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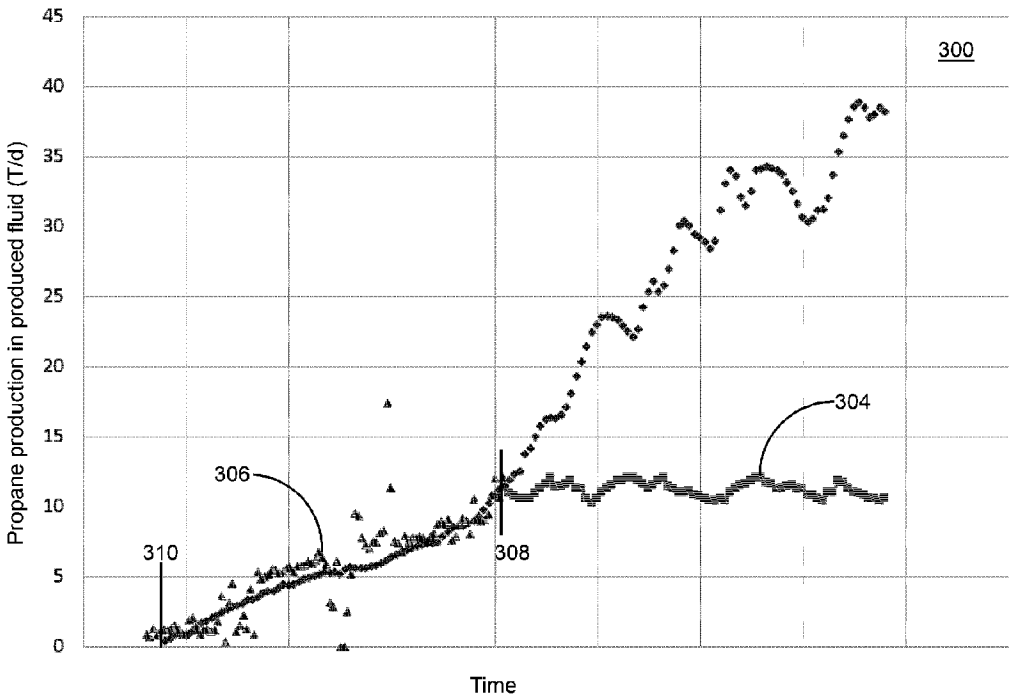
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(54) Titre : PROCEDE DE RECUPERATION AU MOYEN DE SOLVANT AVEC SURPRESSION DE VAPEUR ABREGEE
(54) Title: SOLVENT-DRIVEN RECOVERY PROCESS WITH ABBREVIATED STEAM BOOST



(57) Abrégé/Abstract:
Disclosed are methods of recovering hydrocarbons from a subterranean reservoir, comprising: (i) selecting a solvent that has a liquid phase and a vapour phase; (ii) in a solvent-driven phase (SDP), modulating production of mobilized fluids while injecting the solvent at a constant or variable SDP rate such that a SDP bottom-hole pressure-temperature condition transitions from a first regime to a second regime under which the SDP bottom-hole pressure-temperature condition lies above the vapourization curve of the solvent; and (iii) in an abbreviated steam boost (ASB) phase, modulating production of mobilized fluids while injecting steam at a constant or variable ASB injection rate that is sufficient to provide an ASB bottom-hole pressure-temperature condition, such as a condition that lies below the vapourization curve of the solvent but not sufficient to increase the ASB bottom-hole pressure to more than a select threshold under the second regime.

ABSTRACT

Disclosed are methods of recovering hydrocarbons from a subterranean reservoir, comprising: (i) selecting a solvent that has a liquid phase and a vapour phase; (ii) in a solvent-driven phase (SDP), modulating production of mobilized fluids while injecting the solvent at a constant or variable SDP rate such that a SDP bottom-hole pressure-temperature condition transitions from a first regime to a second regime under which the SDP bottom-hole pressure-temperature condition lies above the vapourization curve of the solvent; and (iii) in an abbreviated steam boost (ASB) phase, modulating production of mobilized fluids while injecting steam at a constant or variable ASB injection rate that is sufficient to provide an ASB bottom-hole pressure-temperature condition, such as a condition that lies below the vapourization curve of the solvent but not sufficient to increase the ASB bottom-hole pressure to more than a select threshold under the second regime.

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SOLVENT-DRIVEN RECOVERY PROCESS WITH ABBREVIATED STEAM BOOST

TECHNICAL FIELD

[0001] The present disclosure generally relates to solvent-driven processes for *in-situ* hydrocarbon recovery. In particular, the present disclosure relates to solvent-driven processes in which hydrocarbon-production conditions are revitalized by a shift in injection/production protocols.

BACKGROUND

[0002] Viscous hydrocarbons can be extracted from some subterranean reservoirs using *in-situ* recovery processes. Some *in-situ* recovery processes are thermal processes wherein heat energy is introduced to a reservoir to lower the viscosity of hydrocarbons *in situ* such that they can be recovered from a production well. In some thermal processes, heat energy is introduced by injecting a heated fluid into the reservoir by way of an injection well. Steam-assisted gravity drainage (SAGD) is a representative thermal-recovery process that uses steam to mobilize hydrocarbons *in situ*.

[0003] Some thermal recovery processes employ injection fluids that include solvent, optionally in combination with steam, as for example disclosed in Canadian Patent Publication 2,956,771. Solvent-aided processes (SAP) are one such category. In the context of the present disclosure, SAP injection fluids comprise less than about 50 % solvent and greater than about 50 % steam on a mass basis. Solvent-driven processes (SDP) are another such category. In the context of the present disclosure, SDP injection fluids comprise greater than about 50 % solvent and less than about 50 % steam on a mass basis. Solvent-driven processes are not widely employed on commercial scale but, when they are, they are typically employed as one phase in a broader recovery profile. For example, a well may be transitioned through: (i) a start-up phase during which hydraulic communication is established between an injection well and a production well; (ii) a SAGD phase during which a production chamber expands primarily in a vertical direction from the injection well and mobilized hydrocarbons are recovered from the production well along with condensed steam; (iii) a SDP phase during which the production chamber expands primarily in a horizontal and/or lateral direction and mobilized hydrocarbons are recovered along with condensed solvent; and (iv) a blow-down

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phase during which non-condensable gas is injected to recover residual hydrocarbons and solvent.

[0004] Successfully executing the SDP phase of a recovery operation is difficult and may introduce economic risk. Heavy-hydrocarbon reservoirs are heterogeneous, production-chamber development is highly complex, reservoir conditions resulting from preceding SAGD phases are hard to predict, and solvent prices/availability are subject to short-term volatility. Accordingly, there is a need for alternative SDP strategies and, more generally, for hydrocarbon recovery processes that allow for a greater degree of flexibility during SDP implementation.

SUMMARY

[0005] Solvent-driven processes (SDP) pose unique challenges as compared to steam assisted gravity drainage (SAGD) and solvent-aided processes (SAP). In particular, the present disclosure contemplates that, after transitioning from a SAGD phase or a SAP phase, a typical SDP phase: (i) may result in declining rates of steam-condensate drainage towards the production well; and (ii) may result in declining reservoir temperature/pressure conditions. The first phenomena increases the potential for solvent shortcutting – the flow of injected solvent from injection well to production well without substantially participating in the development of the production chamber – because declining rates of steam condensate drainage may lead to lower fluid levels in proximity to the production well. The second phenomena may lead to declining rates of hydrocarbon drainage towards the production well due to the impact that reservoir pressure/temperature conditions have on solvent liquid/vapour phase equilibria.

[0006] In view of the foregoing, the present disclosure provides methods for *in-situ* hydrocarbon recovery that include an SDP phase that is punctuated by an abbreviated steam boost (ASB) – a so-called "ASB-SDP" phase. The ASB involves temporarily foregoing solvent-driven injection in favour of steam injection to increase produced-fluid levels (through increased steam-condensate drainage) and to return the reservoir to a desirable temperature/pressure state. Importantly, as highlighted by the results of the present disclosure, the ASB does not require the high rates of steam injection associated with SAGD and/or SAP. For example, steam injection rates for ASB are generally between about 1/4th

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and about 1/3rd typically associated with SAGD. Also importantly, ASB parameters may be configured to provide the enthalpic adjustment required to re-volatilize condensed solvent for further hydrocarbon mobilization. At the same time, ASB parameters may be modulated to mitigate solvent shortcutting.

[0007] Accordingly, in select embodiments, the present disclosure relates to a method of recovering hydrocarbons from a subterranean reservoir, comprising: (i) selecting a solvent that has a liquid phase that is delineated from a vapour phase by a vapourization curve under reservoir conditions; (ii) in a solvent-driven process (SDP) phase of the method, modulating production of mobilized fluids from the reservoir while injecting the solvent into the reservoir at a constant or variable SDP rate such that a SDP bottom-hole pressure-temperature condition transitions from a first regime to a second regime under which the SDP bottom-hole pressure-temperature condition lies above the vapourization curve of the solvent; and (iii) interrupting the SDP phase with an abbreviated steam boost (ASB) phase that comprises modulating production of mobilized fluids from the reservoir while injecting steam into the reservoir at a constant or variable ASB injection rate that is sufficient to provide a desired target increased ASB bottom-hole pressure-temperature condition. In select embodiments, the ASB bottom-hole pressure-temperature condition may be selected so that it that lies below the vapourization curve of the solvent but not sufficient to increase the ASB bottom-hole pressure to more than a threshold value, for example of about 105 %, about 110 %, about 115 %, about 120 %, or about 125 % of the SDP bottom-hole pressure under the first regime.

