ACCELERATED START-UP IN SAGD OPERATIONS

Inventors: Patty Morris, Calgary (CA); Claire Y. Hong, Calgary (CA); Subodh Gupta, Calgary (CA); Kirsten Pugh, Calgary (CA)

Publication Classification

Int. Cl.
E21B 43/16

U.S. Cl.
166/305.1

ABSTRACT

A method of initiating or accelerating the establishment of fluid communication between horizontal wells located in a formation of very limited fluid mobility, such as an oil sand at original temperature or an infill well completed in an immobile hydrocarbon region located between surrounding well patterns in which a gravity-dominated recovery process is or has been operated.
ACCELERATED START-UP IN SAGD OPERATIONS

CROSS REFERENCE TO RELATED APPLICATIONS


FIELD OF THE INVENTION

[0002] The present invention relates to oil and gas production. More particularly, the present invention relates to the recovery of heavy oil or bitumen from, for example an oil sand or tar sand deposit. More particularly, the present invention relates to a method for starting up such operations in a gravity controlled recovery system, such as Steam Assisted Gravity Drainage (SAGD).

BACKGROUND OF THE INVENTION

[0003] Numerous patents, patent applications and technical papers describe means of establishing fluid communication between proximate horizontal wells that are located in porous media of limited fluid mobility, such as an oil sand at original conditions. However, as will be explained, none of these relies on or teaches the key elements of the present invention to accomplish that communication.

[0004] For example, U.S. Pat. No. 3,913,672 filed Oct. 15, 1973, by J. C. Allen and D. A. Redford and titled “Method for establishing communication path in viscous petroleum-containing formations including sand or formations for oil recovery operations” describes a method to establish fluid communication in a viscous petroleum-containing formation such as an oil sand. The method comprises “forming an initial entry zone into the formation by means such as hydraulic fracturing and propping, or utilizing high permeability streaks naturally occurring within the formation, and injecting into the propped fracture zone or high permeability streak a solvent for the petroleum contained in the formation, said solvent being saturated with a gas or containing appreciable quantities of gas dissolved therein”. In contrast to this, the present invention requires no prior establishment or presence of permeable zone or streak. Furthermore, the present invention, while using a solvent, requires no dissolution in that solvent of a gas. Thus, the present invention, in not requiring these well-known aids to fluid conveyance in an oil sand or other formation of limited mobility, is not only novel but also non-obvious.

[0005] The abstract of U.S. Pat. No. 3,706,341 to Redford, and titled “Process For Developing Interwell Communication In A Tar Sand”, reads in part: “A hot, competent, permeable communications zone, connecting injection and production wells completed in a tar sand, is developed as follows: A cold, aqueous solution containing sodium hydroxide and a non-ionic surfactant is injected into a propped fracture system connecting the wells. . . . Bitumen is slowly emulsified in the solution and removed through the fracture system . . . .” The present invention involves none of the chemicals, or chemical combinations, or chemical types described in this patent. Also, Redford utilizes a prior means of communication, described as a “propped fracture system connecting the wells” whereas the present invention relies on no such prior communication artifact.

[0006] U.S. Pat. No. 4,249,604 to Frazier and titled “Recovery method for high viscosity petroleum” states that “. . . the invention relates to oil recovery methods wherein heated aqueous fluids are injected into directionally drilled injection wells which are drilled radially inward towards central producing well . . . .” The present invention differs materially from this patent in both process and well configuration.

[0007] U.S. Pat. No. 4,501,868 filed Oct. 15, 1979 by G. Schrenkel et al titled “Method using hydrocarbon foams as well stimulants” states in the abstract that “This invention relates to the use of silicone-induced hydrocarbon foams as well stimulants, for example as illustrated by their use in fracturing well formations, removal of paraffin in wells, removal of condensate hydrocarbons from blocked gas wells, etc”. The process of the present invention differs materially from that of this patent and specifically does not use foams.

