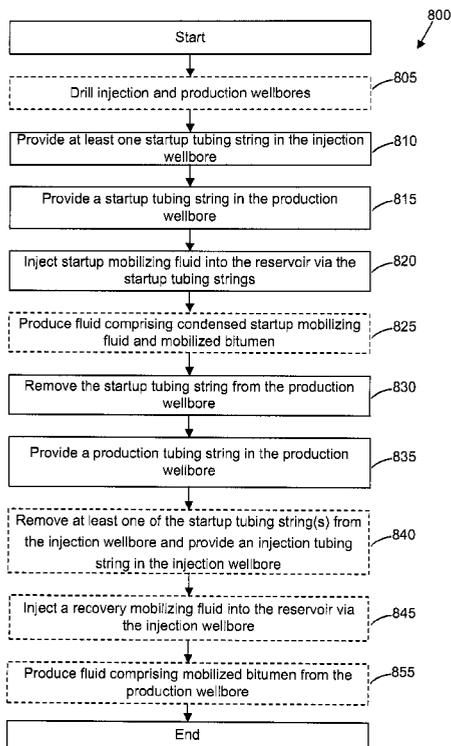




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(57) **Abrégé/Abstract:**

Methods and systems for starting-up a solvent-based operation for recovering hydrocarbons from an underground reservoir are disclosed. Methods include injecting a startup mobilizing fluid comprising a mixture of vapour solvent and steam into the reservoir

(57) **Abrégé(suite)/Abstract(continued):**

via startup tubing strings provided in horizontal segments of injection and production wellbores, removing the startup tubing string from the production wellbore, and providing a production tubing string comprising an artificial lift system in the production wellbore. In some methods, the startup mobilizing fluid comprises a substantially azeotropic mixture of vapour solvent and steam.

## ABSTRACT

Methods and systems for starting-up a solvent-based operation for recovering hydrocarbons from an underground reservoir are disclosed. Methods include injecting a startup mobilizing fluid comprising a mixture of vapour solvent and steam into the reservoir via startup tubing strings provided in horizontal segments of injection and production wellbores, removing the startup tubing string from the production wellbore, and providing a production tubing string comprising an artificial lift system in the production wellbore. In some methods, the startup mobilizing fluid comprises a substantially azeotropic mixture of vapour solvent and steam.

## METHODS AND SYSTEMS FOR START-UP OF SOLVENT-BASED PETROLEUM EXTRACTION OPERATIONS

### FIELD

[0001] This disclosure relates generally to solvent-based operations for recovering hydrocarbons from an underground reservoir, and more specifically to methods and systems for starting-up a solvent-based operation.

### INTRODUCTION

[0002] Various systems and methods are known to extract hydrocarbons from subterranean formations, which also may be referred to herein as reservoirs and/or as underground reservoirs. Typically, a particular extraction process is selected based on one or more properties of the hydrocarbon and/or of the subterranean formation.

[0003] For example, hydrocarbons having a relatively lower viscosity and extending within relatively higher fluid permeability subterranean formations (which may be characterized as conventional hydrocarbons) may be pumped from the subterranean formation utilizing a conventional oil well.

[0004] However, conventional oil wells may be ineffective (or at least economically ineffective) at producing hydrocarbons having a relatively higher viscosity and/or extending within relatively lower fluid permeability subterranean formations (which may be characterized as unconventional hydrocarbons). Examples of unconventional hydrocarbon production techniques that may be utilized to produce viscous hydrocarbons from a subterranean formation include thermal recovery processes and solvent-dominated recovery processes.

[0005] Thermal recovery processes generally inject a thermal recovery stream, at an elevated temperature, into the subterranean formation. The thermal recovery stream contacts the viscous hydrocarbons within the subterranean formation, and heats, dissolves, and/or dilutes the viscous hydrocarbons, thereby generating mobilized viscous hydrocarbons. The mobilized viscous hydrocarbons generally have a lower viscosity than a viscosity of the naturally occurring viscous hydrocarbons at the native

temperature and pressure of the subterranean formation and may be pumped and/or flowed from the subterranean formation.

[0006] A variety of different thermal recovery processes have been utilized, including cyclic steam stimulation processes, solvent-assisted cyclic steam stimulation processes, steam flooding processes, solvent-assisted steam flooding processes, steam-assisted gravity drainage (SAGD) processes, solvent-assisted steam-assisted gravity drainage processes, heated vapor extraction processes, liquid addition to steam to enhance recovery processes, and/or near-azeotropic gravity drainage processes.

[0007] As an example, in a typical SAGD process, two horizontal wellbores are drilled into an oil-containing reservoir. The wellbores are positioned generally parallel to each other and spaced apart vertically, with one wellbore being positioned above the other wellbore, typically by about 4 to 6 meters. During production, high pressure steam is injected into the upper wellbore (also referred to as the injection wellbore or simply the injector) to heat the oil in the surrounding formation, thereby reducing its viscosity such that it can flow through the formation under the force of gravity. The heated oil – along with any condensed steam (i.e. water) – drains into the lower wellbore (also referred to as the production wellbore or simply the producer), and the collected oil and water are pumped to the surface.

[0008] Solvent Assisted - Steam Assisted Gravity Drainage (SA-SAGD), Heated Vapor Extraction (VAPEX), and Azeotropic Heated Vapor Extraction (Azeo H-VAPEX) are examples of other gravity drainage recovery processes for producing heavy oil. SA-SAGD, Heated VAPEX, and Azeotropic Heated Vapor Extraction are similar to SAGD, but instead of (or in addition to) steam, one or more vapourized solvents (e.g. ethane, propane, butane, gas condensate, naphtha) are injected to reduce the viscosity of oil in the surrounding formation. In such processes, at least some of the produced oil's viscosity reduction is obtained by chemical solvation rather than by thermal means.

## **SUMMARY**

[0009] The following introduction is provided to introduce the reader to the more detailed discussion to follow. The introduction is not intended to limit or define any

claimed or as yet unclaimed invention. One or more inventions may reside in any combination or sub-combination of the elements or process steps disclosed in any part of this document including its claims and figures.

5 [0010] In accordance with one broad aspect of this disclosure, there is provided a method for starting-up a solvent-based operation for recovering hydrocarbons from an underground reservoir, the method comprising: providing at least one first startup tubing string in a horizontal segment of an injection wellbore; providing a second startup tubing string in a horizontal segment of a production wellbore; injecting a startup mobilizing fluid comprising a mixture of vapour solvent and steam into the reservoir via the at least  
10 one first startup tubing string and the at least one second startup tubing string to establish fluid communication between the injection wellbore and the production wellbore; after fluid communication between the injection wellbore and the production wellbore has been established: removing the second startup tubing string from the production wellbore; and providing a production tubing string in the production wellbore,  
15 the production tubing string comprising an artificial lift system.

[0011] In some embodiments, the method further comprises, while the startup mobilizing fluid is being injected: producing fluid comprising condensed startup mobilizing fluid and mobilized bitumen from at least one of the injection wellbore and the production wellbore.

20 [0012] In some embodiments, the method further comprises, after providing the production tubing string in the production wellbore: injecting a recovery mobilizing fluid into the reservoir via at least one of the at least one first startup tubing string, and producing fluid comprising mobilized bitumen from the production wellbore.

25 [0013] In some embodiments, the method further comprises, after fluid communication between the injection wellbore and the production wellbore has been established: removing at least one of the at least one first startup tubing string from the injection wellbore; and providing an injection tubing string in the injection wellbore.

[0014] In some embodiments, the method further comprises, after providing the injection tubing string in the injection wellbore: injecting a recovery mobilizing fluid into

the reservoir via the injection tubing string, and producing fluid comprising mobilized bitumen from the production wellbore.

[0015] In some embodiments, the recovery mobilizing fluid comprises steam.

[0016] In some embodiments, the recovery mobilizing fluid comprises a substantially azeotropic mixture of vapour solvent and steam.

[0017] In some embodiments, solvent in the startup mobilizing fluid consists primarily of C4 to C12 hydrocarbons.

[0018] In some embodiments, the startup mobilizing fluid is injected into the reservoir at a temperature of between 8°C to 300°C, and at a pressure of between 100 KPa to 5,000 KPa.

[0019] In some embodiments, the startup mobilizing fluid is injected into the reservoir at a pressure below the fracture pressure of the reservoir.

[0020] In some embodiments, while the startup mobilizing fluid is being injected, a downhole pressure in the injection wellbore and a downhole pressure in the production wellbore are within about 10% of each other.

[0021] In some embodiments, while the startup mobilizing fluid is being injected, a downhole pressure in the injection wellbore is greater than 110% of a downhole pressure in the production wellbore.

[0022] In some embodiments, the injection wellbore and the production wellbore are generally parallel and wherein the injection wellbore is vertically spaced from the production wellbore.

[0023] In some embodiments, the method further comprises, prior to providing the at least one first startup tubing string and the second startup tubing string: drilling and completing the injection wellbore and the production wellbore.

[0024] In some embodiments, the startup mobilizing fluid comprises a substantially azeotropic mixture of vapour solvent and steam.

[0025] In accordance with another broad aspect of this disclosure, there is provided a method for starting-up a solvent-based operation for recovering hydrocarbons from an underground reservoir, the method comprising: providing at least one first startup tubing string in a horizontal segment of an injection wellbore; providing  
5 a second startup tubing string in a horizontal segment of a production wellbore; injecting a startup mobilizing fluid comprising a mixture of vapour solvent and steam into the reservoir via the at least one first startup tubing string and the at least one second startup tubing string to establish fluid communication between the injection wellbore and the production wellbore; after fluid communication between the injection wellbore and  
10 the production wellbore has been established: converting the second startup tubing string to a production tubing string, the production tubing string comprising an artificial lift system.

[0026] In some embodiments, the second startup tubing string comprises the artificial lift system in an unengaged or bypassed state, and converting the second  
15 startup tubing string to the production tubing string comprises engaging the artificial lift system.

[0027] In some embodiments, the method further comprises, while the startup mobilizing fluid is being injected: producing fluid comprising condensed startup mobilizing fluid and mobilized bitumen from at least one of the injection wellbore and the  
20 production wellbore.

