sectional view of a wellbore system including an ESP system deployed in an inner production tubing string of a concentric production tubing string completion in accordance with at least one aspect of the present disclosure.

(3) FIG. **3** is a flowchart illustrating a procedure for installing and operating the wellbore system of FIG. **2** in accordance with at least one aspect of the present disclosure.

DETAILED DESCRIPTION

(4) Embodiments of the present disclosure will now be described in detail with reference to the accompanying Figures. Like elements in the various figures may be denoted by like reference numerals for consistency. Further, in the following detailed description of embodiments of the present disclosure, numerous specific details are set forth in order to provide a more thorough understanding of the claimed subject matter. However, it will be apparent to one of ordinary skill in the art that the embodiments disclosed herein may be practiced without these specific details. In other instances, well-known features have not been described in detail to avoid unnecessarily complicating the description. Additionally, it will be apparent to one of ordinary skill in the art that the scale of the elements presented in the accompanying Figures may vary without departing from the scope of the present disclosure.

(5) Embodiments in accordance with the present disclosure generally relate to a wellbore system and method for producing wellbore fluids from a wellbore which may be below a bubble point pressure for the wellbore fluid. The wellbore system includes an electrical submersible pump (ESP) system with a liquid-gas separator for lowering a gas volume fraction passing through an ESP. The ESP system also includes concentric production tubing strings extending through a casing. An inner production tubing string is provided for receiving wellbore liquids separated by the separator, and pumped by the ESP, and an outer production tubing string for receiving a mixture of the gas separated by the separator and the fluids flowing from the surrounding geologic formation. A packer or other isolation device is positioned between the outer production tubing string and a wellbore casing, but no packer or isolation device forms a seal around the inner production tubing string. The concentric production tubing strings extend to a dual wellhead with a ventilation port fluidly coupled to an annular ventilation pathway between the concentric production tubing strings. The gas separated by the separator may be mixed with the wellbore fluids and vented through the ventilation port. The dual wellhead also includes an outer tubing hanger and an inner tubing hanger supported by a wellhead. In some embodiments, an electrical cable may extend through the annular ventilation pathway to bypass the packer.