[0008] As noted above, in the context of the present disclosure, SDP injection fluids comprise greater than about 50 % solvent and less than about 50 % steam on a mass basis. Those skilled in the art will appreciate that such processes may be implemented in a variety of ways and may be referred to by a variety of different names. In other words, SDP represents a plurality of more specific embodiments that share a common aspect – employing injection fluids comprising greater than about 50 % solvent and less than about 50 % steam on a mass basis. Accordingly, given that the methods of the present disclosure feature an SDP phase that is punctuated by an ASB phase, they may also be characterized as comprising a “principal phase” that is punctuated by an ASB phase, wherein the principle phase employs an injection fluid comprising greater than about 50 % solvent and less than

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about 50 % steam on a mass basis, and wherein the term "principle phase" is used to describe one which is interrupted by an ASB phase. In this respect, for example: (i) an SDP injection rate may be characterized as a principle-phase injection rate, (ii) an SDP bottom-hole pressure-temperature condition may be characterized as a principle-phase bottom-hole pressure-temperature condition, (iii) an SDP bottom-hole pressure may be characterized as a principle-phase bottom-hole pressure, and (iv) an SDP bottom-hole temperature may be characterized as a principle-phase bottom-hole temperature.

[0009] Select embodiments of the present disclosure relate to a method of recovering hydrocarbons from a subterranean reservoir, comprising: selecting a solvent that has a liquid phase that is delineated from a vapour phase by a vapourization curve under reservoir conditions; in a principle phase of the method, modulating production of mobilized fluids from the reservoir while injecting an injection fluid comprising the solvent into the reservoir at: (i) a constant or variable principle-phase solvent concentration of at least about 50 wt. % of the injection fluid, and (ii) a constant or variable principle-phase injection rate, such that a principle-phase bottom-hole pressure-temperature condition transitions from a first regime to a second regime under which the principle-phase bottom-hole pressure-temperature condition lies above the vapourization curve of the solvent; and interrupting the principle phase with an abbreviated steam boost (ASB) phase that comprises modulating production of mobilized fluids from the reservoir while injecting steam into the reservoir at a constant or variable ASB injection rate that is sufficient to provide a target increased ASB bottom-hole pressure-temperature condition.

[0010] In select embodiments of the present disclosure, the target ASB bottom-hole pressure-temperature condition lies below the vapourization curve of the solvent but is not sufficient to increase the ASB bottom-hole pressure to more than about 110 % of the SDP bottom-hole pressure under the first regime (i.e. 110 % of the principle-phase bottom-hole pressure under the first regime).

[0011] In select embodiments of the present disclosure, the ASB bottom-hole pressure-temperature condition comprises an ASB bottom-hole temperature of between about 75 ºC and about 250 ºC.

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[0012] In select embodiments of the present disclosure, the ASB bottom-hole temperature is between about 100 ºC and about 200 ºC.

[0013] In select embodiments of the present disclosure, the ASB bottom-hole pressure-temperature condition comprises an ASB bottom-hole pressure between about 3000 kPa and about 3250 kPa.

[0014] In select embodiments of the present disclosure, the ASB bottom-hole pressure is between about 3100 kPa and about 3250 kPa.

[0015] In select embodiments of the present disclosure, ASB phase is followed by an additional SDP phase (i.e. an additional principle phase).

[0016] In select embodiments of the present disclosure, the ASB phase is followed by a blowdown phase.

[0017] In select embodiments of the present disclosure, the ASB phase is executed for a period of between about 1 weeks and about 25 weeks.

[0018] In select embodiments of the present disclosure, the steam injected during the ASB phase is substantially free of co-injected solvent.

[0019] In select embodiments of the present disclosure, the steam injected during ASB phase is a component of an injection fluid that further comprises between about 3 % and about 50 % of a solvent on a mass basis.

[0020] In select embodiments of the present disclosure, during the ASB phase, the production of the mobilized fluids comprises a production rate of between about 5 T/d and about 500 T/d.

[0021] In select embodiments of the present disclosure, during the ASB phase, the production of the mobilized fluids provides a produced fluid stream having a water cut of between about 10 % and about 40 % by mass.

[0022] In select embodiments of the present disclosure, the water cut is between about 15 % and about 35 % by mass.

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[0023] In select embodiments of the present disclosure, the ASB injection rate is variable within a range of about 20 T/d to about 100 T/d.

[0024] In select embodiments of the present disclosure, the ASB injection rate is constant and between about 20 T/d to and about 100 T/d.

[0025] In select embodiments of the present disclosure, the SDP bottom-hole pressure-temperature condition comprises a SDP bottom-hole temperature between about 75 ºC and about 250 ºC under the first regime (i.e. the principle-phase bottom-hole pressure-temperature condition comprises a principle-phase bottom-hole temperature between about 75 ºC and about 250 ºC under the first regime).

[0026] In select embodiments of the present disclosure, the SDP bottom-hole temperature is between about 100 ºC and about 150 ºC under the first regime (i.e. the principle-phase bottom-hole temperature is between about 100 ºC and about 150 ºC under the first regime).

[0027] In select embodiments of the present disclosure, the SDP bottom-hole pressure-temperature condition comprises a SDP bottom-hole temperature between about 75 ºC and about 250 ºC under the second regime (i.e. the principle-phase bottom-hole pressure-temperature condition comprises a principle-phase bottom-hole temperature between about 75 ºC and about 250 ºC under the second regime).

[0028] In select embodiments of the present disclosure, the SDP bottom-hole temperature is between about 100 ºC and about 150 ºC under the second regime (i.e. the principle-phase bottom-hole temperature is between about 100 ºC and about 150 ºC under the second regime).

[0029] In select embodiments of the present disclosure, the SDP bottom-hole pressure-temperature condition comprises a SDP bottom-hole pressure between about 2500 kPa and about 3500 kPa under the first regime (i.e. the principle-phase bottom-hole pressure-temperature condition comprises a principle-phase bottom-hole pressure between about 2500 kPa and about 3500 kPa under the first regime.).

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[0030] In select embodiments of the present disclosure, the SDP bottom-hole pressure is between about 3000 kPa and about 3300 kPa under the first regime (i.e. the principle phase bottom-hole pressure is between about 3000 kPa and about 3300 kPa under the first regime).

[0031] In select embodiments of the present disclosure, the SDP bottom-hole pressure-temperature condition comprises a SDP bottom-hole pressure between about 2500 kPa and about 3500 kPa under the second regime (i.e. the principle-phase bottom-hole pressure-temperature condition comprises a principle-phase bottom-hole pressure between about 2500 kPa and about 3500 kPa under the second regime).

[0032] In select embodiments of the present disclosure, the SDP bottom-hole pressure is between about 3000 kPa and about 3300 kPa under the second regime (i.e. the principle-phase bottom-hole pressure is between about 3000 kPa and about 3300 kPa under the second regime).

[0033] In select embodiments of the present disclosure, the ASB bottom-hole pressure-temperature condition is sufficient to increase the ASB bottom-hole pressure to between 80 % and about 110 % of the SDP bottom-hole pressure under the first regime (i.e. the ASB bottom-hole pressure-temperature condition is sufficient to increase the ASB bottom-hole pressure to between 80 % and about 110 % of the principle-phase bottom-hole pressure under the first regime).

[0034] In select embodiments of the present disclosure, the ASB bottom-hole pressure-temperature condition is sufficient to increase the ASB bottom-hole pressure to between about 90 % and about 110 % of the SDP bottom-hole pressure under the first regime (i.e the ASB bottom-hole pressure-temperature condition is sufficient to increase the ASB bottom-hole pressure to between about 90 % and about 110 % of the principle-phase bottom-hole pressure under the first regime).

[0035] In select embodiments of the present disclosure, the SDP phase of the method is preceded by a SAGD phase, a SAP phase, or a combination thereof (i.e. the principal phase of the method is preceded by a SAGD phase, a SAP phase, or a combination thereof).

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[0036] In select embodiments of the present disclosure, solvent comprises primarily propane, butane, diluent, natural gas condensate, or a combination thereof.

[0037] In select embodiments of the present disclosure, the solvent comprises propane.

BRIEF DESCRIPTION OF THE DRAWINGS

[0038] These and other features of the present disclosure will become more apparent in the following detailed description in which reference is made to the appended drawings. The appended drawings illustrate one or more embodiments of the present disclosure by way of example only and are not to be construed as limiting the scope of the present disclosure.

[0039] **FIG. 1** provides a phase diagram for steam and a set of archetypal solvents under reservoir conditions. For each solvent, the phase diagram delineates temperature/pressure conditions under which the solvent is substantially in the vapour phase from those under which the solvent is substantially in the liquid phase.

[0040] **FIG. 2** provides a flow diagram of a broader hydrocarbon recovery process that includes a solvent driven process (SDP) phase that is punctuated by an abbreviated steam boost (ASB) phase.

[0041] **FIG. 3** provides a schematic plot of propane production in produced fluid as a function time. The schematic differentiates an SDP process from an ASB-SDP process.

DETAILED DESCRIPTION

[0042] Extensive modeling and trials indicate that, during a prolonged period of hydrocarbon recovery within a solvent driven process (SDP) phase of a broader recovery scheme, discontinuing solvent injection in favour of low-rate steam injection (*i.e.* executing an abbreviated steam boost (ASB) phase as defined herein) has the potential to provide a number of potential benefits and/or to mitigate a number of potential problems. At a high-level, the ASB strategies set out herein allow for hydrocarbon recovery under SDP conditions that would otherwise be associated with: (i) insufficient rates of steam-condensate drainage

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to maintain the liquid level at the production well without compromising production rates, and (ii) insufficient reservoir temperature/pressure conditions to maintain solvent substantially in the vapour phase.