[0028] In some embodiments, the method further comprises, after providing the production tubing string in the production wellbore: injecting a recovery mobilizing fluid into the reservoir via at least one of the at least one first startup tubing string, and producing fluid comprising mobilized bitumen from the production wellbore.

25 [0029] In some embodiments, the method further comprises, after fluid communication between the injection wellbore and the production wellbore has been established: removing at least one of the at least one first startup tubing string from the injection wellbore; and providing an injection tubing string in the injection wellbore.

- [0030] In some embodiments, the method further comprises, after providing the injection tubing string in the injection wellbore: injecting a recovery mobilizing fluid into the reservoir via the injection tubing string, and producing fluid comprising mobilized bitumen from the production wellbore.
- 5 [0031] In some embodiments, the recovery mobilizing fluid comprises steam.
- [0032] In some embodiments, the recovery mobilizing fluid comprises a substantially azeotropic mixture of vapour solvent and steam.
- [0033] In some embodiments, solvent in the startup mobilizing fluid consists primarily of C4 to C12 hydrocarbons.
- 10 [0034] In some embodiments, the startup mobilizing fluid is injected into the reservoir at a temperature of between 8°C to 300°C, and at a pressure of between 100 KPa to 5,000 KPa.
- [0035] In some embodiments, the startup mobilizing fluid is injected into the reservoir at a pressure below the fracture pressure of the reservoir.
- 15 [0036] In some embodiments, while the startup mobilizing fluid is being injected, a downhole pressure in the injection wellbore and a downhole pressure in the production wellbore are within about 10% of each other.
- [0037] In some embodiments, while the startup mobilizing fluid is being injected, a downhole pressure in the injection wellbore is greater than 110% of a downhole pressure in the production wellbore.
- 20 [0038] In some embodiments, the injection wellbore and the production wellbore are generally parallel and wherein the injection wellbore is vertically spaced from the production wellbore.
- [0039] In some embodiments, the method further comprises, prior to providing the first startup tubing string and the second startup tubing string: drilling and completing the injection wellbore and the production wellbore.
- 25

[0040] In some embodiments, the startup mobilizing fluid comprises a substantially azeotropic mixture of vapour solvent and steam.

[0041] It will be appreciated by a person skilled in the art that a method or apparatus disclosed herein may embody any one or more of the features contained  
5 herein and that the features may be used in any particular combination or sub-combination.

[0042] These and other aspects and features of various embodiments will be described in greater detail below.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

10 [0043] For a better understanding of the described embodiments and to show more clearly how they may be carried into effect, reference will now be made, by way of example, to the accompanying drawings in which:

[0044] Figure 1 is an exemplary schematic longitudinal cross-section view of a pair of horizontal wellbores through a formation being used in a gravity drainage  
15 recovery process, with an artificial lift device and a tubing string located in the lower wellbore;

[0045] Figure 2 is a plot of dew point curves of vapor mixtures of n-alkanes solvents with water at 0.5 MPa pressure;

[0046] Figure 3 is an exemplary schematic longitudinal cross-section view of a pair of horizontal wellbores with startup tubing strings provided in each of the wellbores;  
20

[0047] Figure 4 is an exemplary schematic longitudinal cross-section view of a pair of horizontal wellbores with startup tubing strings provided in the upper wellbore and a production tubing string provided in the lower wellbore;

[0048] Figure 5 is an exemplary schematic longitudinal cross-section view of a pair of horizontal wellbores with an injection tubing string provided in the upper wellbore  
25 and a production tubing string provided in the lower wellbore;

[0049] Figure 6 is an exemplary schematic longitudinal cross-section view of a pair of horizontal wellbores with injection tubing strings provided in the upper wellbore and a production tubing string provided in the lower wellbore;

5 [0050] Figure 7 is an exemplary schematic longitudinal cross-section view of a pair of horizontal wellbores with a startup tubing string and an injection tubing string provided in the upper wellbore and a production tubing string provided in the lower wellbore;

[0051] Figure 8 is an exemplary schematic longitudinal cross-section view of a tubing string in a producer wellbore, with an artificial lift device in a bypassed  
10 configuration;

[0052] Figure 9 is an exemplary schematic longitudinal cross-section view of the tubing string of Figure 8, with the artificial lift device in an engaged configuration;

[0053] Figure 10 is a simplified process flow diagram for a method starting-up a solvent-based operation for recovering hydrocarbons from an underground reservoir in  
15 accordance with one embodiment; and

[0054] Figure 11 is a simplified process flow diagram for a method starting-up a solvent-based operation for recovering hydrocarbons from an underground reservoir in accordance with another embodiment.

[0055] The drawings included herewith are for illustrating various examples of  
20 articles, methods, and apparatuses of the teachings of the present specification and are not intended to limit the scope of what is taught in any way.

## **DESCRIPTION OF EXAMPLE EMBODIMENTS**

[0056] Various apparatuses, methods and compositions are described below to  
25 provide an example of an embodiment of each claimed invention. No embodiment described below limits any claimed invention and any claimed invention may cover apparatuses and methods that differ from those described below. The claimed inventions are not limited to apparatuses, methods and compositions having all of the features of any one apparatus, method or composition described below or to features

common to multiple or all of the apparatuses, methods or compositions described below. It is possible that an apparatus, method or composition described below is not an embodiment of any claimed invention. Any invention disclosed in an apparatus, method or composition described below that is not claimed in this document may be the subject matter of another protective instrument, for example, a continuing patent application, and the applicant(s), inventor(s) and/or owner(s) do not intend to abandon, disclaim, or dedicate to the public any such invention by its disclosure in this document.

[0057] Furthermore, it will be appreciated that for simplicity and clarity of illustration, where considered appropriate, reference numerals may be repeated among the figures to indicate corresponding or analogous elements. In addition, numerous specific details are set forth in order to provide a thorough understanding of the example embodiments described herein. However, it will be understood by those of ordinary skill in the art that the example embodiments described herein may be practiced without these specific details. In other instances, well-known methods, procedures, and components have not been described in detail so as not to obscure the example embodiments described herein. Element numbers that are numbered the same and are used in multiple figures will have the same meaning as described in prior figure descriptions unless specifically noted. Also, the description is not to be considered as limiting the scope of the example embodiments described herein.

[0058] Figure 1 illustrates a schematic axial cross-section of a typical gravity drainage recovery process (e.g. a SAGD process). A pair of parallel horizontal wellbore segments 100, 200 are provided in a formation or reservoir 10 and are spaced apart vertically by a distance  $d$ . During normal operation, a mobilizing fluid (e.g. steam, solvent, or a mixture of steam and solvent) is pumped down from the surface through the vertical section 102 – e.g. via a tubing string (not shown in Figure 1) – and along the upper wellbore 100, where it passes into the formation 10 via one of a number of apertures 110 (e.g. orifices, slots, perforations, outflow control devices, screens) provided in the wellbore casing between the heel 104 and the toe 108 of the wellbore 100, as indicated by arrows 12. Upper wellbore 100 may also be referred to as an

injection wellbore, an injector wellbore, or simply an injector. The upper wellbore 100 comprises a horizontal section 106.

[0059] As the mobilizing fluid is injected, thermal energy from the mobilizing fluid is transferred to the formation. This thermal energy increases the temperature of  
5 petroleum products present in the formation (e.g. heavy crude oil or bitumen), which reduces their viscosity. Where the mobilizing fluid comprises solvent, at least some of the produced oil's viscosity reduction is obtained by chemical solvation rather than by thermal means.

[0060] For example, azeotropic heated VAPEX (alternatively referred to herein as  
10 Azeo H-VAPEX, or simply azeo-VAPEX) is a recovery process in which steam is co-injected with hydrocarbon solvent in vapor phase, with the mixture being injected at substantially azeotropic conditions – i.e. the steam and solvent are injected under conditions wherein the solvent molar fraction of the combined steam and solvent is under “near azeotropic” conditions or a “substantially azeotropic mixture”, preferably at  
15 about 70-100% of the azeotropic solvent molar fraction of the steam and the solvent as measured at the reservoir operating pressure and temperature. In preferred embodiments, the steam and solvent are injected under other “near azeotropic” or “substantially azeotropic” conditions/mixtures wherein the solvent molar fraction of the combined steam and solvent is 80-100%, 90-100%, or 95-100% of the azeotropic  
20 solvent molar fraction of the steam and the solvent as measured at the reservoir operating pressure and temperature. The reservoir operating pressure and temperature may be measured or calculated at the point in the reservoir of the injection of the steam and solvent mixture. Simulation results have shown that the total injected energy per volume of bitumen produced and the bitumen production rate are not be considerably  
25 affected by varying the composition of the injected fluid in this range. These compositions translate to different dew point temperature ranges for each solvent. By way of example, Figure 2 is a plot of collective dew point temperature curves for vapor mixtures of n-alkane hydrocarbon solvents of n-C4 to n-C9, with water as a function of solvent mole fraction.

[0061] Theoretically, available solvents to use in an Azeo H-VAPEX process include light hydrocarbon mixtures such as natural gas liquids (NGLs), liquefied petroleum gas (LPG), and naphtha, along with mixtures including heavier fractions, including mixtures mainly composed of hydrocarbon compounds with 3 to 12 carbon atoms, or with more than 12 carbon atoms. These compounds may form vapor mixtures with steam wherein the vapor mixture exhibits azeotropic behavior.

[0062] As noted above, Figure 2 illustrates collective dew point curves for C4 to C9 at 0.5 MPa. Solvent in a vapor phase and water vapor tend to co-condense at the azeotropic temperature for the composition (at a given pressure) into two immiscible liquid phases. Also, a mixture of liquid water and solvent in a liquid phase tends to evaporate to a single vapor phase at the azeotropic temperature for the composition (at a given pressure). In general, the azeotropic temperature for vapor mixtures of water and solvent compounds at a given pressure is equal to or less than the saturation temperature of pure water vapor and pure solvent compounds at that pressure.

[0063] For an Azeo H-VAPEX recovery process, a near azeotropic/minimum boiling point mixture of solvent and steam may contain 70-100% of the azeotropic/minimum boiling point solvent molar fraction of the steam and the solvent as measured at the reservoir operating pressure and temperature. Depending on the solvent type, a near azeotropic/minimum boiling point mixture of solvent and steam contains 15-98 vol. % solvent and 2-85 vol. % steam, in cold liquid equivalents, calculated at standard temperature and pressure.