(6) FIG. **1** illustrates an example embodiment of a wellbore system **100** that includes an ESP system **102**. The ESP system **102** is disposed in a wellbore **106** extending from a surface location "S" and traversing a geologic formation "G." In the illustrated example, the wellbore **106** is substantially vertical. In other embodiments, aspects of the disclosure may be practiced in a wide variety of vertical, directional, deviated, slanted and/or horizontal portions therein, and may extend along any trajectory through the geologic formation "G." As illustrated in FIG. **1**, the wellbore **106** is lined with a casing string **108**, however, in other embodiments, the wellbore **106**, or portions of the wellbore **106**, may be open hole and otherwise not cased.
(7) In the example embodiment illustrated, the ESP system **102** is deployed (conveyed downhole) on a production tubing string **110**. In other embodiments, the ESP system **102** may be deployed on other wellbore conduits or conveyances, such as coiled tubing. A wellbore annulus **112** is defined radially between the production tubing string **110** and the surrounding structure, e.g., the casing string **108**. The production tubing string **110** extends through an isolation device, such as packer **114**, that forms a seal with the production tubing string **110** and the surrounding casing string **108**. The packer **114** fluidly isolates a lower portion **112**L of the wellbore annulus **112** surrounding the ESP system **102** from an upper portion **114**U above the packer **114**.
(8) The ESP system **102** includes a submersible pump **116** coupled at a lower end of the production tubing string **110**. The submersible pump **116** may be a multi-stage centrifugal pump that operates by transferring pressure to the wellbore fluids **118** to propel the wellbore fluids **118** to the surface location "S" at a desired pumping rate. The submersible pump **116** may have any suitable size or construction based on the characteristics, e.g., wellbore size, desired pumping rate, etc., of the wellbore operation for which the submersible pump **116** is employed. The submersible pump **116** may operate to transfer pressure to the wellbore fluids **118** by employing a motor (not shown) operably coupled to one or more impellers (not shown) and diffusers (not shown) as generally recognized in the art.
(9) The wellbore fluids **118** may include oil and dissolved gas, and may travel through the production tubing string **110** to a wellhead **120** at the surface location "S." The wellhead **120** generally provides a suspension point for the casing string **108** and the production tubing string **110**. For example, the wellhead **120** includes a tubing hanger **122** coupled to an upper end of the production tubing string **110** from which the production tubing string **110** may be suspended in the wellbore **106**. A Christmas tree **124** is provided above the wellhead **120**, which generally provides pressure control for the wellbore **106**. The Christmas tree **124** may include a system of valves and adaptors in fluid communication with the production tubing string **110** that distribute the wellbore fluids **118** produced through the production tubing string **110** to appropriate destinations remote from the wellbore **106**. For example, wellbore fluids **118** may be directed from the production string **110** to a collection tank, a pipeline or another destination (not shown).
(10) The submersible pump **116** may be powered by an electrical power source **126** disposed at the surface location "S." The electrical power source **126** may include one or more batteries, a generator or any other available source of electrical power. An electrical cable **128** extends from the electrical power source **126** along an outside surface of the production tubing string **110** to the submersible pump **116**. The electrical cable **128** may penetrate or pass through the packer **114** installed around the production tubing string **110**.
(11) If a pressure of the wellbore fluids **118** in the lower portion **112**L of the wellbore annulus **112** is above a bubble point pressure, gas production through the submersible pump **116** may be avoided. However, gas production may be unavoidable if the wellbore **106** is producing below bubble point pressure. In this case, the gas may either be separated or handled. Separation of the gas from a liquid component of the wellbore fluids **118** may be particularly helpful when there is a ventilation path for the separated gas to exit the wellbore **106**. The packer **114** installed around the production tubing string **110** may present a barrier to the ventilation of free gas (e.g., the gas component **208** of FIG. **2**) and therefore, gas handling may be more appropriate when the wellbore

106 produces below the bubble point pressure.
(12) Gas handling may encompass a collection of distinct solutions designed to ease the flow of the gas through the submersible pump **116** and reduce gas locking. These solutions may include one or more helico-axial stages of the submersible pump **116**, which are commonly referred to as "gas handlers," as well as tapered pumps and other designs that serve to homogenize the gas-fluid mixture. When handled properly, gas provides natural buoyancy to the wellbore fluids **118**, thus allowing an operator to improve lifting efficiency and recover the wellbore fluids **118** to the surface location "S" more quickly. In some embodiments, a gas separator may be placed below a set of helico-axial stages to remove larger gas bubbles, while the helico-axial stages of the submersible pump **116** help trap the smaller bubbles in the wellbore fluid **118** before entering and damaging the submersible pump **116**.
(13) Referring now to FIG. **2**, illustrated is another example wellbore system **200** that includes an ESP system **202** in accordance with example embodiments of the present disclosure. The ESP system **202** is disposed in the wellbore **106** at the lower end of the production tubing string **110**, similar to the ESP system **102** of the wellbore system **100** of FIG. **1** described above. In the wellbore system **200**, however, the ESP system **202** also includes a gas/liquid separator **204** installed within the submersible pump **116** and an outer production tubing string **206** circumscribing the inner production tubing string **110**.
(14) The submersible pump **116** and the gas/liquid separator are coupled in a lower portion **110**L of the inner production tubing string **110** protruding through an open longitudinal end **206**E of the outer production tubing string **206**. In some embodiments, the submersible pump **116** may define a lowermost (most downhole) component of the inner production tubing string **110**. In the wellbore system **200**, the packer **114** forms a seal with the outer production tubing string **206** to isolate the upper portion **112**U from the lower portion **112**L of the wellbore annulus **112**. As may be appreciated by those skilled in the art, the packer **114** helps maintain the integrity and efficiency of the wellbore system **200**.
(15) The gas/liquid separator **204** may employ inverted shrouds, cyclonic motion, internal baffling and/or other mechanisms for separating the wellbore fluids **118** into a gas component **208** and a liquid component **210**. The liquid component **210** may be discharged from the gas/liquid separator **204** and into the interior of the inner production tubing string **110**, and subsequently pumped uphole to the Christmas tree **124** by the submersible pump **116**, as generally described above. The liquid component **210** may then be distributed through the Christmas tree **124** to an appropriate destination remote from the wellbore **106**.
(16) In contrast, the gas component **208** may be expelled through one or more radial discharge ports **212** defined in the gas/liquid separator **204** and discharged into the lower portion **112**L of the wellbore annulus **112** below the packer **114**. The packer **114** may not provide a ventilation pathway therethrough for the gas component **208**, and thus, the gas component **208** may be mixed with the wellbore fluids **118** within the lower portion **112**L of the wellbore annulus **112**, and may be produced through an annular ventilation pathway **214** defined between the outer production tubing string **206** and the inner production tubing string **110**. In some embodiments, the inner and outer production tubing strings **110**, **206** are concentrically arranged with respect to one another such that the annular ventilation pathway **214** uniformly surrounds the inner production tubing string **110**.
(17) The gas component **208** mixes with the existing column of wellbore fluids **118**, which may be primarily liquid oil. Due to the mixing, the wellbore fluids **118** may become more buoyant, and rise along a vertical length "L" between the radial discharge ports **212** and an opening defined at a lower longitudinal end **206**E of the outer production tubing string **206** before entering the annular ventilation pathway **214**. An annular opening to the annular ventilation pathway **214** is defined within the lower portion **112**L of the wellbore annulus **112** between the longitudinal end **206**E of the outer production tubing string **206** and the lower portion **110**L of the inner production tubing string **110**. The vertical length "L" allows the gas component **208** to effectively mix with the