[0043] With respect to (i), the emulsion-production rates associated with some implementations of SDP phases are only a fraction of those associated with conventional SAGD phases. For example, transitioning from a conventional SAGD phase to a conventional SDP phase may reduce the rate of emulsion production from about 20 m^3/hr to about 4 m^3/hr. This may result, at least in part, from a substantial reduction in the amount of steam condensate in the emulsion. For example, transitioning from a conventional SAGD phase to a conventional SDP phase may reduce the water cut of a produced emulsion stream from about 80 % to about 30 % on a mass basis. As the conventional SDP process continues, the operative level of liquid around the producer is reduced. This progression creates a condition where solvent short cutting is likely – it becomes difficult to control the rate of solvent production in the gaseous phase without compromising the rate of hydrocarbon production. ASB-SDP is an alternative approach that provides flexibility in attending to the rate of solvent production in the gaseous phase and the rate of hydrocarbon production. For example, in ASB-SDP, the injection of steam at a low rate, such as about 80 T/d, may add an additional about 3.3 m^3/hr to the conventional SDP emulsion-production rate of about 4 m^3/hr. In this way, ASB-SDP may allow for increasing emulsion accumulation around the production well, which may allow for better gaseous solvent production control.

[0044] With respect to (ii), during a conventional SDP phase the temperature/pressure in the production chamber may decrease from a condition that is sufficient to maintain the solvent substantially in the vapour phase as it migrates to the chamber front, to one that is not. For example, during a conventional SDP phase the temperature of the production chamber may decrease from about 225 ºC to about 113 ºC over about 450 days. Under typical reservoir conditions, solvents such as propane and/or butane exist substantially in the liquid phase at about 113 ºC, and they are likely to pool in proximity to the production well where their ability to further develop the production chamber is limited. The ASB phase requires relatively little steam, and yet it provides a means to revitalize the reservoir temperature/pressure profile in relatively short order. For example, The ASB phase may increase reservoir temperature back to about 225 ºC from about 113 ºC

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in as little as about 60 days at a steam injection rate of about 80 T/d. Solvents such as propane and/or butane exist substantially in the vapour phase under high-reservoir temperature conditions such as about 225 ºC, hence ASB provides a means to increases reservoir temperature/pressure conditions which may advance solvent gas perpetuation, bitumen mobilization, and/or chamber development.

[0045] Because ASB provides a means to mitigate: (i) insufficient rates of steam-condensate drainage to maintain the liquid level at the production well without compromising production rates; and (ii) insufficient reservoir temperature/pressure conditions to maintain solvent substantially in the vapour phase, it introduces a degree of flexibility into SDP-based hydrocarbon recovery methods that may be advantageous in a variety of contexts. As a first example, in select embodiments of the present disclosure, ASB-SDP may be well suited for hydrocarbon recovery during periods of solvent price volatility. As a second example, in select embodiments of the present disclosure, ASB-SDP may be well suited for hydrocarbon recovery when solvent supply to the recovery operation is tenuous. As a third example, in select embodiments of the present disclosure, ASB-SDP may be well suited for hydrocarbon recovery during periods where there is additional steam capacity due to lower utilization from the neighboring wells. As a fourth example, in select embodiments of the present disclosure, ASB-SDP may be useful for evaluating the steam and/or solvent requirement to re-pressurize a production chamber. As a fifth example, in select embodiments of the present disclosure, ASB-SDP may increase solvent efficacy within the recovery scheme. As a sixth example, in select embodiments of the present disclosure, ASB-SDP may be useful as a regulation technique for *in situ* upgrading. Moreover, in select embodiments of the present disclosure, ASB-SDP may be advantageous in more than one such contexts.

[0046] Select embodiments of the present disclosure will now be described with reference to **FIG. 1** to **FIG. 3** without limiting the scope of the present disclosure.

[0047] In select embodiments, the present disclosure relates to a method of recovering hydrocarbons from a subterranean reservoir, comprising: (i) selecting a solvent that has a liquid phase that is delineated from a vapour phase by a vapourization curve under reservoir conditions; (ii) in a solvent-driven process (SDP) phase of the method, modulating production of mobilized fluids from the reservoir while injecting the solvent into the reservoir at a constant or variable SDP rate such that a SDP bottom-hole pressure-temperature

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condition transitions from a first regime to a second regime under which the SDP bottom-hole pressure-temperature condition lies above the vapourization curve of the solvent; and (iii) interrupting the SDP phase with an abbreviated steam boost (ASB) phase that comprises modulating production of mobilized fluids from the reservoir while injecting steam into the reservoir at a constant or variable ASB injection rate that is sufficient to provide a target ASB bottom-hole pressure-temperature condition. For example, the target ASB bottom-hole pressure-temperature condition may be selected so that it lies below the vapourization curve of the solvent but is not sufficient to increase the ASB bottom-hole pressure to more than a target SDP bottom-hole pressure, for example a target of about 110% of the SDP bottom-hole pressure under the first regime.

[0048] As noted above, in the context of the present disclosure, SDP injection fluids comprise greater than about 50 % solvent and less than about 50 % steam on a mass basis. Those skilled in the art will appreciate that such processes may be implemented in a variety of ways and may be referred to by a variety of different names. In other words, SDP represents a plurality of more specific embodiments that share a common aspect – employing injection fluids comprising greater than about 50 % solvent and less than about 50 % steam on a mass basis. Accordingly, given that the methods of the present disclosure feature an SDP phase that is punctuated by an ASB phase, they may also be characterized as comprising a "principal phase" that is punctuated by an ASB phase, wherein the principle phase employs an injection fluid comprising greater than about 50 % solvent and less than about 50 % steam on a mass basis, and wherein the term "principle phase" is used to describe one which is interrupted by an ASB phase. In this respect, for example: (i) an SDP injection rate may be characterized as a principle-phase injection rate, (ii) an SDP bottom-hole pressure-temperature condition may be characterized as a principle-phase bottom-hole pressure-temperature condition, (iii) an SDP bottom-hole pressure may be characterized as a principle-phase bottom-hole pressure, and (iv) an SDP bottom-hole temperature may be characterized as a principle-phase bottom-hole temperature.

[0049] Select embodiments of the present disclosure relate to a method of recovering hydrocarbons from a subterranean reservoir, comprising: selecting a solvent that has a liquid phase that is delineated from a vapour phase by a vapourization curve under reservoir

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conditions; in a principle phase of the method, modulating production of mobilized fluids from the reservoir while injecting an injection fluid comprising the solvent into the reservoir at: (i) a constant or variable principle-phase solvent concentration of at least about 50 wt. % of the injection fluid, and (ii) a constant or variable principle-phase injection rate, such that a principle-phase bottom-hole pressure-temperature condition transitions from a first regime to a second regime under which the principle-phase bottom-hole pressure-temperature condition lies above the vapourization curve of the solvent; and interrupting the principle phase with an abbreviated steam boost (ASB) phase that comprises modulating production of mobilized fluids from the reservoir while injecting steam into the reservoir at a constant or variable ASB injection rate that is sufficient to provide a target increased ASB bottom-hole pressure-temperature condition.

[0050] In the context of the present disclosure, the word "hydrocarbon" is generally used interchangeably with "petroleum" and/or "oil" to refer to mixtures of widely varying composition, as will be evident from the context in which the word is used. It is common practice to categorize hydrocarbon substances of high viscosity and density into two categories, "heavy oil" and "bitumen". For example, some sources define "heavy oil" as a hydrocarbon-containing mixture that has a mass density of greater than about 900 kg/m^3. Bitumen is sometimes described as that portion of a hydrocarbon-containing mixture that exists in the semi-solid or solid phase in natural deposits, with a mass density greater than about 1000 kg/m^3 and a viscosity greater than about 10,000 centipoise (cP; or 10 Pa·s) measured at original temperature in the deposit and atmospheric pressure, on a gas-free basis. Although these terms are in common use, references to heavy oil and bitumen represent categories of convenience, and there is a continuum of properties between heavy oil and bitumen. Accordingly, references to heavy oil and/or bitumen herein include the continuum of such substances, and do not imply the existence of some fixed and universally recognized boundary between the two substances. In particular, the term "heavy oil" includes within its scope all "bitumen" including hydrocarbons that are present in semi-solid or solid form.

[0051] In the context of the present disclosure, a "reservoir" or "hydrocarbon-bearing formation" is a subsurface formation containing one or more natural accumulations of moveable hydrocarbons, which are generally confined by relatively impermeable rock. An "oil

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sand" reservoir is generally comprised of strata of sand or sandstone containing viscous hydrocarbons, such as bitumen. Viscous petroleum, such as bitumen, may also be found in reservoirs whose solid structure consists of carbonate material rather than sand material. Such reservoirs are sometimes referred to as "bituminous carbonates".

[0052] In the context of the present disclosure, SAP injection fluids comprise less than about 50 % solvent and greater than about 50 % steam on a mass basis. In the context of the present disclosure, SDP injection fluids comprise greater than about 50% solvent and less than about 50 % steam on a mass basis. For example, an SDP injection fluid may comprise about 80 % solvent and about 20 % steam on a mass basis. Those skilled in the art will appreciate that SAGD, SAP, and SDP processes can each be implemented in a variety of ways, such that each of these categories comprise a plurality of more specific embodiments. For example, the terms "solvent assisted process" and "SAP" incorporate more specific embodiments that employ injection fluids comprising less than about 50 % solvent and greater than about 50 % steam on a mass basis, such as so called "Expanding solvent SAGD" or "ES-SAGD".