[0008] U.S. Pat. No. 7,464,756 filed Feb. 4, 2005 by I. Gates and A. Gutke and titled “Process for in situ recovery of bitumen and heavy oil” includes as claim 1 in its entirety the following: “A method to recover heavy hydrocarbons from an underground reservoir, the underground reservoir being penetrated by an injection well and a production well, the method comprising the steps of: (a) injecting steam and a heavy hydrocarbon solvent into the injection well over time, while producing reservoir hydrocarbons from the production well; (b) transitioning from steam and heavy hydrocarbon solvent injections to a lighter hydrocarbon solvent injection, while continuing to produce hydrocarbons from the production well; (c) continuing to inject the lighter hydrocarbon solvent while producing hydrocarbons from the production well; and (d) enhancing the solubility of solvents in steps (a) through (c) by monitoring and adjusting reservoir pressure”. The cited patent describes a recovery process rather than an interwell communication technique. That aside, the process initially requires the injection of steam as a concomitant of the solvent injection “over time” while producing from the production well. The present invention requires no concomitant injection fluid along with the solvent, and involves no step of concurrently producing at another well while the solvent is being injected. Indeed, the present invention requires injection of only the solvent with no injection of other fluids on either a precedent, concomitant, or successor basis. It should also be noted that, according to claims of the cited patent, solvent injection occurs only at the injection well. In the present invention, solvent is a means of establishing interwell communication and occurs at either an injector or a producer or both.

[0009] Numerous patents involve well stimulation using a solvent in which that solvent is heated by some means, such as the concomitant injection of steam or prior heating of solvent, for example by electrical means.

[0010] By way of illustration two of the patents that include these features are:

[0011] U.S. Pat. No. 5,400,430 by J. Nenniger filed Jan. 21, 1994 and titled “Method for injection well stimulation”. The process involves electrical heating of a solvent prior to its injection into the reservoir. Also, as the title implies, and as described therein, the process is intended only for an injection well.

stimulating heavy oil production” describes in the abstract a process which “has the steps of heating a solvent, such as propane, and then placing the solvent into the extraction chamber at a temperature and a pressure sufficient for the solvent to be in a vapor state in the chamber and to condense on the extraction surface”. Not only does the patent describe the heating of the solvent, but it describes the necessity for the solvent to be in a vapor state. The present invention requires neither the prior heating of the solvent, nor the requirement that it be in a vapor state nor the need for a change of state.

[0013] Other processes involving solvent include U.S. Pat. No. 6,769,486 by G. Lim et al. filed May 30, 2002 and titled “Cyclic solvent process for in situ bitumen and heavy oil production”. This patent involves injection of a solvent at a pressure sufficiently high to cause formation dilation or pore fluid compression, allowing solvent and hydrocarbons to mix at pore dilation conditions, and then reducing the reservoir pressure so as to cause a solvent gas drive. The present invention entails no dilation of the formation, involves injection of the solvent strictly to establish interwell communication, and does not function as part of a solvent gas drive.

[0014] U.S. Pat. No. 5,607,016 by Butler filed November 1993 and titled “Process and apparatus for the recovery of hydrocarbons from a reservoir of hydrocarbons” describes in the abstract the process as follows: “A method for the recovery of hydrocarbons from a reservoir of hydrocarbons including injecting a hydrocarbon solvent into the reservoir along with a displacement gas to mobilize hydrocarbons in the reservoir of hydrocarbons; and producing mobilized hydrocarbons from the reservoir of hydrocarbons. The hydrocarbon solvent is injected along one or more predominantly horizontal injection wells in the aquifer that are spaced from the production well or wells. The hydrocarbon solvent is a hydrocarbon solvent selected from the group consisting of ethane, propane butane”. The present invention differs materially from this patent. According to the claims, the patent involves the use of a gas to first establish a communications path, and then continued use of gas as a concomitant of solvent injection. The present invention requires no prior step, such as gas injection, to establish communication, and involves injection into the reservoir of the solvent alone, without any concomitant fluids. Also, one embodiment of the present invention involves the injection of xylene, whereas the Butler patent confines its specifications to a solvent from the group consisting of ethane, propane, butane.

SUMMARY OF THE INVENTION

[0015] This invention pertains to a method of establishing or accelerating fluid communication between horizontal wells located in a formation of very limited fluid mobility, such as an oil sand reservoir. The horizontal wells may be vertically displaced from each other, for example as are the injector and producer in a SAGD pattern. Or they may be staggered with respect to each other, for example as when a horizontal infill well is situated in the region between two surrounding SAGD well patterns.