wellbore fluids **118** before entering the annular ventilation pathway **214**.
(18) The inner and outer production tubing strings **110**, **206** extend upwardly all the way to the wellhead **120** where inner production tubing string **104** is suspended by the inner tubing hanger **122** and the outer production tubing string **206** is suspended from an outer tubing hanger **216**. The annular ventilation pathway **214** extends the entire length of the outer production tubing string **206**, which may be devoid of any seals or obstructions therein. An annular chamber **218** is defined between the inner tubing hanger **122** and the outer tubing hanger **216**, which is in fluid communication with the annular ventilation pathway **214**. A ventilation port **220** extends through the outer tubing hanger **216** to permit the gas component **208** mixed in with the wellbore fluids to be ventilated from the wellbore **106**.
(19) As described above, the submersible pump **116** may be powered by the electrical power source **126** disposed at the surface location “S.” In the wellbore system **200**, the electrical cable **128** extends from the electrical power source **126** through the annular ventilation pathway **214** along the outside surface of the inner production tubing string **110** to the submersible pump **116**. The electrical cable **128** may bypass, or pass around, the packer **114**, which is installed around the electrical cable **128** and the outer production tubing string **206**. In some embodiments, the electrical cable **128** will be attached to the inner production tubing string **110** using standard cable clamps (not shown) installed thereon. The electrical cable **128** will be installed along with the inner production tubing string **110** after completing the outer production tubing string **206** installation. Accordingly, the electrical cable **128** will be disposed between the two inner and outer production tubing strings **110**, **206**.
(20) Referring now to FIG. **3**, a procedure **300** for installing and operating the wellbore system **200** is described in accordance with at least one aspect of the present disclosure. Although the example method **300** depicts a particular sequence of operations, the sequence may be altered without departing from the scope of the present disclosure. For example, some of the operations depicted may be performed in parallel or in a different sequence that does not materially affect the function of the procedure **300**. In other examples, different components of an example system that implements the procedure **300** may perform functions at substantially the same time or in a specific sequence. Initially at step **302**, the outer production tubing string **206** may be suspended in the wellbore **106**. For example, the outer production tubing string **206** may be run into the wellbore with the packer **114** installed around a lower portion thereof. Once the packer **114** is appropriately positioned, the outer tubing string **206** may be suspended from the outer tubing hanger **216** and the packer **114** may be radially expanded to engage the casing string **108** (or the geologic formation “G”). Expanding the packer **114** isolates the upper portion **112**U of the wellbore annulus **112** from the lower portion **112**L. Next, at step **304**, the submersible pump **116** along with the gas/liquid separator **204** may be run into the wellbore **106** on the inner production tubing string **110**. The inner production tubing string **110** may be lowered through the outer tubing string **206** to establish the annular ventilation pathway **214** between the inner and outer production tubing strings **110**, **206**. Once the submersible pump **116** and the gas/liquid separator **204** are appropriately positioned, e.g., protruding from the lower end of the outer tubing string **206**, the inner production tubing string **110** may be hung from the inner tubing hanger **122**.
(21) At step **306**, the submersible pump **116** may be operated to draw the wellbore fluid **118** from the lower portion **112**L of the wellbore annulus **112** into the gas/liquid separator **204**. The submersible pump **116** may be powered by the electrical power source **126** at the surface location through the electrical cable **128**. The gas/liquid separator **204** separates the wellbore fluid into the liquid component **210** and the gas component **208**. The liquid component **210** may be pumped (at step **308**) through an interior of the inner production tubing string **110** to the surface location “S.” The liquid component **210** may be distributed by the Christmas tree **124** to an appropriate location or destination remote from the wellbore **106** for further processing or consumption. The gas component **208** may be discharged through the radial discharge ports **212** back into the lower