[0053] In the context of the present disclosure, "selecting a solvent that has a liquid phase that is delineated from a vapour phase by a vapourization curve under reservoir conditions" may be facilitated by considering a phase diagram. **FIG. 1** provides a phase diagram 100 for a set of archetypal solvents, under example reservoir conditions.

[0054] The phase diagram 100 plots comprises a vertical pressure axis and a horizontal temperature axis. The phase diagram 100 comprises a propane vapourization curve 102 that delineates: (i) a region of reservoir temperature-pressure conditions 104 under which propane is substantially in the liquid phase, from (ii) a region of reservoir temperature/pressure conditions 106 under which propane is substantially in the vapour phase. Analogous vapourization curves for butane, pentane, hexane, heptane, and octane are indicated by reference numbers 110, 112, 114, 116, and 188, respectively. The phase diagram 100 also comprises a vapourization curve 108 for water. Considering a solvent vapourization curve in combination the water vapourization curve 108 provides useful context for reservoir behavior during a transition from a SAGD phase to a SDP phase. For example, steam injection at about 3000 kPa may provide a temperature of about 240 ºC in proximity to the injection well (curve 108 at a pressure of 3000 kPa). Maintaining this pressure and

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transitioning to a SDP phase equates to a shift along dashed line 120 towards the vapourization curve for propane 102. Continued SDP may provide a pressure-temperature condition into region 104, under which propane exists primarily in the liquid phase. ASB-SDP may be utilized to transition the reservoir to region 106 where propane exists primarily in the vapour phase as indicated in **FIG. 1** by dashed arrow 122, for example.

[0055] Many solvents are characterized by a liquid phase that is delineated from a vapour phase by a vapourization curve under reservoir conditions. As will be appreciated by those skilled in the art who have benefitted from the teachings of the present disclosure, the solvent may be vapourizable at the operational pressure and temperature near the injection well and in a central region of the production chamber, so that the solvent can enter the reservoir in the vapour phase and can remain in the vapour phase until the solvent vapour reaches the production chamber front. The solvent may also be substantially condensable at the edges, margins, or boundaries of the production chamber, where the local temperature is significantly lower than the temperature in the central region of the vapour chamber. The condensed solvent may be capable of dissolving hydrocarbons such that the condensed solvent (*i.e.* liquid solvent) may reduce the viscosity of the hydrocarbons, or increase the mobility of the hydrocarbons, which may assist hydrocarbon drainage and may improve the rate of hydrocarbon production. There may be a number of underlying mechanisms for increasing mobility of hydrocarbons in the reservoir formation as will be understood by those skilled in the art. A suitable solvent may be selected to assist drainage of hydrocarbons based on any of these mechanisms or a combination of such mechanisms. For example, a solvent may be selected based on its ability to reduce the viscosity of hydrocarbons, to dissolve in the reservoir fluid, or to reduce surface and interfacial tension between hydrocarbons and sands or other solid or liquid materials present in the reservoir. The solvent may also be selected to act as a wetting agent or surfactant. When oil attachment to sand or other immobile solid materials in the reservoir is reduced, the oil mobility can be increased. The solvent may function as an emulsifier for forming hydrocarbon-water emulsions, which may help to improve oil mobility with water in the reservoir. In select embodiments of the present disclosure, the solvent may comprise propane, butane, pentane, diluent, natural gas condensate, or a combination thereof. In select embodiments of the present disclosure, the solvent is propane. In select embodiments of the present disclosure, the solvent is butane. Compositions comprising primarily methane, ethane, O_2, CO_2, N_2, CO, H_2S, H_2, NH_3, flue

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gas, or a combination thereof are typically not condensable under the majority of reservoir conditions contemplated in the present disclosure and, as such, these non-condensable gases may fall outside of the present definition of "solvent".

[0056] In the context of the present disclosure, modulating production of mobilized fluids from the reservoir while injecting the solvent into the reservoir at a constant or variable SDP rate such that a SDP bottom-hole pressure-temperature condition lies above the vapourization curve of the solvent" may involve manipulating: (i) production pump rates; (ii) injection rates; (iii) injection fluid composition; or (iv) a combination thereof. In the context of the present disclosure, such manipulations may result in a temperature/pressure transition from a first regime (such as one associated with a conventional SAGD or SAP phase) to a second regime (such as one associated with a conventional SDP phase). In select embodiments of the present disclosure, under the first regime, the SDP bottom-hole pressure-temperature condition comprises a SDP bottom-hole temperature between about 75 ºC and about 300 ºC (such as between about 110 ºC and about 250 ºC). In select embodiments of the present disclosure, under the first regime, the SDP bottom-hole pressure-temperature condition comprises a SDP bottom-hole pressure between about 2500 kPa and about 3500 kPa (such as between about 3000 kPa and about 3300 kPa or between about 3150 kPa and about 3250 kPa). In select embodiments of the present disclosure, under the second regime, the SDP bottom-hole pressure-temperature condition comprises a SDP bottom-hole temperature between about 100 ºC and about 300 ºC (such as between about 110 ºC and about 250 ºC). In select embodiments of the present disclosure, under the second regime, the SDP bottom-hole pressure-temperature condition comprises a SDP bottom-hole pressure between about 2500 kPa and about 3500 kPa (such as between about 3000 kPa and about 3300 kPa or between about 3150 kPa and about 3250 kPa).

[0057] During the SDP phase, the injected solvent may play the dominant role in further expansion, particularly lateral or horizontal expansion of the production chamber. In select embodiments of the present disclosure, the SDP phase is preceded by a SAGD phase, a SAP phase, or a combination thereof. While the production chamber may be dominated by steam from an earlier SAGD or SAP process, after a period of operation under SDP conditions, the solvent may become the dominant vapour in the production chamber having regard to the solvent-dominated composition of the injection fluid during the SDP phase. This

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transition may be associated with a reduction in reservoir pressure leading to bottom-hole pressure-temperature conditions that are not sufficiently energetic to re-volatilize condensed solvent from the pool in proximity to the production well. In selected embodiments of the present disclosure, during the SDP phase, the solvent may be co-injected with a small amount of steam. In such a case, the amount of the injected steam may be sufficient to heat and vapourize the injected solvent, and maintain the solvent in the vapour phase in the production chamber to allow the solvent to travel to the chamber front (*i.e. the* edges or margins of the production chamber). However, the weight ratio of co-injected steam to co-injected solvent is relatively small, such as less than about 20 wt.% or less than about 30 wt. %, so that steam plays only a minor role in further expansion the production chamber and does not provide a sufficient enthalpic boost to re-volatilize a substantial amount of condensed solvent in proximity to the production well.

[0058] In the context of the present disclosure, interrupting the SDP phase with an abbreviated steam boost (ASB) that comprises modulating production of mobilized fluids from the reservoir while injecting steam into the reservoir at a constant or variable ASB injection rate that is sufficient to provide an ASB bottom-hole pressure-temperature condition that lies below the vapourization curve of the solvent may involve manipulating: (i) production pump rates; (ii) injection rates; (iii) injection fluid composition; or (iv) a combination thereof. In select embodiments of the present disclosure, the ASB bottom-hole pressure-temperature condition comprises an ASB bottom-hole temperature of between about 75 ºC and about 300 ºC (such as between about 110 ºC and about 250 ºC). In select embodiments of the present disclosure, the ASB bottom-hole pressure-temperature condition comprises an ASB bottom-hole pressure between about 2500 kPa and about 3500 kPa (such as between about 3000 kPa and about 3300 kPa or between about 3150 kPa and about 3250 kPa). In select embodiments of the present disclosure, the ASB phase is executed for a period of between about 1 day, about 2 days, about 3 days, about 4 days, about 5 days, about 6 days, or about 7 days and about 2 weeks, about 3 weeks, about 4 weeks, about 5 weeks, or about 6 weeks.

[0059] Reservoir simulations indicate that, under SDP conditions, *in situ* hydrocarbon mobilization may be sensitive to relatively modest changes in solvent vapour pressure. For example, a reservoir at 3200 kPa producing an emulsion with a water cut of about 30 % may provide an emulsion rate of about 3.5 m^3/hr at about 100 ºC and an emulsion rate of about

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4.2 m^3/hr at about 115 ºC. An ASB phase as set out in the present disclosure may be employed to direct this change in order to improve solvent efficiencies (such as cSOR and iSOR).

[0060] In select embodiments of the present disclosure, the steam injected during the ASB phase may be a component of an injection fluid that further comprises between about 50 % and about 90 % of a solvent on a mass basis. In select embodiments of the present disclosure, during the ASB phase, the production of the mobilized fluids comprises a production rate of between about 5 T/d and about 250 T/d. In select embodiments of the present disclosure, during the ASB phase, the production of the mobilized fluids provides a produced fluid stream having a water cut of between about 5 % and about 80 % by mass. In select embodiments of the present disclosure, the water cut is between about 10 % and about 80 % by mass.

[0061] In select embodiments of the present disclosure, the ASB injection rate is variable within a range of about 5 T/d to about 500 T/d. In select embodiments of the present disclosure, the ASB injection rate is constant and between about 5 T/d and about 500 T/d.

[0062] In select embodiments of the present disclosure, the steam injected during the ASB phase is substantially free of co-injected solvent.