[0016] The method of accelerating communication according to this invention involves injecting a modest amount of solvent, one embodiment of which is xylene, into a subject well. A subject well is herein defined as a well that is located in a region of the reservoir that has very limited fluid mobility and from which communication is to be established with a target well by means of solvent injection. Conversely, a target well is herein defined as a well with which communication is to be established by means of solvent injection into the subject well.

[0017] The solvent is injected via the subject well into the reservoir at sub-fracturing pressures. Injection of the solvent may be into any individual subject well or into any combination of subject wells. After some time period of soak, and without the aid of previously created flow channels at a subject well, such as through fracturing or pre-injection of mobile fluids, and without the aid of prior or concurrent thermal means to establish or enhance communication at a subject well, such as steam or in situ combustion or electrical heating, communication between a subject well and a target well is established, notwithstanding the modest volume of solvent injected at the subject well.

[0018] In some instances, the subject well and the target well may both be situated in a region of immobile bitumen. One embodiment of this instance involves a SAGD well pair that has not yet been placed in operation. In this embodiment, the subject well might be either the injector, or the producer, or both.

[0019] In other instances, the subject well may be situated in an extensive region of immobile bitumen whose distal boundary is defined, in part or in whole, by an adjacent region of mobile bitumen. One embodiment of this instance involves an infill horizontal well that is located within the unheated region between adjacent operating SAGD horizontal well pairs. In this embodiment, the infill well is the subject well and the target wells are those located within a SAGD steam chamber or heated zone, which zone is separated from the subject well by a region containing bitumen of very limited mobility.

[0020] In the case of a new SAGD well pair, the communication thus achieved is sufficient to then permit inception of a gravity-dominated process, such as SAGD, or other gravity-dominated processes such as those involving the use of solvents as part of a thermal or non-thermal technique, without the need for additional procedures or processes whose purpose is to further facilitate or expedite inter-well communication, such as steam circulation in the wells.

[0021] In the case of an infill well located within a region of very limited fluid mobility that is situated between SAGD well pairs, communication is thus achieved without the need for additional procedures or processes and is sufficient to permit the infill well to participate in the recovery process by acting as a supplementary means of production.

[0022] In one aspect, the present invention provides a method wherein a selected amount of solvent is injected at sub-fracturing conditions (pressure or rate or both) and ambient temperature into a first horizontal well located in an immobile formation or reservoir, so as to accelerate fluid communication in the formation or reservoir between the first horizontal well and a second horizontal well with which the first horizontal well is not in fluid communication.

[0023] In an embodiment of the present invention the solvent is xylene, benzene, toluene, phenol or mixtures or derivatives thereof. In an embodiment of the present invention the solvent is substantially xylene.

[0024] In an embodiment of the invention, the solvent is injected into either the first horizontal well or the second horizontal well, or into both the first horizontal well and the second horizontal well.

[0025] In an embodiment of the invention, the immobile formation or reservoir is an oil sand reservoir at original
In an embodiment of the invention, the original conditions include a bitumen or heavy oil density of about 12° API or heavier. In an embodiment of the invention, the original conditions include a bitumen or heavy oil density of about 15° API or heavier.

In an embodiment of the invention, the selected amount of solvent is a volume less than ten times the volume of the first horizontal well completion.

In an embodiment of the invention, a further selected amount of solvent is injected at sub-fracturing conditions and ambient temperature into the second horizontal well. In an embodiment of the invention, the further selected amount of solvent is a volume less than ten times the volume of the second horizontal well completion. In an embodiment of the invention, the total of the selected amount of solvent and the further selected amount of solvent is a volume less than ten times the volume of the total of the first horizontal well completion and the second horizontal well completion.

In an embodiment of the invention, the solvent is displaced into the immobile formation or reservoir using a displacing fluid sufficient to displace substantially all of the selected volume of solvent into the formation or reservoir. In an embodiment of the invention, the displacing fluid is a non-condensing, non-oxidizing gas. In an embodiment of the invention, the displacing fluid is substantially nitrogen.

In an embodiment of the invention, the injected solvent is allowed to remain resident in the immobile formation or reservoir for a selected period of time before a subsequent recovery process is implemented. In an embodiment of the invention, the solvent is displaced into the immobile formation or reservoir using a displacing fluid sufficient to displace substantially all of the selected volume of solvent into the formation or reservoir after the selected period of time before the subsequent recovery process is implemented.

