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[54] **RECOVERY OF PETROLEUM FROM VISCOUS PETROLEUM CONTAINING FORMATIONS INCLUDING TAR SAND DEPOSITS**

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[51] **Int. Cl.**[2] **E21B 43/24**

[58] **Field of Search** .... 166/272, 271, 303, 252, 166/305 R, 306

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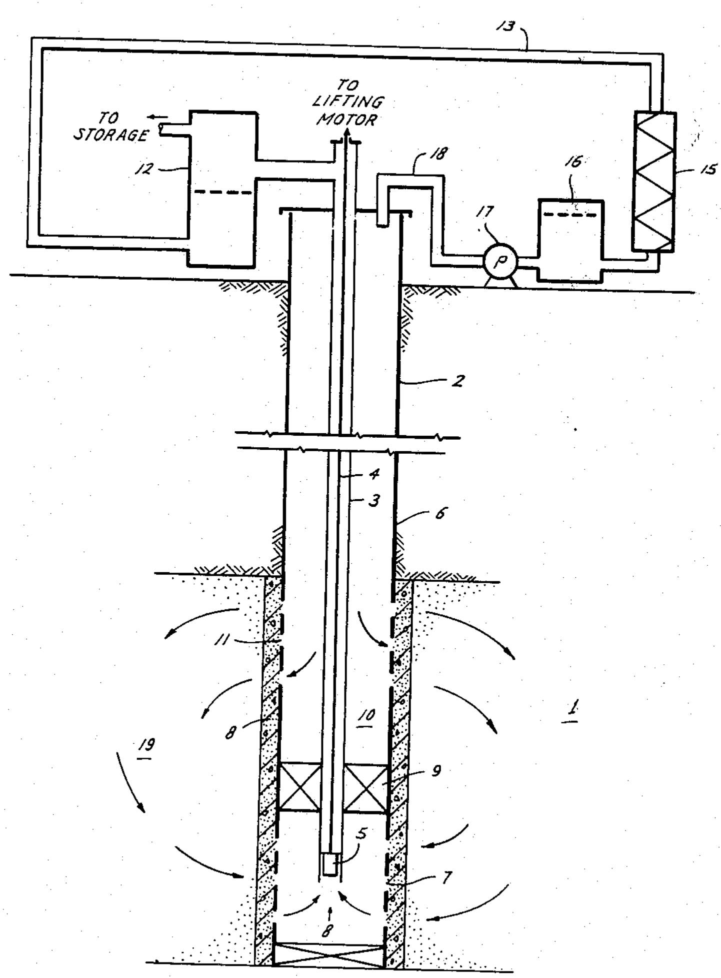
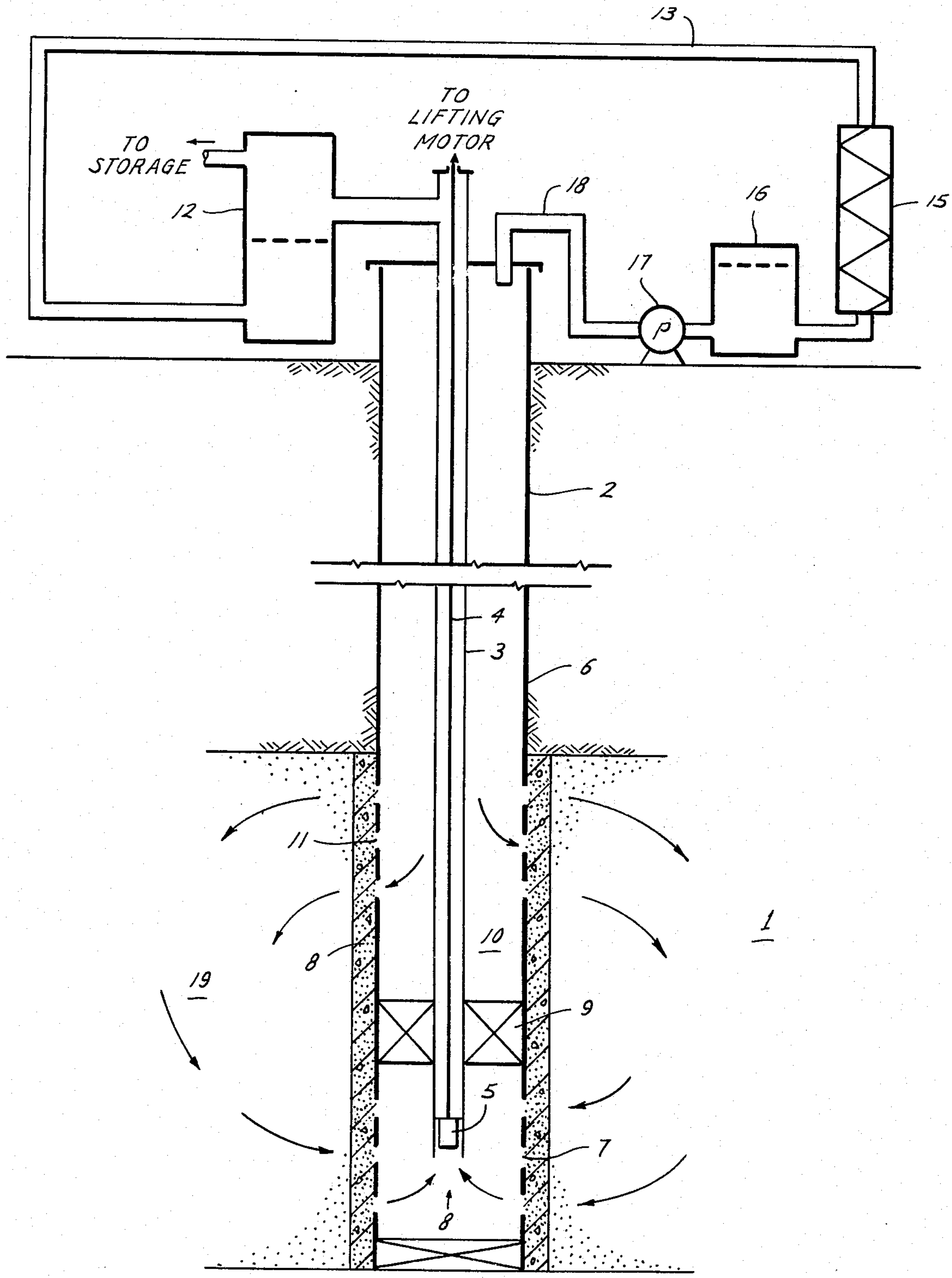
[57] **ABSTRACT**