[0064] References describing azeotropic heated VAPEX include Canadian Patent Publication No. 2,972,068 A1 (Khaledi et al.), and Canadian Patent Publication No. 2,915,571 A1 (Boone et al.).

[0065] Returning to Figure 1, the reduction in the viscosity (whether by thermal and/or chemical means) allows the 'mobilized' petroleum products, along with condensate from the injected fluids, to flow downwards under the influence of gravity towards the lower wellbore 200, where it passes into the wellbore 200 via one of a number of apertures 210 (e.g. orifices, slots, perforations, inflow control devices,

screens) provided along the horizontal segment 206 of the production wellbore casing between the heel 204 of the production wellbore and the toe 208. Lower wellbore 200 may also be referred to as a producer wellbore or simply a producer. During production, one or more artificial lift devices 300 (e.g. electrical submersible pumps) may be used to pump fluids collected along the horizontal segment 206 of the production wellbore 200 up to the surface through the vertical section 202 (e.g. via a tubing string 428).

[0066] In the illustrated example, the line 50 represents the liquid level  $h$  in the formation (e.g. the level of the liquid at the bottom of a steam chamber) above the production wellbore 200 along its horizontal segment.

10 [0067] While during normal operation lower wellbore 200 acts as a producer (i.e. fluid is extracted from the formation via wellbore 200), it will be appreciated that wellbore 200 may alternately act as an injector.

[0068] For example, during start-up of an SAGD process, steam may be pumped into both wellbores 100 and 200 to initially heat the formation proximate both the upper and lower wellbores in order to establish fluid communication between the wellbores. Following this initial start-up phase, wellbore 200 may be transitioned to a producer by discontinuing the steam flow into this wellbore. During such a start-up period, heat conduction is the main mechanism for the viscosity reduction and mobilization of the bitumen residing between the two horizontal wells.

20 [0069] In the example illustrated in Figure 3, startup tubing strings have been provided in the injection wellbore 100 and the production wellbore 200. Specifically, in the injection wellbore 100, a tubing string 314 is installed to the heel 104 of the injection wellbore 100, and a tubing string 318 is installed to the toe 108 of the wellbore. In the producer wellbore 200, a tubing string 328 is installed to the toe 208 of the wellbore. These tubing strings 314, 318, and 328 may be used to circulate startup mobilizing fluid to reduce the bitumen viscosity and to establish fluid communication between the well pair 100, 200.

[0070] In the example illustrated in Figure 3, the tubing strings in the injector are shown in a concentric arrangement. That is, tubing string 318 is positioned interior of

tubing string 314. In this configuration, during a start-up phase, steam (or another mobilizing fluid) may be pumped down through tubing string 318 to enter the injector wellbore 100 proximate the toe 108. In such an arrangement, fluid within the horizontal section 106 of wellbore 100 may be produced to the surface via the annulus between the interior of tubing string 314 and the exterior of tubing string 318, and/or via the annulus between the exterior of tubing string 314 and the interior of the vertical section 102 of the wellbore 100.

[0071] Also, during a start-up phase, steam (or another mobilizing fluid) may be pumped down through tubing string 328 to enter the producer wellbore 200 proximate the toe 208. In such an arrangement, fluid within the horizontal section 206 of wellbore 200 may be produced to the surface via the annulus between the exterior of tubing string 328 and the interior of the vertical section 102 of the wellbore 100.

[0072] It will be appreciated that startup tubing strings in an injector wellbore may be provided in either a concentric arrangement (e.g. as illustrated by tubing strings 314, 318 in Figure 3) or in a parallel arrangement (e.g. as illustrated by tubing strings 314, 318 in Figure 4).

[0073] Typically, start-up mobilizing fluid is injected into both the tubing string 318 at the toe 108 of the injector wellbore 100 and the tubing string 328 at the toe 208 of the producer wellbore 200. Upon releasing heat to the formation, condensed start-up mobilizing fluid (and some mobilized bitumen) may be transferred to the surface via the casing annulus. For example, start-up mobilizing fluid may be injected at higher pressures to overcome the gravity head of the condensed fluid and bitumen, returning the fluid to the surface. Alternatively, start-up mobilizing fluid may be injected at lower pressures and the condensed fluid and mobilized bitumen may be produced to the surface using one or more artificial lift systems (e.g. downhole pumps or gas lifts (not shown)).

[0074] An Azeo H-VAPEX process also typically requires a start-up phase during which bitumen in the reservoir between the two horizontal wells is mobilized and fluid communication between the wells is established. Once fluid communication has been

established as a result of the start-up phase, the recovery process can be transitioned to an operating phase, during which there may be substantially continuous injection of a near-azeotropic solvent/steam mixture into the formation via the injector wellbore, and substantially continuous fluid production from the production wellbore.

5 [0075] The mobilizing fluid used during the production phase of an Azeo H-VAPEX recovery process (e.g. a solvent-steam vapour mixture at or near azeotropic conditions) generally has a lower temperature than steam, however, it contains high contents of hydrocarbon solvent. During typical Azeo H-VAPEX production, greater than 50% of the produced oil's viscosity reduction may be obtained by chemical solvation rather than by thermal means. Thus, an Azeo H-VAPEX recovery processes may be characterized as a solvent-dominated recovery process (SDRP).

10 [0076] The inventors have recognized that the effectiveness of a solvent-steam mixture (that contains the required energy and solvent for heating and dilution of bitumen in the reservoir) as a startup mobilizing fluid – in particular an azeotropic solvent-steam mixture – may in many cases be greater than the effectiveness of using steam alone as a startup mobilizing fluid.

15 [0077] Methods disclosed herein for the startup of an Azeo H-VAPEX process involve the injection of a vapour mixture of steam and solvent, and preferably an azeotropic (or near azeotropic) vapour mixture of steam and solvent, as a startup mobilizing fluid to establish fluid communication required for continuous process operation between horizontal well pairs.

20 [0078] The use of a mixture of vapour solvent and steam, in particular a substantially azeotropic mixture of vapour solvent and steam, as a startup mobilizing fluid may have one or more advantages. For example, it may shorten the duration of a start-up period, when compared to the use of e.g. pure steam as a startup mobilizing fluid.

25 [0079] Also, in a typical SAGD recovery process, the surface facility includes one or more steam generation plants that are designed to provide relatively large quantities of steam for injection during normal SAGD operation (i.e. after the start-up phase).

Accordingly, the steam generation plant(s) in a typical SAGD surface facility can typically accommodate the quantities of steam required to start-up an SAGD process by concurrently injecting steam into both the injection and production wellbores. In a typical Azeo H-VAPEX recovery process, the surface facility is designed to provide a solvent-steam vapour mixture at or near azetropic conditions, which may require a relatively smaller quantity of steam as compared to steam quantities required in e.g. a SAGD process. Accordingly, the steam output capacity of steam generation plant(s) provided in a surface facility for Azeo H-VAPEX recovery may not be able to accommodate the quantities of steam required to start-up the well pair by concurrently injecting steam into both the injection and production wellbores.

[0080] For an Azeo H-VAPEX process, after the start-up phase has established fluid communication between the wellbores, the process may transition to a production phase. This may involve removing and/or repositioning one or more tubing strings used during the start-up phase, and/or providing one or more new tubing strings more suitable for the production phase.

[0081] For example, referring to Figure 3 as an example of a configuration that may be used during a startup phase, during the transition to a production phase of the recovery process, one or more of the startup tubing strings 314, 318, and 328 used to circulate startup mobilizing fluid may be removed and replaced with a production tubing string.

[0082] In the example illustrated in Figure 4, startup tubing string 328 that was shown in the example illustrated in Figure 3 has been removed and replaced with a production tubing string 428. In this example, tubing string 428 extends towards the heel 204 of the wellbore 200, and includes an artificial lift device 300 (e.g. an electrical submersible pump or a gas lift system). While only one lift device 300 is shown in Figure 4, it will be appreciated that two or more artificial lift devices 300 may be provided as part of a production tubing string 428 in alternative embodiments.

[0083] In the example illustrated in Figure 4, tubing strings 314 and 318 may be used during both the start-up and production phases of an Azeo H-VAPEX process. For

example, during the start-up phase a startup mobilizing fluid may be injected into wellbore 100 via tubing string 318, and during the production phase a recovery mobilizing fluid may be injected into wellbore 100 via tubing strings 318 and/or 314. It will be appreciated that while both the startup mobilizing fluid and the recovery mobilizing fluid may comprise a substantially azeotropic mixture of vapour solvent and steam, the startup and recovery mobilizing fluids may have different relative compositions of solvent and steam, and/or different solvent compositions.

[0084] In the example illustrated in Figure 5, startup tubing string 328 that was shown in the example illustrated in Figure 3 has been removed and replaced with a production tubing string 428. In this example, tubing string 428 extends towards the toe 208 of the wellbore 200, and includes one or more apertures 410 (e.g. orifices, slots, perforations, inflow control devices, outflow control devices) along the horizontal portion between the heel 204 and the toe 208 of the wellbore 200. Optionally, as shown, tubing string 418 may also include one or more apertures 410 as shown. Notably, tubing string 428 includes an artificial lift device 300 (e.g. an electrical submersible pump or a gas lift system). While only one lift device 300 is shown in Figure 4, it will be appreciated that two or more artificial lift devices 300 may be provided as part of a production tubing string 428 in alternative embodiments. Also, startup tubing strings 314 and 318 have been removed from the injector wellbore 100 and replaced with an injection tubing string 418.

[0085] In the example illustrated in Figure 6, startup tubing string 328 that was shown in the example illustrated in Figure 3 has been removed and replaced with a production tubing string 428. Also, startup tubing strings 314 and 318 have been removed and replaced with injection tubing strings 418 and 428 (which are illustrated in a concentric configuration).