portion **112**L of the wellbore annulus **112** at step **310**. The gas component **208** rejoins the column of wellbore fluids **118** below the packer **114**. At step **312**, the gas component **208** mixes with the wellbore fluids **118**, which may make the wellbore fluids **118** more buoyant. In some embodiments, the gas component **208** will mix naturally with wellbore fluids **118** since the gas component **208** has high solubility/miscibility, and the pressure difference between the gas component **208** and the wellbore fluids **118** may not be sufficiently great to maintain a separation between the gas component **208** and the wellbore fluids **118**. At step **314**, the gas component **208** mixed together with the wellbore fluids **118** may be vented through the annular ventilation pathway **214** between the inner and outer production tubing strings **110**, **206**. The gas component **208** may be discharged through the annular chamber **218** and ventilation port **220** for distribution to an appropriate remote location. The procedure **300** thus enables installation of a submersible pump **116** in wellbores **106** with higher gas volume fraction while improving the operational efficiency and reliability of the submersible pump **116**.

(22) Embodiments disclosed herein include: A. A system for producing a wellbore fluid from a wellbore. The system includes an inner tubing hanger and an outer tubing hanger disposed at a surface location and defining an annular chamber therebetween. An inner production tubing string is suspended from the inner tubing hanger and an outer production tubing string suspended from the outer tubing hanger. The inner and outer production tubing strings extend into the wellbore and define an annular ventilation pathway therebetween in fluid communication with the annular chamber. A packer forms an annular seal around the outer production tubing string and fluidly isolating an upper portion from a lower portion of a wellbore annulus around the outer production tubing string. An electrical submersible pump (ESP) is coupled in the inner production tubing string and is operable to propel the wellbore fluid through the inner tubing string to the surface location. A gas/liquid separator is coupled in the inner production tubing string. The gas/liquid separator is operable to discharge a liquid component of the wellbore fluid into the inner production tubing string and to discharge a gas component of the wellbore fluid into the lower portion of the wellbore annulus. The system also includes an opening to the annular ventilation pathway defined in the lower portion of the wellbore annulus through which a mixture of the gas component within the wellbore fluid may enter the ventilation pathway. B. A method for producing a wellbore fluid from a wellbore. The method includes (a) operating a submersible pump to draw a wellbore fluid from a lower portion of a wellbore annulus into a gas/liquid separator, (b) separating a gas component from a liquid component of the wellbore fluid with the gas/liquid separator, (c) discharging the gas component from the gas/liquid separator into the lower portion of the wellbore annulus, (d) pumping the liquid component from the gas/liquid separator to a surface location through an inner production tubing string suspended from an inner tubing hanger at the surface location, and (e) venting a mixture of the gas component within the wellbore fluid through an annular ventilation pathway defined between the inner production tubing string and an outer production tubing string suspended from an outer tubing hanger at the surface location. C. A system for producing a wellbore fluid from a wellbore. The system includes an inner tubing hanger and an outer tubing hanger disposed at a surface location and defining an annular chamber therebetween. The system also includes an inner production tubing string suspended from the inner tubing hanger and an outer production tubing string suspended from the outer tubing hanger. The inner and outer production tubing strings extend into the wellbore and define an annular ventilation pathway therebetween in fluid communication with the annular chamber. A packer forms an annular seal around an exterior surface of the outer production tubing string and fluidly isolates an upper portion of a wellbore annulus around the outer production tubing string from a lower portion of the wellbore annulus. An electrical submersible pump (ESP) is coupled to the inner production tubing string below the packer and is operable to propel the wellbore fluid through the inner production tubing string to the surface location. A gas/liquid separator is coupled in the inner production tubing string below the packer. The gas/liquid separator is operable to discharge a liquid component