[0063] As noted above, in select embodiments of the present disclosure, ASB-SDP may provide one or more advantages in the context of *in-situ* hydrocarbon recovery. As a first example, ASB-SDP may be well suited for hydrocarbon recovery during periods of solvent price volatility. Solvent prices, such as propane prices and/or butane prices, tend to fluctuate in a volatile way based on a supply/demand curve and/or seasonality. For example, between January 2018 and January 2019, the price of butane varied from about 40 US$/bbl to about 4 US$/bbl. During the same time period, the price of propane varied between about 30 US$/bbl and about 10 US$/bbl. In select embodiments of the present disclosure, ASB-SDP may be used as a means to navigate economic conditions that make conventional solvent-driven processes untenable. For example, ASB-SDP could be executed based on a threshold violation of an economic parameter such as a price ratio between Western Canada Select (WCS) and solvent. In select embodiments of the present disclosure, the threshold may be a WCS-to-solvent ratio of between about 2.5:1 and about 4.0:1.0.

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[0064] As a second example, ASB-SDP may be well suited for hydrocarbon recovery when solvent supply to the recovery operation is tenuous. For example, steam injection at a rate of between about 5 T/d and about 50 T/d for a period of about 1 week to about25 weeks may be adapted so as to maintain dormant conditions for between about 1 month and about 6 months such that production via a conventional SDP phase may continue thereafter.

[0065] As a third example, ASB-SDP may be well suited for hydrocarbon recovery during periods where there is additional steam capacity due to lower utilization from the neighboring wells. For example, if a neighboring well failed or transitioned to an SDP well, the spare steam could be used for the ASB-SDP phase.

[0066] As a fourth example, ASB-SDP may be useful for testing solvent and/or steam requirements to pressurize the production chamber. For example, an ASB phase based on about 80 T/d of steam injection rate could replace about 40 T/d of propane injection and about 26 T/d of steam injection during SDP. When implementing the ASB, the process may comprise reducing the solvent injection rate from about 40 T/d to about 0 T/d and monitoring the bottom-hole pressure while injecting a sufficient volume of steam to maintain the bottom-hole pressure at about 3200 kPa. The volume of steam required may be constant, or it may vary over time. For example, the volume of steam required may be about 80 T/d, or it may be increased from about 40 T/d to about 80 T/d over a period of weeks, which may result in a more efficient recovery and better environmental performance.

[0067] As a fifth example, ASB-SDP may be useful for *in-situ* upgrading of hydrocarbons resources during production. For example, pilot scale trials suggest that asphaltene particles may break apart during ASB-SDP. Production-chamber core samples indicate a significant deviation in asphaltene precipitation along the vertical section of the core. In one instance, an asphaltene content of about 26 % was observed at the higher and middle sections of the production chamber and lower content of about 18 % was observed at IHS zones and next to injection well. Without being bound to any particular theory, this may indicate that bitumen upgrading occurs due to the extraction of the heavier particles from the oleic phase as the solubility of the solvent increases and decreasing temperature within the production chamber. The ASB-SDP may act as a regulation technique to achieve improved upgrading performance while also improving production chamber development. This may be particularly effective after a prolonged SDP phase.

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[0068] In select embodiments of the present disclosure, the ASB phase may be followed by an additional SDP phase. In select embodiments of the present disclosure, the ASB phase may be followed by a blowdown phase. More generally, select embodiments of the ASB-SDP of the present disclosure may be implemented as described with reference to **FIG. 2**, which provides an archetypal flow chart describing an *in situ* hydrocarbon recovery process that features ASP-SDP.

[0069] In **FIG. 2**, At 200, a reservoir is subjected to an initial phase of a SAGD process, referred to as the "start-up" phase or stage, in which fluid communication between an injection well and a production well is established. To permit drainage of mobilized hydrocarbons and condensate to the production well, fluid communication between the injection well and the production well must be established. Fluid communication in this context refers to fluid flow between the injection well and the production well. Establishment of such fluid communication typically involves mobilizing viscous hydrocarbons in the reservoir to form a mobilized reservoir fluid and removing the mobilized reservoir fluid to create a porous pathway between the wells. Viscous hydrocarbons may be mobilized by heating such as by injecting or circulating pressurized steam or hot water through the injection well or the production well. In some cases, steam may be injected into, or circulated in, both the injection well and the production well for faster start-up. A pressure differential may be applied between the injection well and the production well to promote steam/hot water penetration into the porous geological formation that lies between the wells of the well pair. The pressure differential promotes fluid flow and convective heat transfer to facilitate communication between the wells.

[0070] Additionally or alternatively, other techniques may be employed during the start-up phase 200. For example, to facilitate fluid communication, a solvent may be injected into the reservoir region around and between the injection well and the production well. The region may be soaked with a solvent before or after steam injection. An example of start-up using solvent injection is disclosed in CA 2,698,898. In further examples, the start-up phase 200 may include one or more start-up processes or techniques disclosed in CA 2,886,934, CA 2,757,125, or CA 2,831,928.

[0071] Once fluid communication between the injection well and the production well has been achieved, hydrocarbon production or recovery may commence during phase 205.

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As the hydrocarbon production rate is typically low initially and will increase as the production chamber develops, this early production phase is known as the "ramp-up" phase or stage. During the ramp-up phase 205, steam is typically injected continuously into the injection well, at constant or varying injection pressure and temperature. At the same time, mobilized heavy hydrocarbons and aqueous condensate are continuously removed from the production well, typically in the form of an emulsion having oleic and aqueous phases. During the ramp-up phase 205, the zone of communication between the injection well and the production well may continue to expand axially along the full length of the horizontal portions thereof.

[0072] As injected steam heats up the reservoir, hydrocarbons in the heated region are softened, resulting in reduced viscosity. Further, as heat is transferred from steam to the reservoir, steam condenses. The aqueous condensate and mobilized hydrocarbons will drain downward due to gravity, in a gravity-dominated process. As a result of depletion of the heavy hydrocarbons, a porous region is formed in the reservoir, which is referred to as a production chamber. When the void space in a production chamber is filled with mainly steam, it is commonly referred to as a "steam chamber." The aqueous condensate and hydrocarbons drained towards the production well and collected in the production well are then produced (transferred to the surface, typically as an oil in water emulsion), such as by gas lifting or through pumping as is known to those skilled in the art.

[0073] As alluded to above, the production chamber is formed and gradually expands due to depletion of hydrocarbons and other *in-situ* materials from regions within the reservoir, generally above the injection well. Injected steam tends to rise up to reach the top of the production chamber before it condenses, and steam can also spread laterally as it travels upward. Therefore, during early stages of chamber development, the production chamber generally expands upwardly and laterally from the injection well. During the ramp-up phase 205, the production chamber can grow vertically towards an overburden. Depending on the size of the reservoir (and the pay therein) and the distance between the injection well and the overburden, it can take a long time, such as many months and up to two years, for the production chamber to reach the overburden especially when the pay zone is relative thick as is typically found in some operating oil sands reservoirs. However, in a thinner pay zone the production chamber can reach the overburden sooner. The time to reach the vertical expansion limit can also be longer in cases where the pay zone is higher or highly

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heterogeneous, or the reservoir has complex overburden geologies such as with inclined heterolithic stratification, top water, top gas, or other stratigraphic complexities.

[0074] In the next phase, the reservoir may be subject to a conventional SAGD production process 210, where the oil production rate is sufficiently high for economic recovery of hydrocarbons and the cumulative steam oil ratio continues to decrease or remain relatively stable. During the conventional SAGD production process 210 (or a similar but modified steam-driven recovery process), one or more chemical additives may be added to steam or co-injected with steam to enhance hydrocarbon recovery. For example, a surfactant, which lowers the surface tension of a liquid, the interfacial tension (IFT) between two liquids, or the IFT between a liquid and a solid, may be added. The surfactant may act, for example, as a detergent, a wetting agent, an emulsifier, a foaming agent, or a dispersant to facilitate the drainage of the softened hydrocarbons to the production well. An organic solvent, such as an alkane or alkene, may also be added to dilute the mobilized hydrocarbons so as to increase the mobility and flow of the diluted hydrocarbon fluid to the production well for improved recovery. Other materials in liquid or gas form may also be added to enhance recovery performance.

[0075] The start-up phase 200, the ramp-up phase 205, and the SAGD production process phase 210 described above are non-limiting examples, and there are numerous conventional and innovative techniques known to those skilled in the art that result in the formation of a production chamber. In alternative embodiments, rather than using a well pair, one or more single horizontal or vertical wells may be used for providing a production chamber. For example, CA 2,844,345 discloses a process that provides a production chamber using a single vertical or inclined well. The process may be preceded by start-up acceleration techniques to establish communication in the formation between an injection means and a production means within the single well.

[0076] When the vapour chamber grows vertically, oil production rates normally continue to increase, and the cumulative steam to oil ratio normally continues to decrease. Steam utilization during such chamber growth is relatively efficient. However, when the top front of the vapour chamber approaches or reaches an overburden, vertical growth of the vapour chamber will slow down and eventually stop. While the vapour chamber may continue to grow or expand laterally, which may be at a slower pace, steam utilization during slow

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lateral growth may be less efficient. As a result, oil production rate may reach a peak value or plateau, and then start to decline. The cumulative steam-to-oil ratio may bottom out and start to increase. Thus, such changes in chamber growth, oil production rate and cumulative steam-to-oil ratio may be used to define threshold violations to trigger a transition to a solvent-driven process (SDP) phase 215. To initiate conditions suitable for SDP, a suitable solvent and transition condition are selected (according to various factors and considerations as set out herein). As can be appreciated by those skilled in the art having benefited from the teachings of the present disclosure, the selection may be performed at any time prior to solvent injection, and may be performed in any order depending on the particular situation and application.