[0086] In the example illustrated in Figure 7, startup tubing string 328 that was shown in the example illustrated in Figure 3 has been removed and replaced with a production tubing string 428. Also, startup tubing string 318 (which extended to the toe 108 of the injector 100) has been removed and replaced with an injection tubing string

418. In this example, startup tubing string 314 remains in the wellbore, and may be used during the production phase to assist in injecting fluid to the heel 104 of wellbore 100.

5 [0087] In the examples illustrated in Figures 4 to 7, to transition from a start-up phase to a production phase, tubing strings that were in the producer wellbore 200 during start-up are removed from the wellbore 200 and a production tubing string is provided. Alternatively, a tubing string present in the producer wellbore 200 during the start-up phase may be converted to a production tubing string.

10 [0088] For example, as illustrated schematically in Figure 8, tubing string 528 includes an artificial lift device 300 that can be bypassed (or otherwise disabled) such that fluid can flow substantially unimpeded through the string 528. For example, in such a 'bypassed' configuration, steam (or another mobilizing fluid) may be pumped down through tubing string 528 to enter the wellbore via one or more apertures 510 (e.g. orifices, slots, perforations, inflow control devices, outflow control devices).

15 [0089] To transition tubing string 528 from a start-up phase to a production phase, as illustrated schematically in Figure 9 the artificial lift device 300 can be engaged (or otherwise enabled) such that fluid can be driven through the string 528 using the artificial lift device 300. For example, in such an 'engaged' configuration, artificial lift device 300 may assist in pumping fluid from wellbore 200 to the surface  
20 through tubing string 528.

[0090] Converting a start-up tubing string to a production tubing string may have one or more advantages. For example, this may be faster than removing one or more startup tubing strings and providing one or more production tubing strings, particularly where the producer wellbore 200 is long and/or has a relatively small inner diameter.

25 [0091] The flowing is a description of a method for starting-up a solvent-based operation for recovering hydrocarbons from an underground reservoir, which may be used by itself or in combination with one or more of the other features disclosed herein including the use of any of the apparatus and/or any of the methods disclosed herein.

[0092] Referring to Figure 10, there is illustrated a method 800 for starting-up a solvent-based operation for recovering hydrocarbons from an underground reservoir. Method 800 may be performed using apparatus described with reference to Figures 1 and/or 3 to 9, or any other suitable apparatus.

5 [0093] Optionally, at 805, an injection and a production wellbore may be drilled in the formation. For example, the injection and production wellbores may include horizontal segments that are parallel to each other, with the horizontal segment of the injection wellbore being vertically offset (e.g. by about 5 m) from the horizontal segment of the production wellbore.

10 [0094] At 810, at least one startup tubing string is provided in the horizontal segment of the injection wellbore. For example, a tubing string 314 that extends to an area proximate the heel of the wellbore may be provided along with a tubing string 318 that extends to an area proximate the toe of the wellbore. Optionally, tubing strings 314, 318 may be provided in a concentric configuration.

15 [0095] At 815, a startup tubing string is provided in the horizontal segment of the production wellbore. For example, a tubing string 328 that extends to an area proximate the toe of the wellbore may be provided.

[0096] It will be appreciated that the startup tubing strings may be provided in their respective wellbores in any order, or substantially concurrently.

20 [0097] At 820, startup mobilizing fluid is injected into the reservoir via the at least one startup tubing string in the injector wellbore and the startup tubing string in the producer wellbore to establish fluid communication between the wellbores. The startup mobilizing fluid comprises a mixture of vapour solvent and steam, and preferably comprises a substantially azeotropic mixture of vapour solvent and steam. Preferably,  
25 solvent in the startup mobilizing fluid may consist primarily of C4 to C12 hydrocarbons. In preferred embodiments, the startup mobilizing fluid may consist of at least 75%, at least 80%, at least 90%, or at least 95% by weight C4 to C12 hydrocarbons.

[0098] It will be appreciated that the startup mobilizing fluid may be introduced into the reservoir at any suitable pressure and/or temperature, including pressures and/or temperatures to promote substantially azeotropic conditions (i.e. azeotropic or near-azeotropic) of the solvent/steam mixture in the formation. For example, the startup mobilizing fluid may be injected into the reservoir at a temperature of between 8°C to 300°C, and at a pressure of between 100 KPa to 5,000 KPa.

[0099] Optionally, startup mobilizing fluid may be injected into the reservoir at a pressure below the fracture pressure of the reservoir.

[00100] Optionally, the downhole pressure in the injection wellbore and the downhole pressure in the production wellbore are within about 10% of each other while startup mobilizing fluid is being injected. An advantage of maintaining relatively equal downhole pressures is that it may inhibit or prevent injected startup fluid from 'short-circuiting' from one wellbore to the other (e.g. inhibiting or preventing a situation analogous to steam coning).

[00101] Optionally, the downhole pressure in the injection wellbore may be greater than 110% of the downhole pressure in the production wellbore while startup mobilizing fluid is being injected. An advantage of maintaining a relatively higher pressure in the injection wellbore is that it may promote improved 'sweeping' of mobilized bitumen between the two wellbores and/or may assist in producing mobilized fluid from producer. For example, the downhole pressure in the injection wellbore may be maintained at greater than 110% of the downhole pressure in the production wellbore towards the end of a start-up phase (e.g. when the bitumen between the two well pairs has been heated up) to accelerate the hydraulic communication between the well pairs.

[00102] Optionally, at 825, while startup mobilizing fluid is being injected, fluid may be produced from one or both of the injection wellbore and the production wellbore. Fluid produced at this time would comprise condensed startup mobilizing fluid and mobilized bitumen.

[00103] At 830, the startup tubing string in the production wellbore is removed, and at 835 a production tubing string is provided in the production wellbore. Preferably, the

production tubing string comprises at least one artificial lift device. Once the production tubing string has replaced the startup tubing string in the production wellbore, the recovery process may be characterized as having transitioned from a startup phase to a production phase.

5 [00104] Optionally, at 840, the startup tubing string in the injection wellbore may be removed, and an injection tubing string may be provided in the injection wellbore. For example, the injection string for the injection wellbore may comprise one or more outflow control devices to improve a steam outflow distribution along the horizontal section of the injection wellbore.

10 [00105] It will be appreciated that the production and injection tubing strings may be provided in their respective wellbores in any order, or substantially concurrently.

[00106] Optionally, at 845, a recovery mobilizing fluid may be injected into the reservoir via the injection wellbore (e.g. via the startup string provided at 810, or via the injection string provided at 840). For example, recovery mobilizing fluid may be pumped  
15 down through tubing string 318 to enter the wellbore proximate the toe 108, and optionally may also be pumped down through the annulus between the interior of tubing string 314 and the exterior of tubing string 318 to enter the wellbore proximate the heel 104.

[00107] In some embodiments, the recovery mobilizing fluid may comprise a  
20 substantially azeotropic mixture of vapour solvent and steam. The recovery mobilizing fluid may have a substantially similar composition as the startup mobilizing fluid, or it may have a different composition. It will be appreciated that the recovery mobilizing fluid may comprise a non-azeotropic mixture of steam and solvent, and may be introduced into the reservoir at any suitable pressure and/or temperature.

25 [00108] Optionally, at 855, fluid comprising mobilized bitumen may be produced from the reservoir via the production wellbore. The produced fluid may also include one or more light hydrocarbons, or condensed solvent and/or water injected at 845 and/or at 820.

[00109] Referring to Figure 11, there is illustrated a method 900 for starting-up a solvent-based operation for recovering hydrocarbons from an underground reservoir. Method 900 may be performed using apparatus described with reference to Figures 1 and/or 3 to 9, or any other suitable apparatus. Steps similar to those in method 800 have been numbered similarly (incremented by 100) and will not be described in detail.

[00110] In method 800, the startup tubing string in the production wellbore is removed at 830, and at 835 a production tubing string is provided in the production wellbore. In contrast, in method 900, at 930 at least one of the startup tubing strings in the production wellbore is converted to a production tubing string. For example, as discussed with reference to Figure 8 and 9, a startup tubing string may include one or more artificial lift devices in a bypassed (or otherwise disabled) configuration. Such a tubing string may be converted from a start-up phase to a production phase by engaging (or otherwise enabling) the one or more artificial lift devices.

[00111] As used herein, the wording “and/or” is intended to represent an inclusive - or. That is, “X and/or Y” is intended to mean X or Y or both, for example. As a further example, “X, Y, and/or Z” is intended to mean X or Y or Z or any combination thereof.

[00112] While the above description describes features of example embodiments, it will be appreciated that some features and/or functions of the described embodiments are susceptible to modification without departing from the spirit and principles of operation of the described embodiments. For example, the various characteristics which are described by means of the represented embodiments or examples may be selectively combined with each other. Accordingly, what has been described above is intended to be illustrative of the claimed concept and non-limiting. It will be understood by persons skilled in the art that other variants and modifications may be made without departing from the scope of the invention as defined in the claims appended hereto. The scope of the claims should not be limited by the preferred embodiments and examples, but should be given the broadest interpretation consistent with the description as a whole.

CLAIMS:

1. A method for starting-up a solvent-based operation for recovering hydrocarbons from an underground reservoir, the method comprising:
  - providing at least one first startup tubing string in a horizontal segment of an injection wellbore;
  - providing a second startup tubing string in a horizontal segment of a production wellbore wherein the second startup tubing string comprises an artificial lift system in an unengaged or bypassed state;
  - injecting a startup mobilizing fluid comprising a mixture of vapour solvent and steam into the reservoir via the at least one first startup tubing string and the at least one second startup tubing string to establish fluid communication between the injection wellbore and the production wellbore;
  - after fluid communication between the injection wellbore and the production wellbore has been established:
    - converting the second startup tubing string to a production tubing string, wherein converting the second startup tubing string to the production string comprises engaging the artificial lift system.
2. The method of claim 1, further comprising, while the startup mobilizing fluid is being injected:
  - producing fluid comprising condensed startup mobilizing fluid and mobilized bitumen from at least one of the injection wellbore and the production wellbore.
3. The method of claim 1 or claim 2, further comprising, after providing the production tubing string in the production wellbore:
  - injecting a recovery mobilizing fluid into the reservoir via at least one of the at least one first startup tubing string, and
  - producing fluid comprising mobilized bitumen from the production wellbore.