of the wellbore fluid into the inner production tubing string and to discharge a gas component of the wellbore fluid into the annular ventilation pathway through the lower portion of the wellbore annulus. The system further includes an electrical cable extending through the annular ventilation pathway and electrically coupled to the ESP.

(23) Each of embodiments A through C may have one or more of the following additional elements in any combination: Element 1: further comprising a ventilation port defined through the outer tubing hanger through which the mixture of the gas component within the wellbore fluid may be directed to a remote location with respect to the wellbore through the ventilation port. Element 2: further comprising a Christmas tree disposed at the surface location and fluidly coupled to the inner production tubing string such that the liquid component of the wellbore fluid may be directed to a remote location with respect to the wellbore through the Christmas tree. Element 3: wherein the opening to the annular ventilation pathway annular is an annular opening defined between an open longitudinal end of the outer production tubing string and a lower portion of the inner production tubing string protruding through the longitudinal end of the outer production tubing string. Element 4: wherein the ESP and the gas/liquid separator are coupled in the lower portion of the inner production tubing string below the annular opening, and wherein the gas/liquid separator includes radial discharge ports through which the gas component may be discharged into the lower portion of the wellbore annulus. Element 5: wherein the annular ventilation path extends an entire length of the outer production tubing string between the longitudinal end and the outer tubing hanger. Element 6: wherein the gas/liquid separator is installed within the ESP such that operation of the ESP draws the wellbore fluid into the gas/liquid separator. Element 7: further comprising an electrical cable extending through the annular ventilation pathway and electrically coupled to the ESP.

(24) Element 8: further comprising directing the mixture of the gas component within the wellbore fluid through a ventilation port defined through the outer tubing hanger to a remote location with respect to the wellbore through the ventilation port. Element 9: further comprising directing the liquid component through a Christmas tree fluidly coupled to the inner production tubing string. Element 10: wherein venting the mixture of the gas component within the wellbore fluid includes passing the mixture through an annular opening to the annular ventilation pathway defined between an open longitudinal end of the outer production tubing string and a lower portion of the inner production tubing string protruding through the longitudinal end of the outer tubing string. Element 11: wherein discharging the gas component from the gas/liquid separator includes supporting the gas/liquid separator within the lower portion of the inner production tubing string and discharging the gas component through radial discharge ports defined in the gas/liquid separator. Element 12: wherein venting the mixture includes passing the mixture through an entire length of the outer production tubing string through the annular ventilation pathway. Element 13: further comprising powering the submersible pump with an electrical cable extending through the annular ventilation pathway. Element 14: further comprising installing a packer around the outer production tubing string and the electrical cable to fluidly isolate the lower portion of the wellbore annulus from an upper portion of the wellbore annulus.

(25) Element 15: wherein the electrical cable extends to an electrical power source at the surface location. Element 16: wherein the ESP and the gas/liquid separator are coupled in a lower portion of the inner production tubing string extending below an open longitudinal end of the outer production tubing string. Element 17: wherein the electrical cable extends along an exterior surface of the inner production tubing string below the longitudinal end of the outer production tubing string.