In an embodiment of the invention, a subsequent recovery process is implemented following application of the method to establish inter-well communication. In an embodiment of the invention, the subsequent recovery process is SAGD or other gravity-dominated recovery processes that involved the use of solvents, either thermally or non-thermally.

In an embodiment of the invention, the first horizontal well is an infill well completed in an immobile hydrocarbon region located between surrounding well patterns of a gravity-dominated recovery process.

In an embodiment of the invention, the immobile hydrocarbon region is in a bypassed region, remaining between adjacent mobilized hydrocarbon regions of a gravity-dominated recovery process.

In an embodiment of the invention, fluid communication is established between the first horizontal well and an adjacent mobilized hydrocarbon region of a gravity-dominated recovery process.

In an embodiment of the invention, fluid communication is established between the first horizontal well and an adjacent common mobilized hydrocarbon region of a gravity-dominated recovery process.

Other aspects and features of the present invention will become apparent to those ordinarily skilled in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will now be described, by way of example only, with reference to the attached Figures, wherein:

FIG. 1 illustrates the method of the present invention applied to a SAGD well pair;

FIG. 2 illustrates a section 2-2 of FIG. 1;

FIG. 3 illustrates the method of the present invention applied to an infill well completed between adjacent SAGD well pairs; and

FIG. 4 illustrates the method of the present invention applied to an infill well completed adjacent a SAGD well pair.

DETAILED DESCRIPTION

Referring to FIGS. 1 and 2, a typical SAGD recovery system 10 is shown, having an injection well 20 for injecting steam and a production well 30 for producing fluids completed in an immobile formation or reservoir 40. A portion of the injection well 20 is open to the immobile formation or reservoir 40 via an horizontal injection well completion 50. Similarly, a portion of the production well 30 is open to the immobile formation or reservoir 40 via a horizontal production well completion 60. These horizontal well completions are typically perforations, slotted liner, screens, or a combination thereof known to one skilled in the art.

In order to establish fluid communication between the injection well 20 and the production well 30 in an accelerated manner, a selected amount of solvent is injected at sub-fracturing conditions (pressure or rate or both) and ambient temperature into either the injection well 20 or the production well 30 or both the injection well 20 and the production well 30.

The selected amount of solvent may be a relatively small volume, for example less than about ten times the volume of the horizontal well completion. As an example, if the horizontal production well completion 60 includes a 7 inch (approximately 0.180 m) nominal diameter slotted liner, 800 m long, the volume of the horizontal production well completion 60 is approximately 20 cubic metres. In such a case, a volume of less than about 200 cubic metres may be selected.

Referring to FIG. 3, after a period of time of operation of the SAGD recovery system 10, a mobilized region 70a develops around the injection well 20a and the production well 30a (and likewise a mobilized region 70b develops around the injection well 20b and the production well 30b etc.). However, a portion of the immobile formation or reservoir 40ab remains between the adjacent well pairs. In the case where the mobilized region 70a and the mobilized region 70b merge or coalesce to form a common mobilized region 70ab, the portion of the immobile formation or reservoir 40ab remaining may be referred to as a bypassed region 40ab.

An infill well 80 is completed in the immobile formation or reservoir 40ab. A portion of the infill well 80 is open to the immobile formation or reservoir 40ab via an horizontal infill well completion 90. In order to establish communication between the infill well 80 and the mobilized region 70a or the mobilized region 70b or both, or the common mobilized region 70ab (and thus to the production well 30a or the production well 30b or both), a selected amount of solvent is injected at sub-fracturing conditions (pressure and flow rate or both) and ambient temperature into the infill well. The selected amount or solvent may be less than about ten times the volume of the horizontal infill well completion 90.

Referring to FIG. 4, after a period of time of operation of the SAGD recovery system 10, a mobilized region 70 develops around the injection well 20 and the production well 30.
30. However, a portion of the immobile formation or reservoir 40 remains adjacent the well pair.

[0047] An infill well 80 is completed in the immobile formation or reservoir 40. A portion of the infill well 80 is open to the immobile formation or reservoir 40 via a horizontal infill well completion 90. In order to establish communication between the infill well 80 and the mobilized region 70 (and thus to the production well 30), a selected amount of solvent is injected at sub-fracturing conditions (pressure and flow rate or both) and ambient temperature into the infill well. The selected amount or solvent may be less than about ten times the volume of the horizontal infill well completion 90.