4. The method of claim 1 or claim 2, further comprising, after fluid communication between the injection wellbore and the production wellbore has been established:  
removing at least one of the at least one first startup tubing string from the injection wellbore; and  
providing an injection tubing string in the injection wellbore.
5. The method of claim 4, further comprising, after providing the injection tubing string in the injection wellbore:  
injecting a recovery mobilizing fluid into the reservoir via the injection tubing string, and  
producing fluid comprising mobilized bitumen from the production wellbore.
6. The method of claim 3 or claim 5, wherein the recovery mobilizing fluid comprises steam.
7. The method of claim 3 or claim 5, wherein the recovery mobilizing fluid comprises a substantially azeotropic mixture of vapour solvent and steam.
8. The method of any one of claims 1 to 7, wherein solvent in the startup mobilizing fluid consists primarily of C4 to C12 hydrocarbons.
9. The method of any one of claims 1 to 8, wherein the startup mobilizing fluid is injected into the reservoir at a temperature of between 8°C to 300°C, and at a pressure of between 100 KPa to 5,000 KPa.
10. The method of claim 9, wherein the startup mobilizing fluid is injected into the reservoir at a pressure below the fracture pressure of the reservoir.
11. The method of any one of claims 1 to 8, wherein, while the startup mobilizing fluid is being injected, a downhole pressure in the injection wellbore and a downhole pressure in the production wellbore are within about 10% of each other.

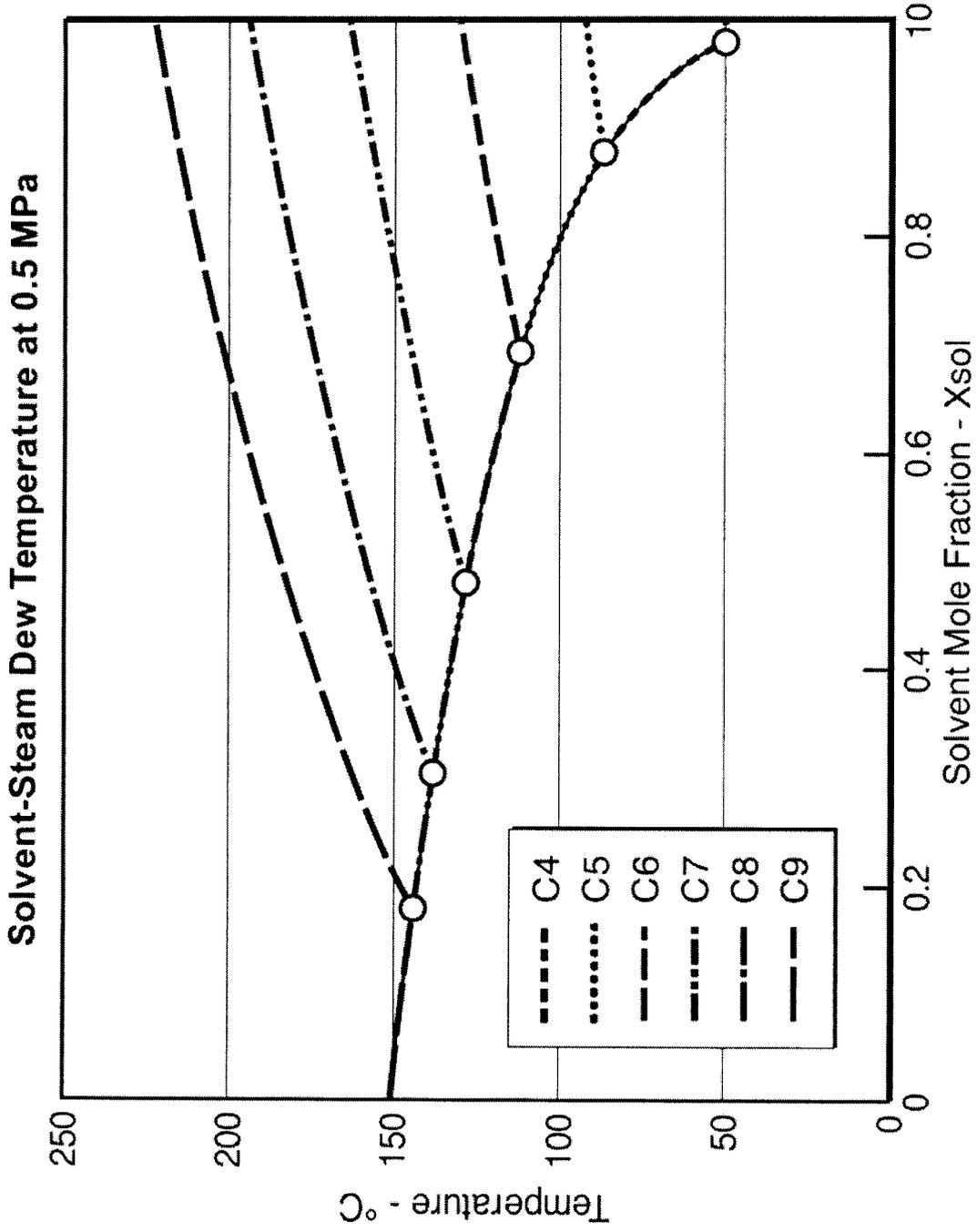
12. The method of any one of claims 1 to 8, wherein, while the startup mobilizing fluid is being injected, a downhole pressure in the injection wellbore is greater than 110% of a downhole pressure in the production wellbore.

13. The method of any one of claims 1 to 12, wherein the injection wellbore and the production wellbore are generally parallel and wherein the injection wellbore is vertically spaced from the production wellbore.

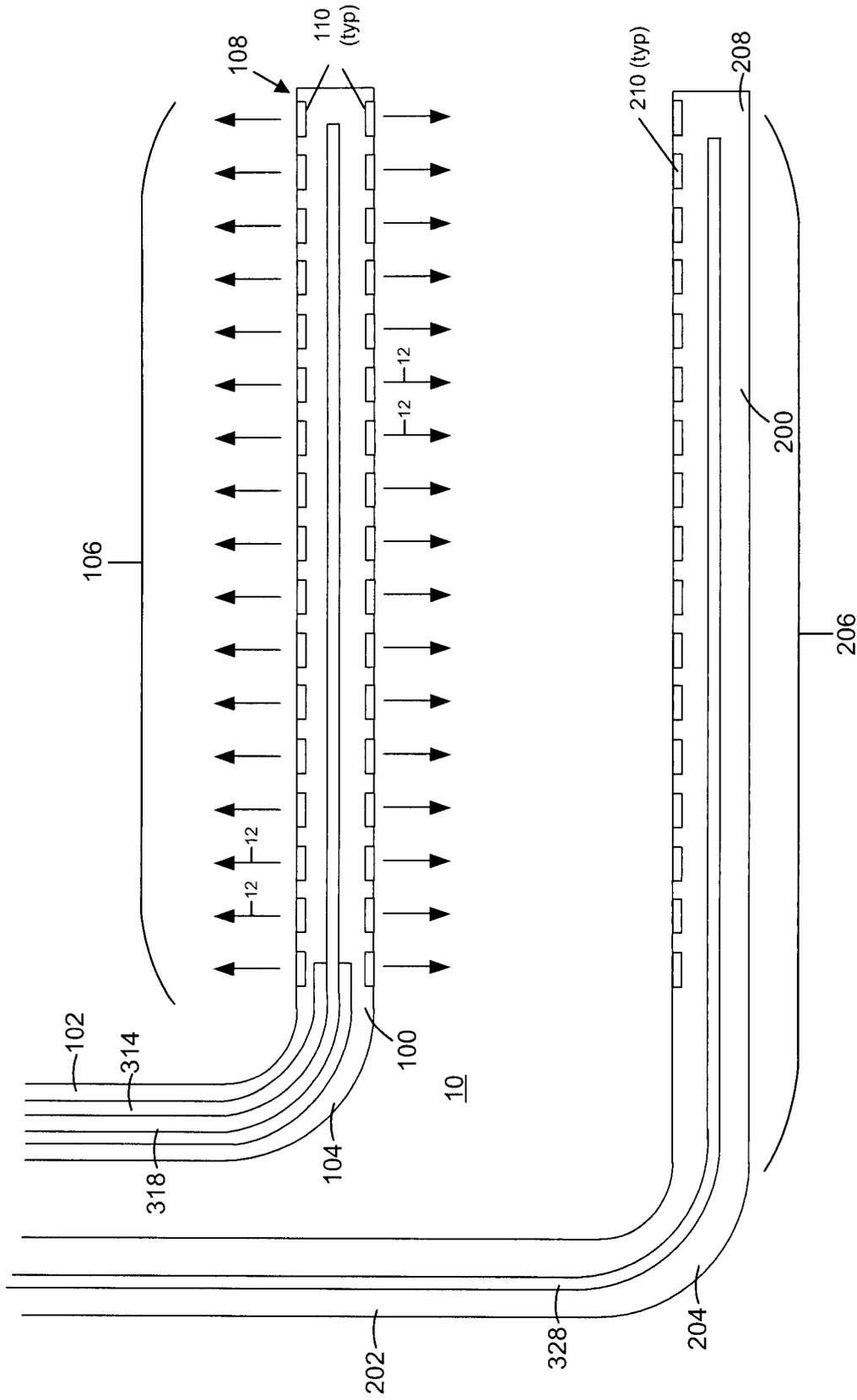
14. The method of any one of claims 1 to 13, further comprising, prior to providing the first startup tubing string and the second startup tubing string:  
drilling and completing the injection wellbore and the production wellbore.

15. The method of any one of claims 1 to 14, wherein the startup mobilizing fluid comprises a substantially azeotropic mixture of vapour solvent and steam.