(26) By way of non-limiting example, exemplary combinations applicable to A through C include: Element 1 with Element 2; Element 3 with Element 4; Element 4 with Element 5; Element 8 with Element 9; Element 10 with Element 11; Element 11 with Element 12; Element 13 with Element 14; and Element 16 with Element 17.

(27) The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, for example, the singular forms “a,” “an,” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “contains”, “containing”, “includes”, “including,” “comprises”, and/or “comprising,” and variations thereof, when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.
(28) Terms of orientation are used herein merely for purposes of convention and referencing and are not to be construed as limiting. However, it is recognized these terms could be used with reference to an operator or user. Accordingly, no limitations are implied or to be inferred. In addition, the use of ordinal numbers (e.g., first, second, third, etc.) is for distinction and not counting. For example, the use of “third” does not imply there must be a corresponding “first” or “second.” Also, if used herein, the terms “coupled” or “coupled to” or “connected” or “connected to” or “attached” or “attached to” may indicate establishing either a direct or indirect connection, and is not limited to either unless expressly referenced as such.
(29) While the disclosure has described several exemplary embodiments, it will be understood by those skilled in the art that various changes can be made, and equivalents can be substituted for elements thereof, without departing from the spirit and scope of the invention. In addition, many modifications will be appreciated by those skilled in the art to adapt a particular instrument, situation, or material to embodiments of the disclosure without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiments disclosed, or to the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims. Moreover, reference in the appended claims to an apparatus or system or a component of an apparatus or system being adapted to, arranged to, capable of, configured to, enabled to, operable to, or operative to perform a particular function encompasses that apparatus, system, or component, whether or not it or that particular function is activated, turned on, or unlocked, as long as that apparatus, system, or component is so adapted, arranged, capable, configured, enabled, operable, or operative.

Claims

1. A system for producing a wellbore fluid from a wellbore, the system comprising: an inner tubing hanger and an outer tubing hanger disposed at a surface location and defining an annular chamber therebetween; an inner production tubing string suspended from the inner tubing hanger and an outer production tubing string suspended from the outer tubing hanger, the inner and outer production tubing strings extending into the wellbore and defining an annular ventilation pathway therebetween in fluid communication with the annular chamber; a packer forming an annular seal around the outer production tubing string and fluidly isolating an upper portion from a lower portion of a wellbore annulus defined between the outer production tubing string and an inner wall of the wellbore; an electrical submersible pump (ESP) coupled in the inner production tubing string and operable to propel the wellbore fluid through the inner tubing string to the surface location; a gas/liquid separator coupled in the inner production tubing string and being operable to discharge a liquid component of the wellbore fluid into the inner production tubing string and to discharge a gas component of the wellbore fluid into the lower portion of the wellbore annulus; and an annular opening to the annular ventilation pathway defined in the lower portion of the wellbore annulus and extending radially between an open longitudinal end of the outer production tubing string and a lower portion of the inner production tubing string in which the ESP is coupled protruding through the open longitudinal end of the outer production tubing string and through which a mixture of the gas component within the wellbore fluid may enter the ventilation pathway.