[0048] As a means of displacing the solvent into the reservoir at the subject well while minimizing the quantity of solvent used, a chasing fluid may be used, although this is not essential. If a chasing fluid is used, it does not enter the reservoir and therefore does not participate in the process of accelerating fluid communication. Typically the chasing or displacing fluid is a non-condensing, non-oxidizing gas, such as nitrogen, sufficient to displace most of the solvent into the formation.

[0049] The present invention relates to a method of establishing communication between a horizontal well that is situated in a hydrocarbon deposit of very limited mobility, such as an oil sand or heavy oil at original temperature, and another well or region. As such, the present invention provides a means of accelerating start-up of a follow-up gravity-dominated recovery process such as SAGD. In another aspect the present invention provides a means of establishing communication between a horizontal well that is within and surrounded by a region of immobile bitumen and a mobilized region that is located at some distance from said horizontal well, such as one or more operating SAGD well patterns.

[0050] This invention relies on the use of a solvent, one embodiment of which is xylene, to mobilize the otherwise immobile bitumen in the immediate vicinity of the horizontal wellbore or wellbores. A designated volume, or slug, of solvent is injected at a well and displaced through its horizontal section, or portions thereof, into the reservoir.

[0051] The solvent or combination of solvents may be selected from a wide variety of compounds. In one embodiment the solvent comprises an organic solvent. In one embodiment the organic solvent comprises an aromatic organic solvent. In another embodiment the aromatic organic solvent comprises one or more of benzene, toluene, phenol, xylene or their derivatives or mixtures. In one embodiment the solvent is substantially xylene.

[0052] An aspect of the invention, and one which incorporates both novel and non-obvious approaches, relates to the manner in which the solvent is injected into the reservoir so as to establish communication between the wells.

[0053] To this end, firstly, the solvent is injected at sub-fracturing pressures, and no means are used to fracture, dilate or otherwise alter the formation so that a preferential path or channel is created in the reservoir. Secondly, the solvent is injected at ambient conditions, is not heated, and no other heating medium, such as steam, and no other displacing fluid such as a gas, accompany the solvent, precede the solvent or follow the solvent into the reservoir as part of the process of establishing inter-well communication.

[0054] An option in applying the present invention is that, after the solvent is displaced into the reservoir, it may be allowed to reside, or soak, within the reservoir for a period of time.

[0055] Through the course of establishing inter-well communication via the subject well, there is no need for any extraneous approach to preparing the formation at said well, such as fracturing, or formation heating, or injection of a precedent fluid, such as a gas, to provide or facilitate the creation of a pre-existing pathway for the solvent, or indeed injection of concomitant or succeeding fluids.

[0056] A second novel and non-obvious aspect of this invention is the absence of need for any means to augment mobility by heating the solvent, or by relying on changes of phase through either temperature or pressure or both.

[0057] A third novel and non-obvious aspect of this invention is the relatively small volume of solvent slug used.

[0058] Solvent is generally very expensive. Therefore, while it may always be possible to establish inter-well communication using a sufficiently large volume of solvent, there will be some net solvent losses to the reservoir, the cost of which will easily negate any advantage provided by acceleration of recovery process start-up. In the present invention, a volume of solvent is used which is small relative to the available pore volume that must be traversed in order to establish interwell communication but which nevertheless achieves this communication.

[0059] The successful establishment of inter-well communication in the manner consistent with this invention in a virgin oil sand using small unheated slugs of xylene has been verified experimentally at new SAGD wells. While many of the treatments that were carried out involved xylene slugs placed or injected at both the injector (injection well, being the upper well in a SAGD well pair) and the producer (production well, being the lower well in a SAGD well pair) at least one successful treatment included placing or injecting the solvent into only the producer. As a further check on the efficacy of the method, the xylene injection treatment obviated the need, during follow-up SAGD operations, for alternative means of establishing interwell communication such as steam circulation in either the injector or producer, or both.