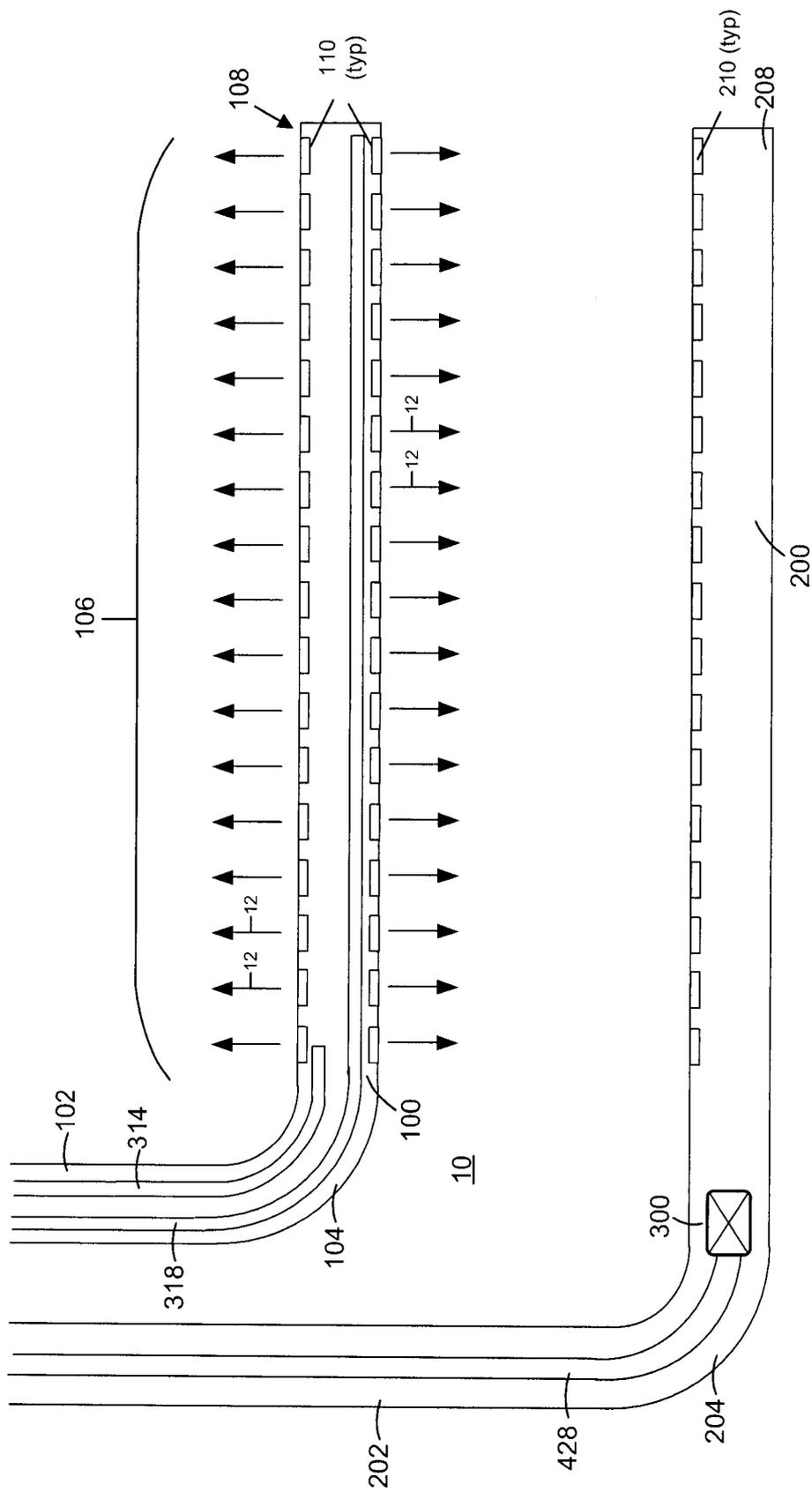




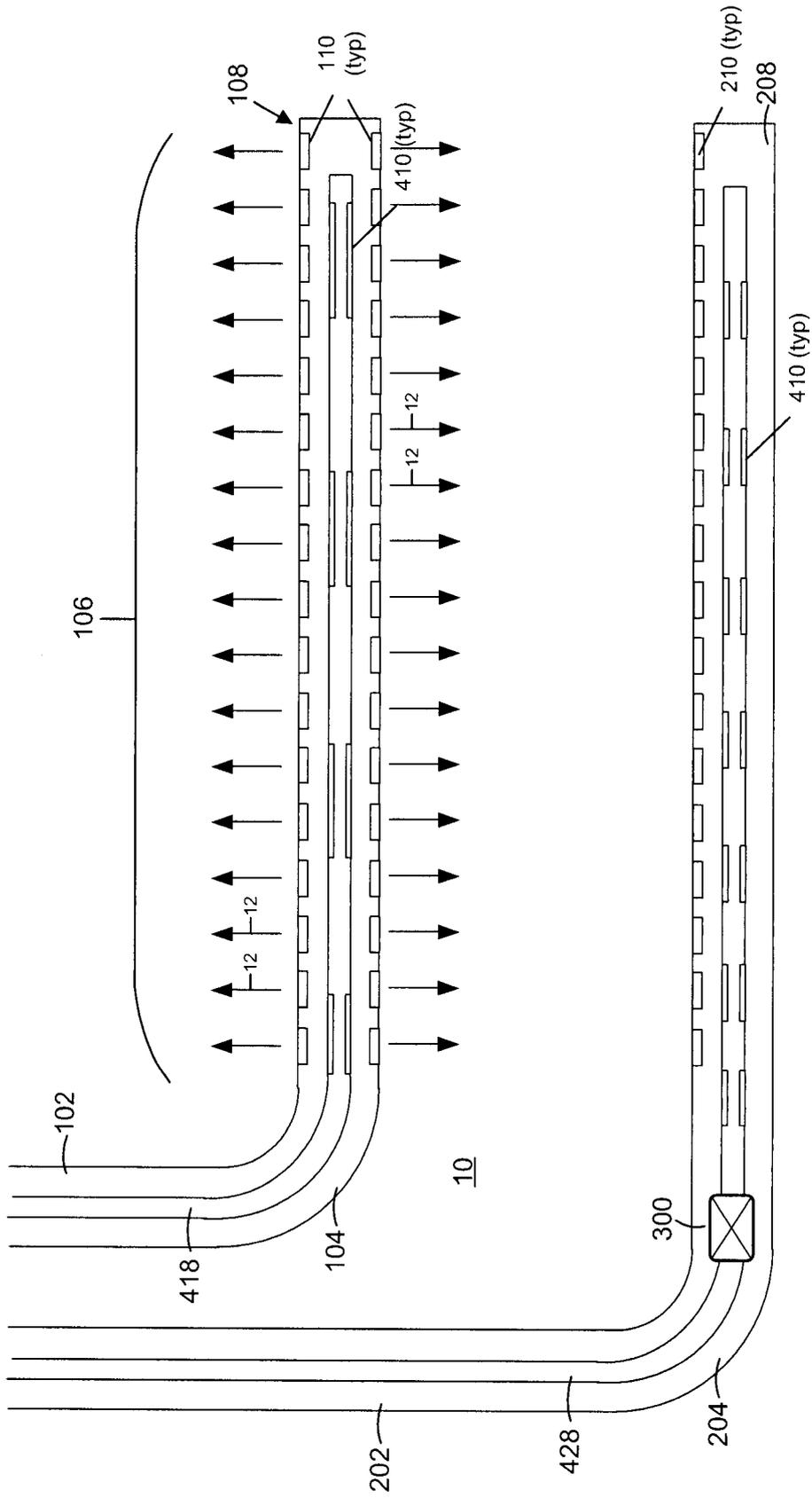
**FIG. 2**



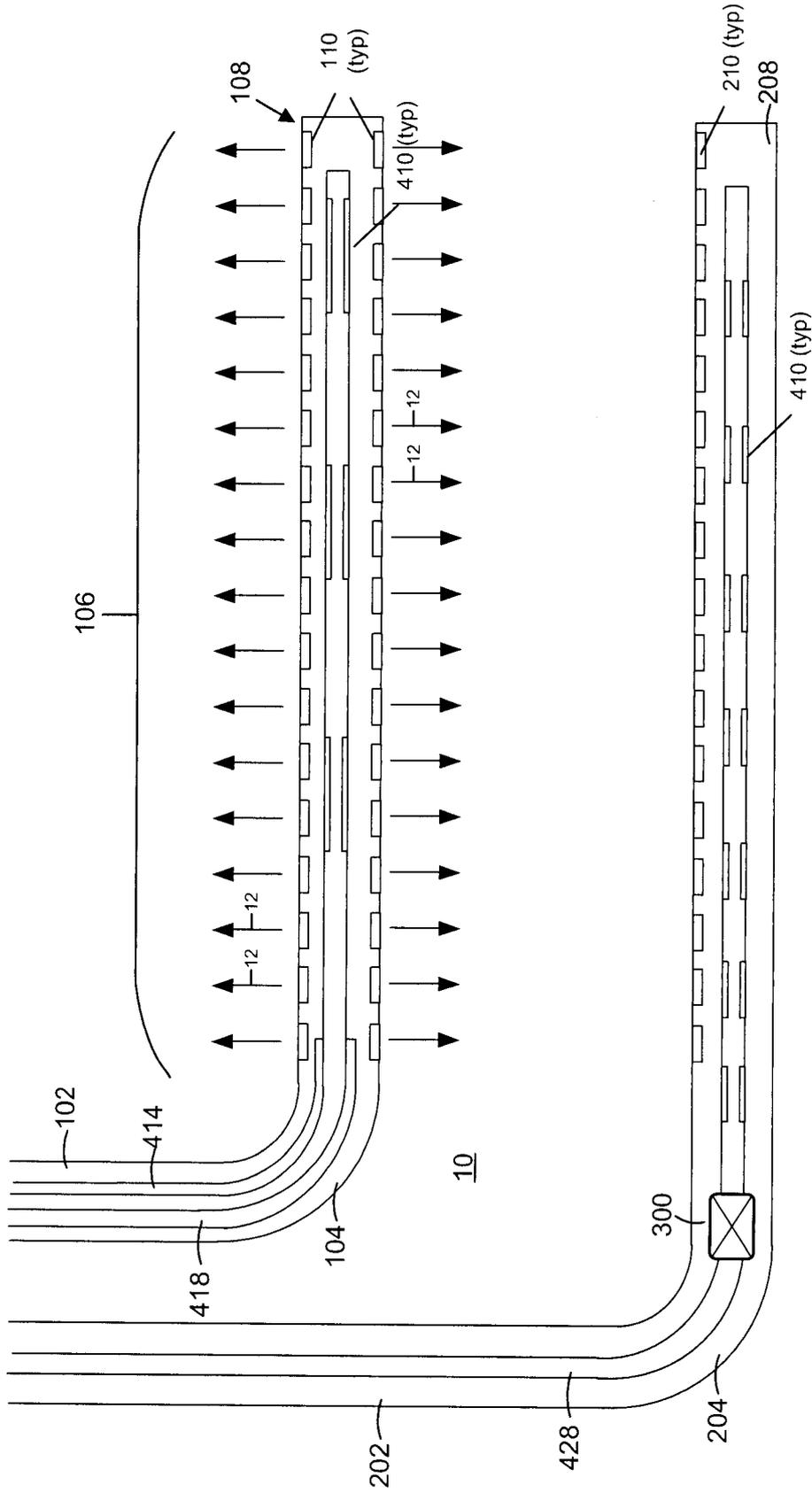
**FIG. 3**



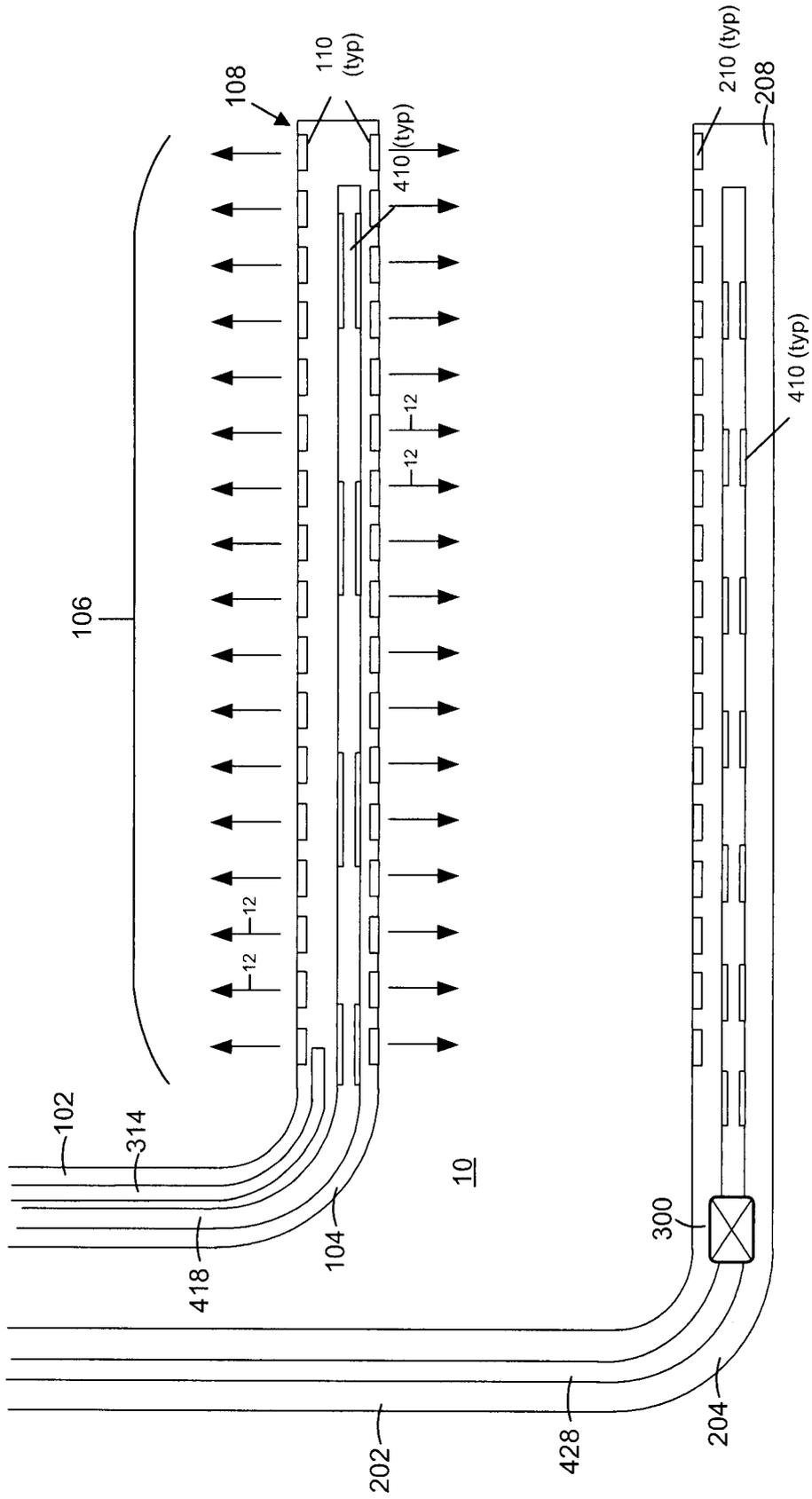
**FIG. 4**



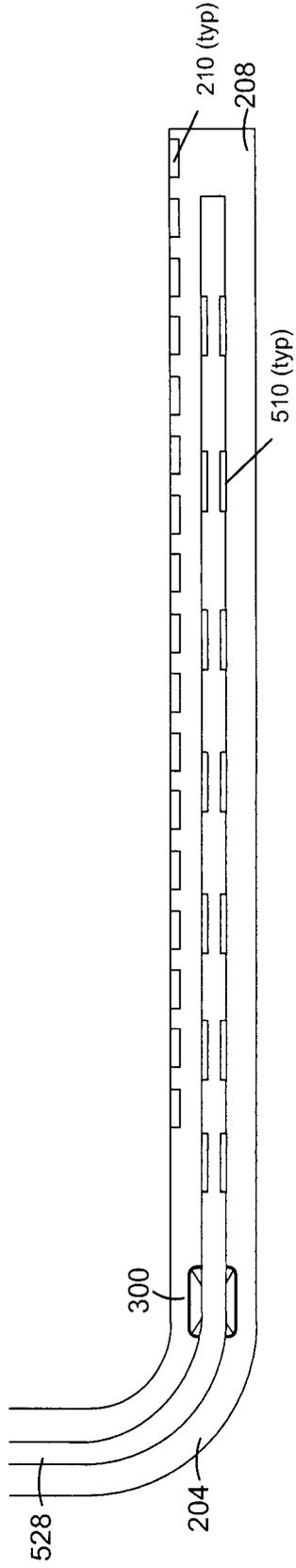
**FIG. 5**



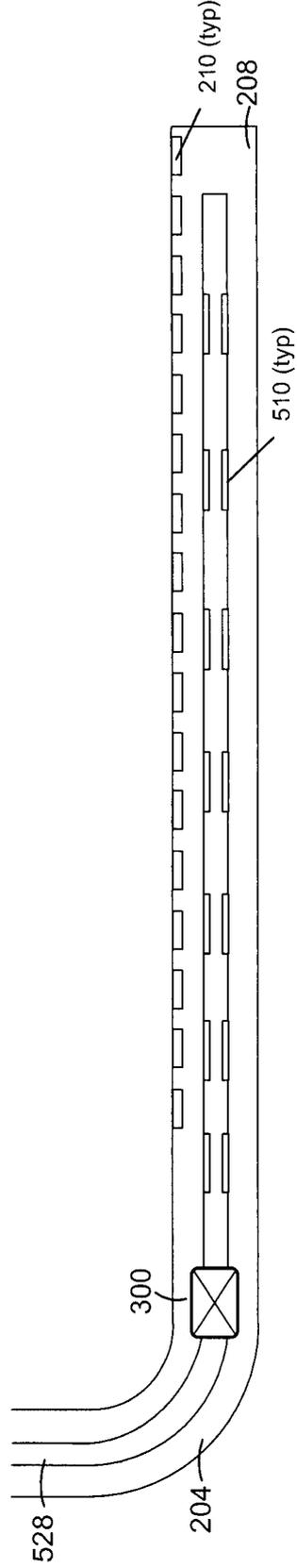
**FIG. 6**



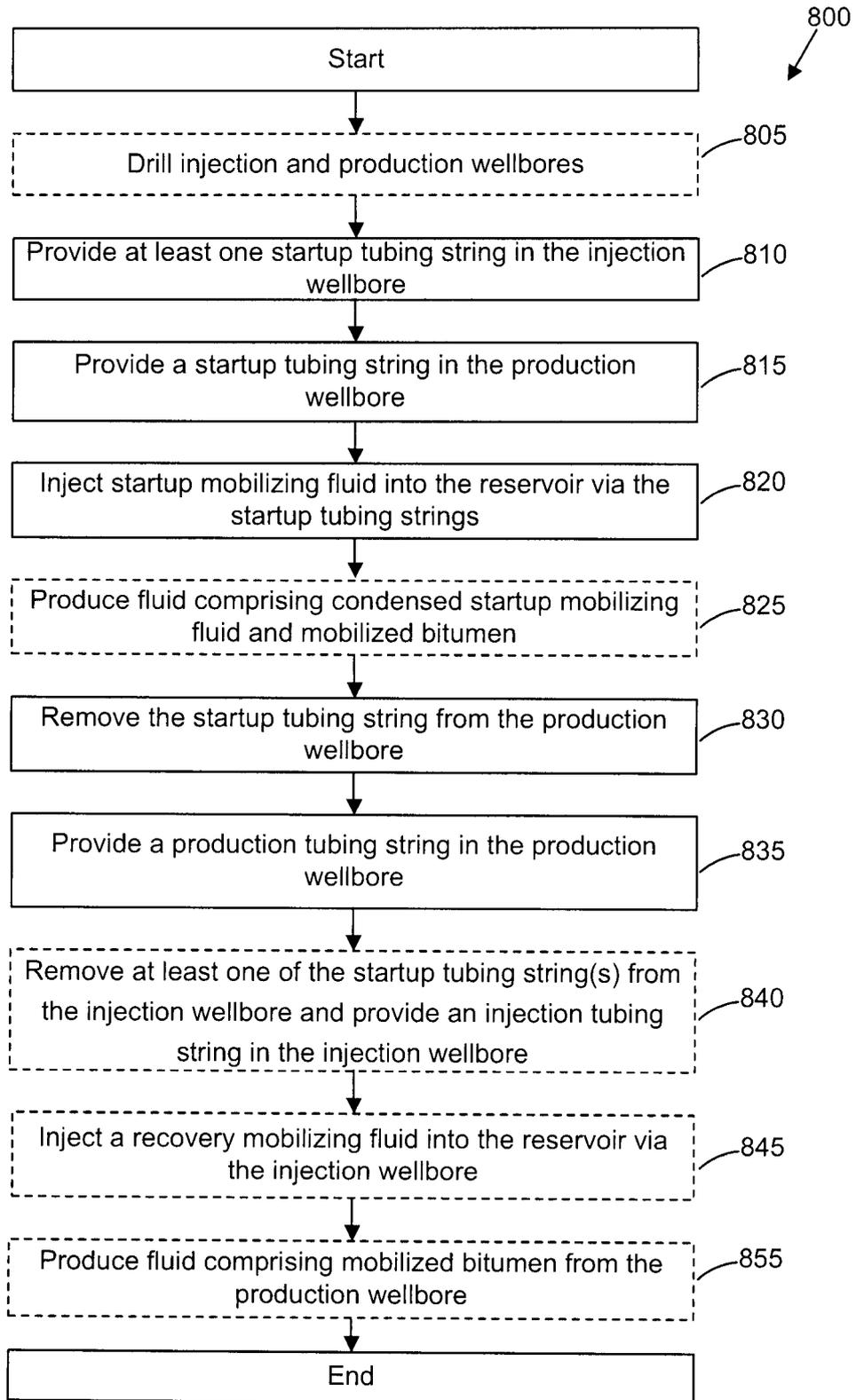
**FIG. 7**



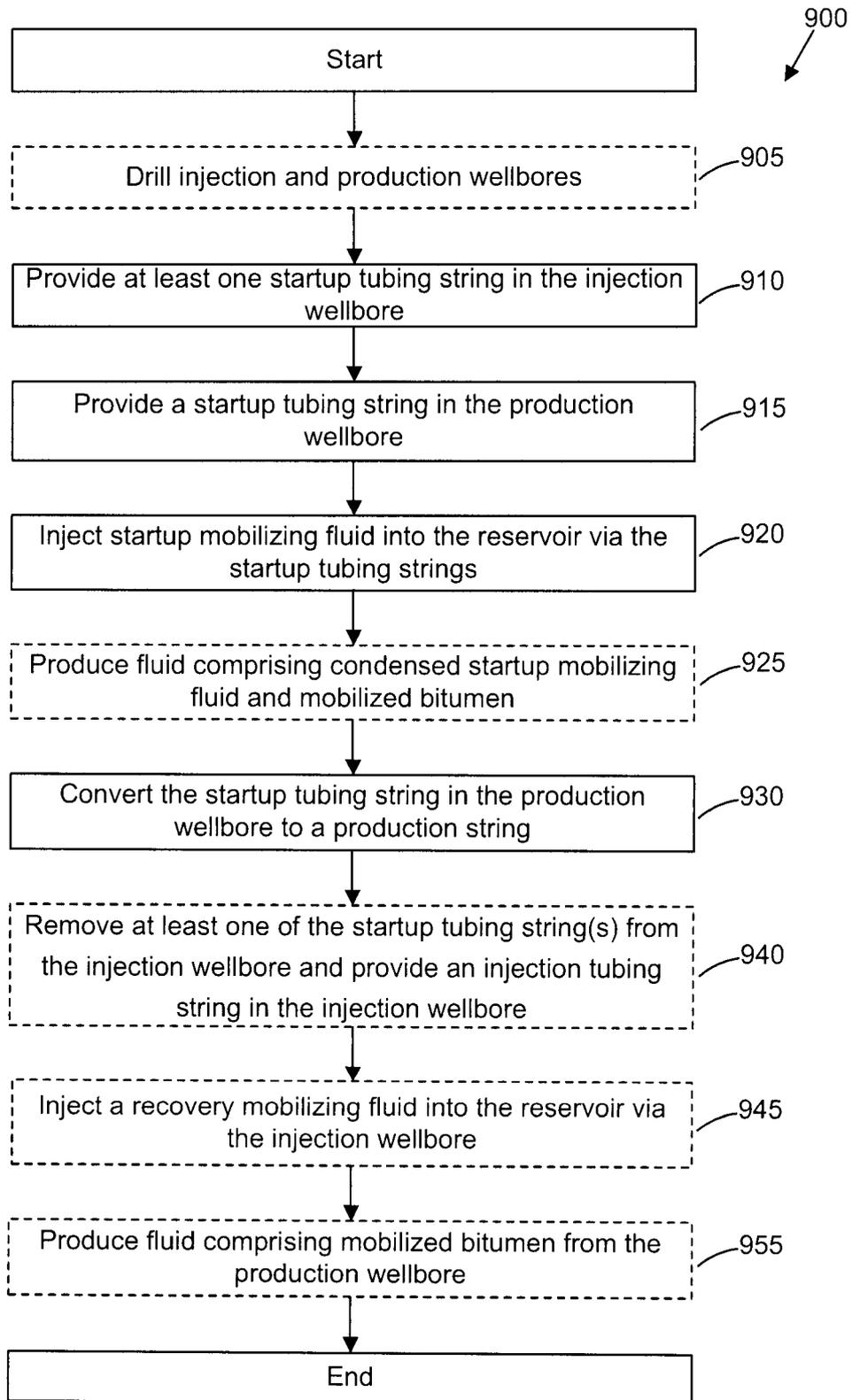
**FIG. 8**

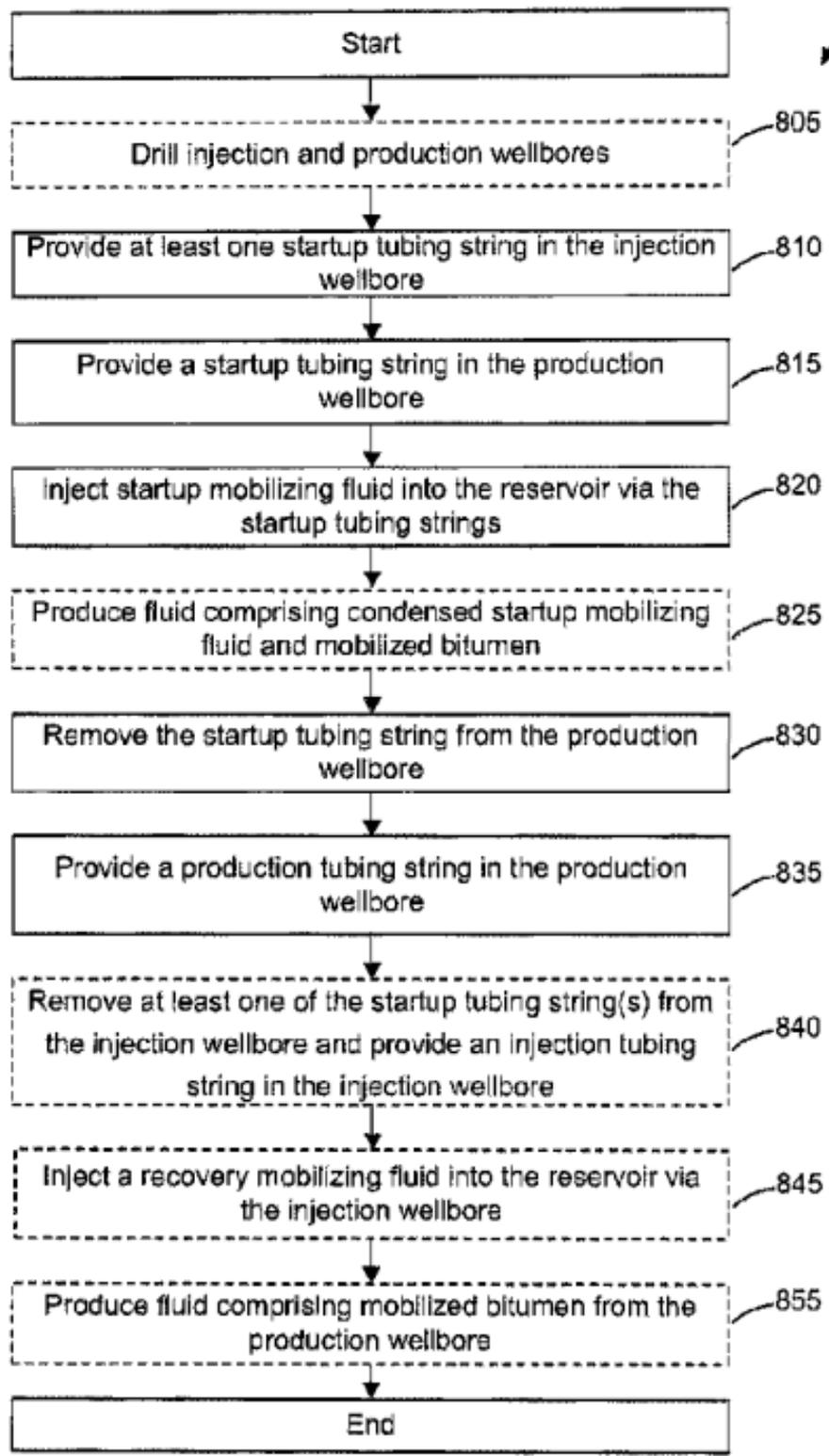


**FIG. 9**



**FIG. 10**

**FIG. 11**



Start

Drill injection and production wellbores

Provide at least one startup tubing string in the injection wellbore

Provide a startup tubing string in the production wellbore

Inject startup mobilizing fluid into the reservoir via the startup tubing strings

Produce fluid comprising condensed startup mobilizing fluid and mobilized bitumen

Remove the startup tubing string from the production wellbore

Provide a production tubing string in the production wellbore

Remove at least one of the startup tubing string(s) from the injection wellbore and provide an injection tubing string in the injection wellbore

Inject a recovery mobilizing fluid into the reservoir via the injection wellbore

Produce fluid comprising mobilized bitumen from the production wellbore

End

805

810

815

820

825

830

835

840

845

855