[0077] The SPD phase 215 involves injection of the selected solvent into the reservoir through the injection well. The solvent is generally injected into the reservoir in a vapour phase. Injection of the solvent in the vapour phase allows solvent vapour to rise in the production chamber and condense at a region away from the injection well. Allowing solvent to rise in the production chamber before condensing may achieve beneficial effects. For example, when solvent vapour is delivered to the production chamber and then allowed to condense and disperse near the edges of the vapour chamber, oil production performance, such as indicated by one or more of oil production rate, cumulative steam-to-oil ratio, and overall efficiency, may be improved. Injection of solvent in the gaseous phase, rather than a liquid phase, may allow vapour to rise in the production chamber before condensing so that condensation occurs away from the injection well. As will be appreciated by those skilled in the art who have benefitted from the teachings of the present disclosure, injecting solvent vapour into the vapour chamber does not necessarily require solvent be fed into the injection well in vapour form. For example, the solvent may be heated downhole and vapourized in the injection well.

[0078] In **FIG. 2**, the SDP phase 215 is interrupted by an abbreviated steam boost (ASB) phase 220. The ASB phase may be triggered by a variety of factors as set out herein. For example, the ASB phase may be triggered by a local pressure drop to a pressure-temperature condition under which the solvent is substantially in the liquid phase. During the ASB phase 220, solvent injection may be stopped or greatly decreased in favour of low injection rate steam injection. The steam injection rate could be at a significantly reduced rate

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as compared to a SAGD like rate (such as that used at 210). For example, steam injection at 220 may be about 75 % less than that at 210. At the same time, steam injection at 220 may be about 300 % that used under SDP conditions (such as that used at 215). For example, 220 may comprise steam injection rates of about 80 T/d, and 215 may employ a steam injection rate of about 26 T/d in combination with propane injection rate of about 40 T/D. In select embodiments of the present disclosure, the bottom-hole pressure may be kept steady during 220. Under such conditions, the temperature in the production chamber is expected to increase back to between about 200 ºC and about 215 ºC due to the higher steam enthalpy of about 2.6 MJ/kg despite the low injected steam rate in comparison to an SDP-like enthalpy of about 0.5 MJ/kg. The temperature increase in the production chamber may results in a benefit where condensed solvent is re-vapourized such that it may advance chamber development. At the same time, during the ASB phase 220, steam injection may reheat the solvent already *in situ* and utilize the condensed steam as a tool to control gaseous solvent production.

[0079] In **FIG. 2**, the ASB phase 220 is followed by a further phase 225, which may be an additional SDP phase, a blow down phase, a SAP phase, a SAGD phase, or a combination thereof.

[0080] **FIG. 3** provides a schematic plot 300 of propane production in produced fluid as a function time. Reference number 304 indicates a schematic plot of the SDP process under such conditions, and reference number 306 provides pilot-scale field data for such a process. In the schematic plot 300, reference number 308 indicates the timing of a potential shift to an ASB-SDP process. Reference number 310 indicates a schematic plot of propane production in produced fluid under such conditions. Comparing schematic plots 304 and 310 highlights how the ASB-SDP process drives re-vapourization of the propane solvent from the produced fluid.

[0081] In the present disclosure, all terms referred to in singular form are meant to encompass plural forms of the same. Likewise, all terms referred to in plural form are meant to encompass singular forms of the same. Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure pertains.

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[0082] As used herein, the term “about” refers to an approximately +/-10 % variation from a given value. It is to be understood that such a variation is always included in any given value provided herein, whether or not it is specifically referred to.

[0083] It should be understood that the compositions and methods are described in terms of "comprising," "containing," or "including" various components or steps, the compositions and methods can also "consist essentially of or "consist of the various components and steps. Moreover, the indefinite articles "a" or "an," as used in the claims, are defined herein to mean one or more than one of the element that it introduces.

[0084] For the sake of brevity, only certain ranges are explicitly disclosed herein. However, ranges from any lower limit may be combined with any upper limit to recite a range not explicitly recited, as well as, ranges from any lower limit may be combined with any other lower limit to recite a range not explicitly recited, in the same way, ranges from any upper limit may be combined with any other upper limit to recite a range not explicitly recited. Additionally, whenever a numerical range with a lower limit and an upper limit is disclosed, any number and any included range falling within the range are specifically disclosed. In particular, every range of values (of the form, "from about a to about b," or, equivalently, "from approximately a to b," or, equivalently, "from approximately a-b") disclosed herein is to be understood to set forth every number and range encompassed within the broader range of values even if not explicitly recited. Thus, every point or individual value may serve as its own lower or upper limit combined with any other point or individual value or any other lower or upper limit, to recite a range not explicitly recited.

[0085] Therefore, the present invention is well adapted to attain the ends and advantages mentioned as well as those that are inherent therein. The particular embodiments disclosed above are illustrative only, as the present invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Although individual embodiments are dis-cussed, the invention covers all combinations of all those embodiments. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. Also, the terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee. It is therefore evident that the particular illustrative embodiments disclosed above may be altered or modified and all such variations are

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considered within the scope and spirit of the present invention. If there is any conflict in the usages of a word or term in this specification and one or more patent(s) or other documents that may be incorporated herein by reference, the definitions that are consistent with this specification should be adopted.

[0086] Many obvious variations of the embodiments set out herein will suggest themselves to those skilled in the art in light of the present disclosure. Such obvious variations are within the full intended scope of the appended claims.

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Claims:

1. A method of recovering hydrocarbons from a subterranean reservoir, comprising:

selecting a solvent that has a liquid phase that is delineated from a vapour phase by a vapourization curve under reservoir conditions;

in a solvent-driven process (SDP) phase of the method, modulating production of mobilized fluids from the reservoir while injecting the solvent into the reservoir at a constant or variable SDP rate such that a SDP bottom-hole pressure-temperature condition transitions from a first regime to a second regime under which the SDP bottom-hole pressure-temperature condition lies above the vapourization curve of the solvent; and

interrupting the SDP phase with an abbreviated steam boost (ASB) phase that comprises modulating production of mobilized fluids from the reservoir while injecting steam into the reservoir at a constant or variable ASB injection rate that is sufficient to provide a target increased ASB bottom-hole pressure-temperature condition.

2. The method of claim 1, wherein the target ASB bottom-hole pressure-temperature condition lies below the vapourization curve of the solvent but is not sufficient to increase the ASB bottom-hole pressure to more than about 110 % of the SDP bottom-hole pressure under the first regime.

3. The method of claim 1 or 2, wherein the ASB bottom-hole pressure-temperature condition comprises an ASB bottom-hole temperature of between about 75 ºC and about 250 ºC.

4. The method of claim 3, wherein the ASB bottom-hole temperature is between about 100 ºC and about 200 ºC.

5. The method of any one of claims 1 to 4, wherein the ASB bottom-hole pressure-temperature condition comprises an ASB bottom-hole pressure between about 3000 kPa and about 3250 kPa.

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6. The method of claim 5, wherein the ASB bottom-hole pressure is between about 3100 kPa and about 3250 kPa.

7. The method of any one of claims 1 to 6, wherein the ASB phase is followed by an additional SDP phase.

8. The method of any one of claims 1 to 7, wherein the ASB phase is followed by a blowdown phase.

9. The method of any one of claims 1 to 8, wherein the ASB phase is executed for a period of between about 1 week and about 25 weeks.

10. The method of any one of claims 1 to 9, wherein the steam injected during the ASB phase is substantially free of co-injected solvent.

11. The method of any one of claims 1 to 9, wherein the steam injected during ASB phase is a component of an injection fluid that further comprises between about 3 % and about 50 % of a solvent on a mass basis.

12. The method of any one of claims 1 to 11 wherein, during the ASB phase, the production of the mobilized fluids comprises a production rate of between about 5 T/d and about 500 T/d.

13. The method of any one of claims 1 to 12, wherein, during the ASB phase, the production of the mobilized fluids provides a produced fluid stream having a water cut of between about 10 % and about 40 % by mass.

14. The method of claim 13, wherein the water cut is between about 15 % and about 35 % by mass.

15. The method of any one of claims 1 to 14, wherein the ASB injection rate is variable within a range of about 20 T/d to about 100 T/d.

16. The method of any one of claims 1 to 14, wherein the ASB injection rate is constant and between about 20 T/d and about 100 T/d.

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17. The method of any one of claims 1 to 16, wherein the SDP bottom-hole pressure-temperature condition comprises a SDP bottom-hole temperature between about 75 ºC and about 250 ºC under the first regime.

18. The method of claim 17, wherein the SDP bottom-hole temperature is between about 100 ºC and about 150 ºC under the first regime.

19. The method of any one of claims 1 to 18, wherein the SDP bottom-hole pressure-temperature condition comprises a SDP bottom-hole temperature between about 75 ºC and about 250 ºC under the second regime.

20. The method of claim 19, wherein the SDP bottom-hole temperature is between about 100 ºC and about 150 ºC under the second regime.

21. The method of any one of claims 1 to 20, wherein the SDP bottom-hole pressure-temperature condition comprises a SDP bottom-hole pressure between about 2500 kPa and about 3500 kPa under the first regime.

22. The method of claim 21, wherein the SDP bottom-hole pressure is between about 3000 kPa and about 3300 kPa under the first regime.

23. The method of any one of claims 1 to 22, wherein the SDP bottom-hole pressure-temperature condition comprises a SDP bottom-hole pressure between about 2500 kPa and about 3500 kPa under the second regime.