[0060] Simulations of xylene injection process provided a scientific basis for our solvent field results. Simulations runs showed that the path of the injected xylene outward from the subject well is not isotropic. Instead, because of the density difference between the xylene and the bitumen, or between the xylene-bitumen blends that evolve as the xylene migrates within the reservoir, and the bitumen, or between the xylene and the formation water, or between the xylene-bitumen blends and the formation water, there is a preferential upward movement of the xylene or xylene-bitumen blend front. Thus whereas, if the flow geometry were radial, certain limited volumes of xylene would fail to traverse the distance between producer and injector, and might thereby fail to establish inter-well communication, the situation in the reservoir created by virtue of this invention, with its resulting flow anisotropy, enables that same xylene volume to establish inter-well communication.

[0061] In one embodiment the invention provides a method of initiating or accelerating the establishment of fluid communication between horizontal wells located in a formation of very limited fluid mobility, such as an oil sand at original temperature or an infill well completed in an immobile hydrocarbon region located between surrounding well patterns in which a gravity-dominated recovery process is or has been operated.

[0062] In the preceding description, for purposes of explanation, numerous details are set forth in order to provide a
thorough understanding of the embodiments of the invention. However, it will be apparent to one skilled in the art that these specific details are not required in order to practice the invention.

What is claimed is:

1. A method wherein a selected amount of solvent is injected at sub-fracturing conditions (pressure or rate or both) and ambient temperature into a first horizontal well located in an immobile formation or reservoir, so as to accelerate fluid communication in the formation or reservoir between the first horizontal well and a second horizontal well with which the first horizontal well is not in fluid communication.

2. The method of claim 1, wherein the solvent is xylene, benzene, toluene, phenol or mixtures or derivatives thereof.

3. The method of claim 1, wherein the solvent is injected into either the first horizontal well or the second horizontal well, or into both the first horizontal well and the second horizontal well.

4. The method of claim 1, wherein the immobile formation or reservoir is an oil sand reservoir at original conditions.

5. The method of claim 4, wherein the original conditions includes a bitumen or heavy oil density of about 12° API or heavier.

6. The method of claim 5, wherein the bitumen or heavy oil density is about 15° API or heavier.

7. The method of claim 1, wherein the selected amount of solvent is a volume less than ten times the volume of the first horizontal well completion.

8. The method of claim 1, wherein a further selected amount of solvent is injected at sub-fracturing conditions and ambient temperature into the second horizontal well.

9. The method of claim 8, wherein the further selected amount of solvent is a volume less than ten times the volume of the second horizontal well completion.

10. The method of claim 8, wherein the total of the selected amount of solvent and the further selected amount of solvent is a volume less than ten times the volume of the total of the first horizontal well completion and the second horizontal well completion.

11. The method of claim 1, wherein the solvent is displaced into the immobile formation or reservoir using a displacing fluid sufficient to displace substantially all of the selected volume of solvent into the formation or reservoir.

12. The method of claim 11, wherein the displacing fluid is a non-condensing, non-oxidizing gas.

13. The method of claim 12, wherein the displacing fluid is substantially nitrogen.

14. The method of claim 1 wherein the injected solvent is allowed to remain resident in the immobile formation or reservoir for a selected period of time before a subsequent recovery process is implemented.

15. The method of claim 14, wherein the solvent is displaced into the immobile formation or reservoir using a displacing fluid sufficient to displace substantially all of the selected volume of solvent into the formation or reservoir after the selected period of time before the subsequent recovery process is implemented.

16. The method of claim 1 whereby, following application of the method to establish inter-well communication, a subsequent recovery process is implemented.

17. The method of claim 16, wherein the subsequent recovery process is SAGD or other gravity-dominated recovery processes that involved the use of solvents, either thermally or non-thermally.

18. The method of claim 1 wherein the first horizontal well is an infill well that is completed in an immobile hydrocarbon region located between surrounding well patterns of a gravity-dominated recovery process.

19. The method of claim 18 wherein the immobile hydrocarbon region is in a bypassed region, remaining between adjacent mobilized hydrocarbon regions of a gravity-dominated recovery process.

20. The method of claim 18 wherein fluid communication is established between the first horizontal well and an adjacent mobilized hydrocarbon region of a gravity-dominated recovery process.

21. The method of claim 18 wherein fluid communication is established between the first horizontal well and an adjacent common mobilized hydrocarbon region of a gravity-dominated recovery process.

* * * * *