2. The system of claim 1, further comprising a ventilation port defined through the outer tubing hanger through which the mixture of the gas component within the wellbore fluid is directed to a remote location with respect to the wellbore through the ventilation port.
3. The system of claim 2, further comprising a Christmas tree disposed at the surface location and fluidly coupled to the inner production tubing string such that the liquid component of the wellbore fluid is directed to a remote location with respect to the wellbore through the Christmas tree.
4. The system of claim 1, wherein the gas/liquid separator includes one or more radial discharge ports through which the gas component is discharged into the lower portion of the wellbore annulus.
5. The system of claim 4, wherein the annular ventilation path extends an entire length of the outer production tubing string between the open longitudinal end and the outer tubing hanger.
6. The system of claim 1, wherein the gas/liquid separator is installed within the ESP such that operation of the ESP draws the wellbore fluid into the gas/liquid separator.
7. The system of claim 1, further comprising an electrical cable extending through the annular ventilation pathway and electrically coupled to the ESP.
8. A method for producing a wellbore fluid from a wellbore, the method comprising: operating a submersible pump to draw a wellbore fluid from a lower portion of a wellbore annulus into a gas/liquid separator; separating a gas component from a liquid component of the wellbore fluid with the gas/liquid separator; discharging the gas component from the gas/liquid separator into the lower portion of the wellbore annulus; pumping the liquid component from the gas/liquid separator to a surface location through an inner production tubing string suspended from an inner tubing hanger at the surface location; and venting a mixture of the gas component within the wellbore fluid through an annular opening defined in the lower portion of the wellbore annulus and extending radially between an open longitudinal end of an outer production tubing string suspended from an outer tubing hanger at the surface location and a lower portion of the inner production tubing string protruding through the open longitudinal end of the outer production tubing string and in which the submersible pump is coupled, and into an annular ventilation pathway defined between the inner production tubing string and the outer production tubing string.
9. The method of claim 8, further comprising directing the mixture of the gas component within the wellbore fluid through a ventilation port defined through the outer tubing hanger to a remote location with respect to the wellbore through the ventilation port.
10. The method of claim 9, further comprising directing the liquid component through a Christmas tree fluidly coupled to the inner production tubing string.
11. The method of claim 8, wherein discharging the gas component from the gas/liquid separator includes supporting the gas/liquid separator within the lower portion of the inner production tubing string and discharging the gas component through radial discharge ports defined in the gas/liquid separator.
12. The method of claim 11, wherein venting the mixture includes passing the mixture through an entire length of the outer production tubing string through the annular ventilation pathway.
13. The method of claim 8, further comprising powering the submersible pump with an electrical cable extending through the annular ventilation pathway.
14. The further of claim 13, further comprising installing a packer around the outer production tubing string and the electrical cable to fluidly isolate the lower portion of the wellbore annulus from an upper portion of the wellbore annulus.
15. The method of claim 8, further comprising: running the packer into the wellbore on the outer production tubing string; suspending the outer production tubing string on the outer tubing hanger; and radially expanding the packer.
16. The method of claim 15, further comprising: lowering the submersible pump and the gas/liquid separator through the open longitudinal end of the outer production tubing string on the inner production tubing string; and hanging the inner production tubing string from the inner tubing

hanger subsequent to lowering the submersible pump and the gas/liquid separator.

17. A system for producing a wellbore fluid from a wellbore, the system comprising: an inner tubing hanger and an outer tubing hanger disposed at a surface location and defining an annular chamber therebetween; an inner production tubing string suspended from the inner tubing hanger and an outer production tubing string suspended from the outer tubing hanger, the inner and outer production tubing strings extending into the wellbore and defining an annular ventilation pathway therebetween in fluid communication with the annular chamber; a packer forming an annular seal around an exterior surface of the outer production tubing string and fluidly isolating an upper portion of a wellbore annulus around the outer production tubing string from a lower portion of the wellbore annulus; an electrical submersible pump (ESP) coupled to the inner production tubing string below the packer and operable to propel the wellbore fluid through the inner production tubing string to the surface location; a gas/liquid separator coupled in the inner production tubing string below the packer, the gas/liquid separator operable to discharge a liquid component of the wellbore fluid into the inner production tubing string and to discharge a gas component of the wellbore fluid into the annular ventilation pathway through the lower portion of the wellbore annulus and an annular opening defined in the lower portion of the wellbore annulus and extending radially between an open longitudinal end of the outer production tubing string and a lower portion of the inner production tubing string protruding through the open longitudinal end of the outer production tubing string and in which the ESP is coupled; and an electrical cable extending through the annular ventilation pathway and electrically coupled to the ESP.

18. The system of claim 17, wherein the electrical cable extends to an electrical power source at the surface location.

19. The system of claim 17, wherein the gas/liquid separator is coupled in the lower portion of the inner production tubing string.

20. The system of claim 19, wherein the electrical cable extends along an exterior surface of the inner production tubing string below the longitudinal end of the outer production tubing string in the drill string.