24. The method of claim 23, wherein the SDP bottom-hole pressure is between about 3000 kPa and about 3300 kPa under the second regime.

25. The method of any one of claims 1 to 24, wherein the ASB bottom-hole pressure-temperature condition is sufficient to increase the ASB bottom-hole pressure to between about 80 % and about 110 % of the SDP bottom-hole pressure under the first regime.

26. The method of any one of claims 1 to 24, wherein the ASB bottom-hole pressure-temperature condition is sufficient to increase the ASB bottom-hole pressure to between about 90 % and about 110 % of the SDP bottom-hole pressure under the first regime.

27. The method of any one of claims 1 to 24, wherein the SDP phase of the method is preceded by a SAGD phase, a SAP phase, or a combination thereof.

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28. The method of any one of claims 1 to 27, wherein the solvent comprises primarily propane, butane, diluent, natural gas condensate, or a combination thereof.

29. The method of any one of claims 1 to 27, wherein the solvent comprises propane.

30. A method of recovering hydrocarbons from a subterranean reservoir, comprising:

selecting a solvent that has a liquid phase that is delineated from a vapour phase by a vapourization curve under reservoir conditions;

in a principle phase of the method, modulating production of mobilized fluids from the reservoir while injecting an injection fluid comprising the solvent into the reservoir at: (i) a constant or variable principle-phase solvent concentration of at least about 50 wt. % of the injection fluid, and (ii) a constant or variable principle-phase injection rate, such that a principle-phase bottom-hole pressure-temperature condition transitions from a first regime to a second regime under which the principle-phase bottom-hole pressure-temperature condition lies above the vapourization curve of the solvent; and

interrupting the principle phase with an abbreviated steam boost (ASB) phase that comprises modulating production of mobilized fluids from the reservoir while injecting steam into the reservoir at a constant or variable ASB injection rate that is sufficient to provide a target increased ASB bottom-hole pressure-temperature condition.

31. The method of claim 30, wherein the target ASB bottom-hole pressure-temperature condition lies below the vapourization curve of the solvent but is not sufficient to increase the ASB bottom-hole pressure to more than about 110 % of the principle-phase bottom-hole pressure under the first regime.

32. The method of claim 30 or 31, wherein the ASB bottom-hole pressure-temperature condition comprises an ASB bottom-hole temperature of between about 75 ºC and about 250 ºC.

33. The method of claim 32, wherein the ASB bottom-hole temperature is between about 100 ºC and about 200 ºC.

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34. The method of any one of claims 30 to 33, wherein the ASB bottom-hole pressure-temperature condition comprises an ASB bottom-hole pressure between about 3000 kPa and about 3250 kPa.

35. The method of claim 34, wherein the ASB bottom-hole pressure is between about 3100 kPa and about 3250 kPa.

36. The method of any one of claims 30 to 35, wherein the ASB phase is followed by an additional principle phase.

37. The method of any one of claims 30 to 36, wherein the ASB phase is followed by a blowdown phase.

38. The method of any one of claims 30 to 37, wherein the ASB phase is executed for a period of between about 1 week and about 25 weeks.

39. The method of any one of claims 30 to 38, wherein the steam injected during the ASB phase is substantially free of co-injected solvent.

40. The method of any one of claims 30 to 38, wherein the steam injected during ASB phase is a component of an ASB phase injection fluid that further comprises between about 3 % and about 50 % of a solvent on a mass basis.

41. The method of any one of claims 30 to 40 wherein, during the ASB phase, the production of the mobilized fluids comprises a production rate of between about 5 T/d and about 500 T/d.

42. The method of any one of claims 30 to 41, wherein, during the ASB phase, the production of the mobilized fluids provides a produced fluid stream having a water cut of between about 10 % and about 40 % by mass.

43. The method of claim 42, wherein the water cut is between about 15 % and about 35 % by mass.

44. The method of any one of claims 30 to 43, wherein the ASB injection rate is variable within a range of about 20 T/d to about 100 T/d.

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45. The method of any one of claims 30 to 43, wherein the ASB injection rate is constant and between about 20 T/d and about 100 T/d.

46. The method of any one of claims 30 to 45, wherein the principle-phase bottom-hole pressure-temperature condition comprises a principle-phase bottom-hole temperature between about 75 ºC and about 250 ºC under the first regime.

47. The method of claim 46, wherein the principle-phase bottom-hole temperature is between about 100 ºC and about 150 ºC under the first regime.

48. The method of any one of claims 30 to 47, wherein the principle-phase bottom-hole pressure-temperature condition comprises a principle-phase bottom-hole temperature between about 75 ºC and about 250 ºC under the second regime.

49. The method of claim 48, wherein the principle-phase bottom-hole temperature is between about 100 ºC and about 150 ºC under the second regime.

50. The method of any one of claims 30 to 49, wherein the principle-phase bottom-hole pressure-temperature condition comprises a principle-phase bottom-hole pressure between about 2500 kPa and about 3500 kPa under the first regime.

51. The method of claim 50, wherein the principle-phase bottom-hole pressure is between about 3000 kPa and about 3300 kPa under the first regime.

52. The method of any one of claims 30 to 51, wherein the principle-phase bottom-hole pressure-temperature condition comprises a principle-phase bottom-hole pressure between about 2500 kPa and about 3500 kPa under the second regime.

53. The method of claim 52, wherein the principle-phase bottom-hole pressure is between about 3000 kPa and about 3300 kPa under the second regime.

54. The method of any one of claims 30 to 53, wherein the ASB bottom-hole pressure-temperature condition is sufficient to increase the ASB bottom-hole pressure to between about 80 % and about 110 % of the principle-phase bottom-hole pressure under the first regime.

55. The method of any one of claims 30 to 53, wherein the ASB bottom-hole pressure-temperature condition is sufficient to increase the ASB bottom-hole pressure to between

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about 90 % and about 110 % of the principle-phase bottom-hole pressure under the first regime.

56. The method of any one of claims 30 to 53, wherein the principle-phase of the method is preceded by a SAGD phase, a SAP phase, or a combination thereof.

57. The method of any one of claims 30 to 56, wherein the solvent comprises primarily propane, butane, diluent, natural gas condensate, or a combination thereof.

58. The method of any one of claims 30 to 56, wherein the solvent comprises propane.

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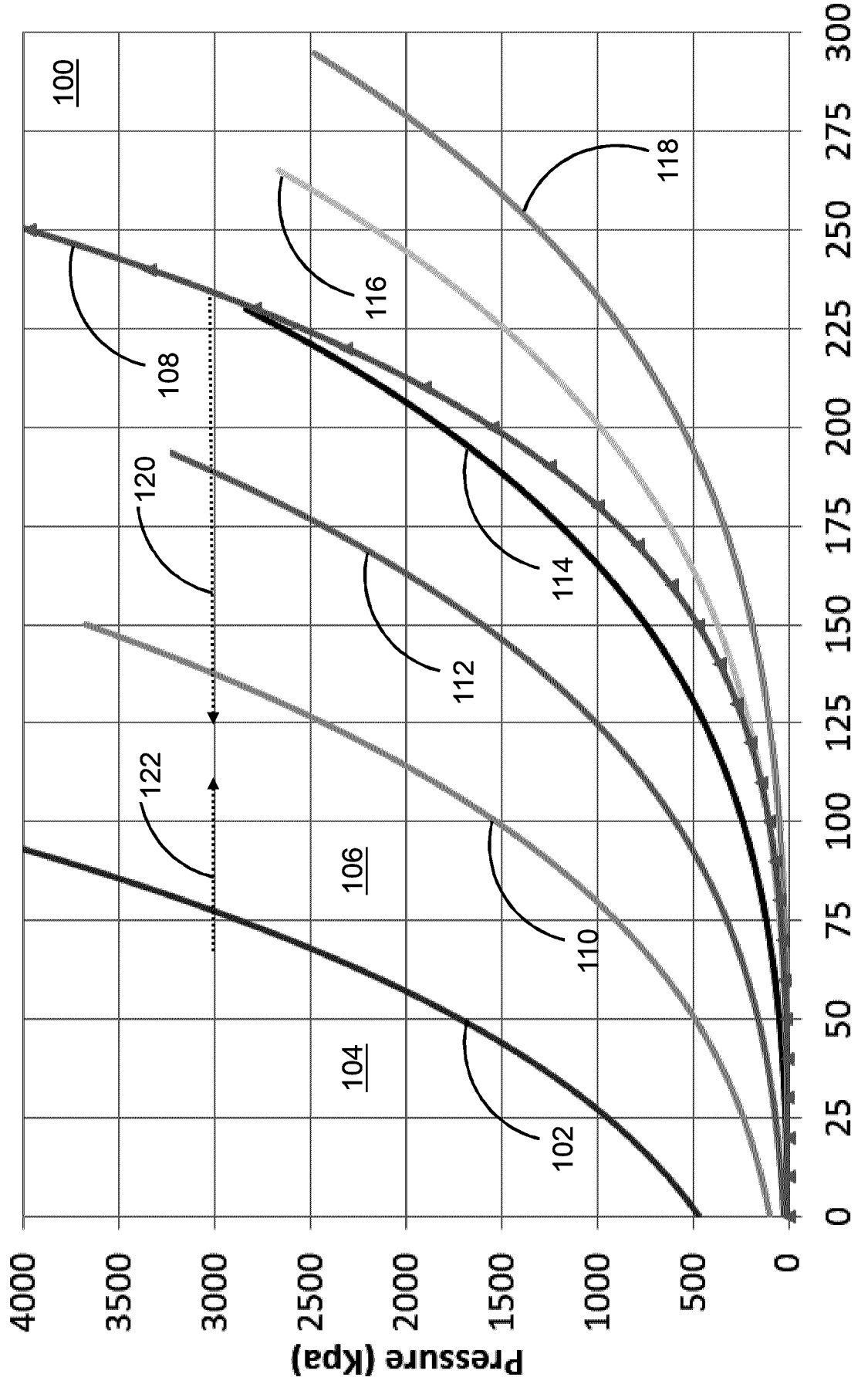


FIG. 1

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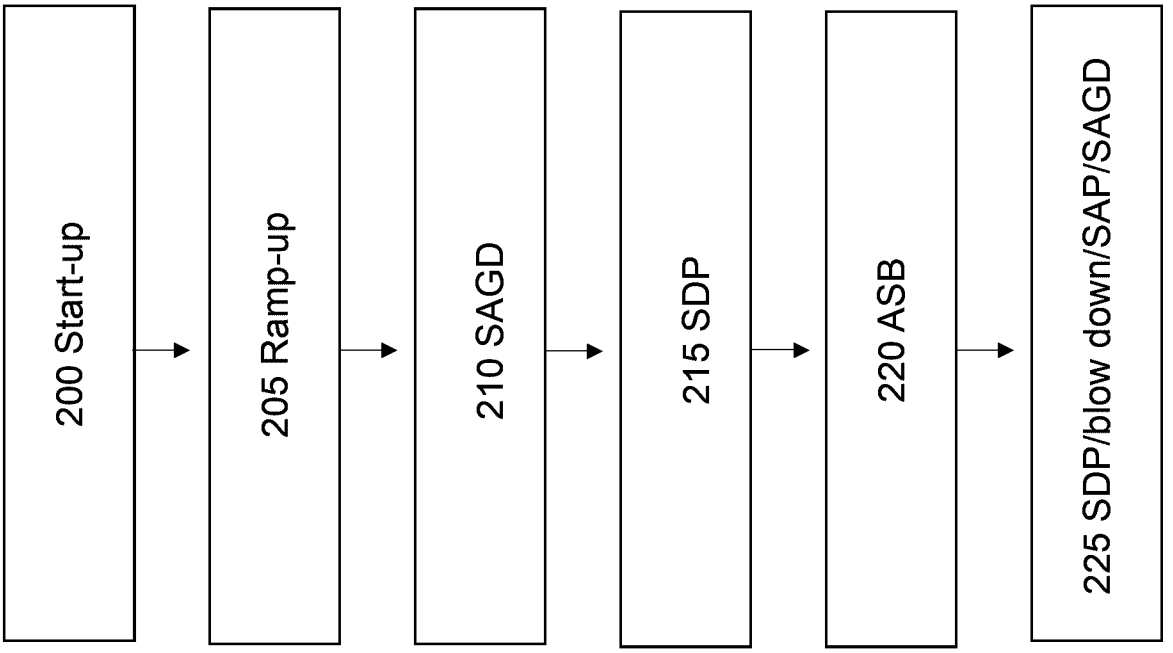


FIG. 2

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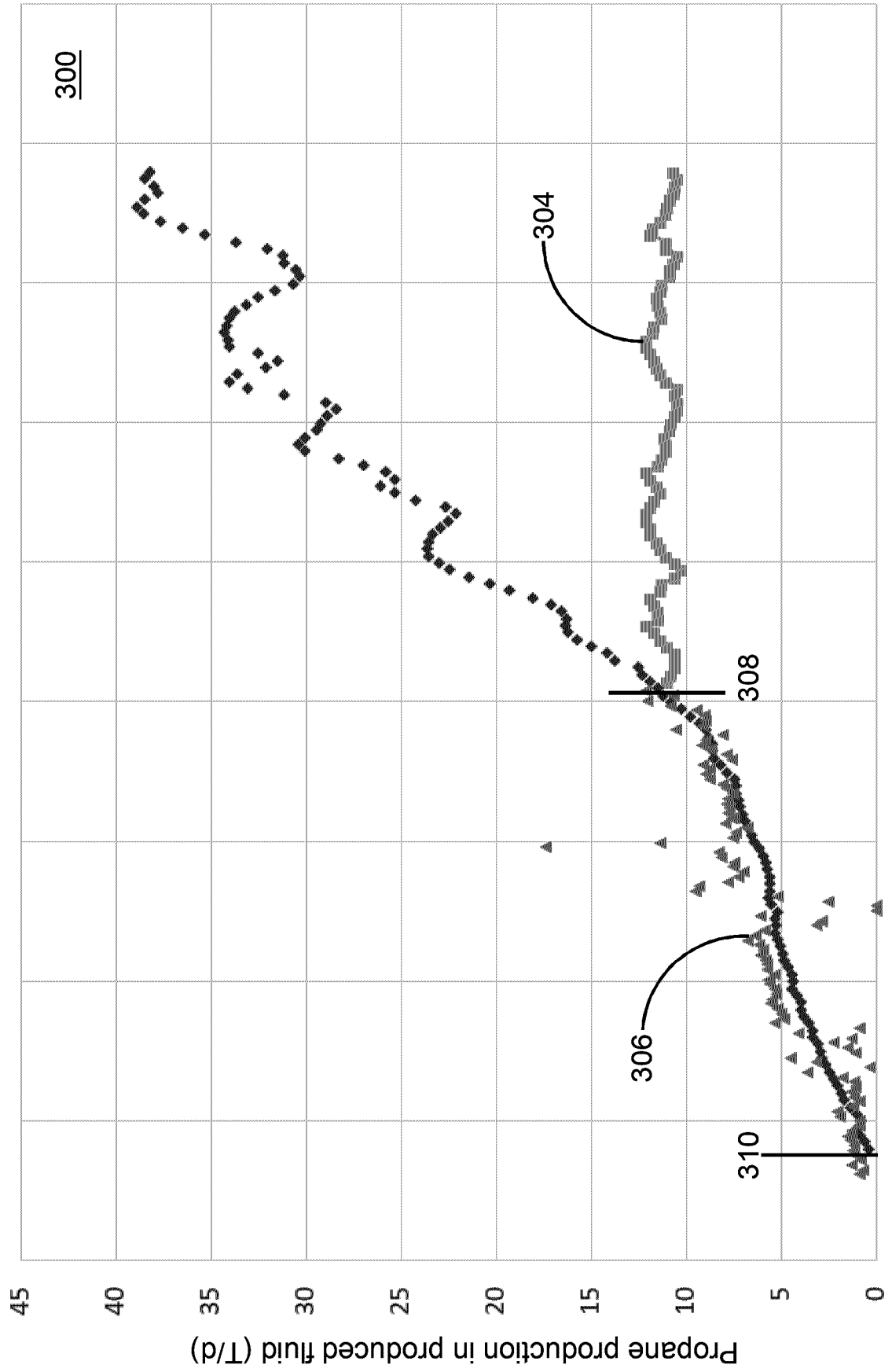
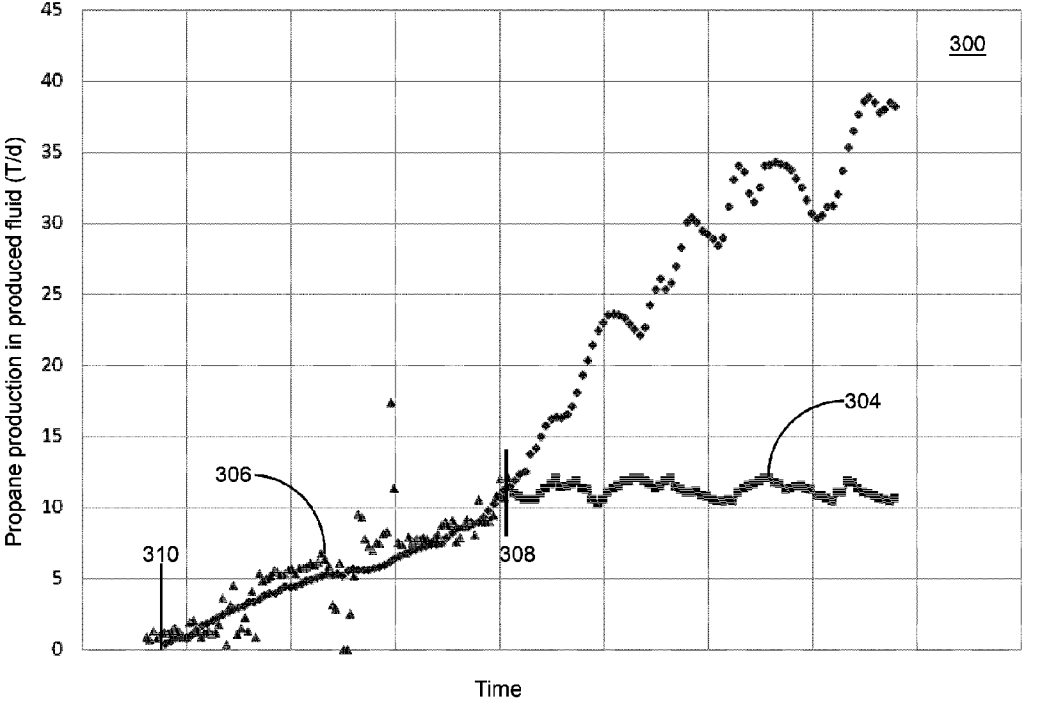


FIG. 3

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300
Propane production in produced fluid (T/d)
45
40
35
30
25
20
15
10
5
0
Time
304
306
310
308