Recovery of viscous petroleum is enhanced by contacting viscous petroleum in the formation near the production well which is restricting flow into the well with an aqueous heating fluid such as steam or hot water. Introduction of the aqueous treating fluid on a continuous or intermittent basis is accomplished by providing a separate flow channel for the heating fluid near the production well. Alkaline material such as sodium hydroxide may be incorporated in the aqueous heating fluid.

10 Claims, 1 Drawing Figure

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RECOVERY OF PETROLEUM FROM VISCOUS PETROLEUM CONTAINING FORMATIONS INCLUDING TAR SAND DEPOSITS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention pertains to a method for recovering viscous petroleum including bitumen from viscous petroleum containing formations including tar sand deposits, and more particularly to a method for treating a portion of a petroleum formation near the production well so as to remove very viscous, semi-solid, immobile hydrocarbon materials deposited there during in situ recovery operations so as to stimulate production of petroleum from the formation.

2. Description of the Prior Art

Many subterranean petroleum-containing formations located throughout the world contain petroleum which is so viscous that it cannot be recovered by conventional means. The most famous of such visocus petroleum-containing formations are the so-called tar sands or bitumen sand deposits. The largest and best known such deposit is the Athabasca Tar Sand Deposit located in the northeastern part of the Province of Alberta, Canada, which contains around 700 billion barrels of petroleum. Extensive deposits of tar sands are also known to exist in the western United States and Venezuela, and smaller deposits are located in Europe and Asia.

Tar sands are massive deposits of sand saturated with an extremely viscous crude petroleum material not recoverable in its natural state through a well by ordinary production methods. The petroleum contained in tar sand deposits is highly bituminous in character, and has a viscosity in the range of millions of centipoise at the temperatures normally existing in the subterranean formation. The sand portion of tar sand deposits is generally fine quartz, and the sand grains are coated with a layer of water and the bituminous petroleum occupies most of the void space around the water wetted sand grains. The balance of the void space may be filled with connate water and occasionally a small volume of air or methane is present. The sand grains are packed to a void volume of about 35 percent, which corresponds to about 83 percent by weight, and the balance of the material is bitumen and water. The sum of the bitumen and water content is fairly consistently about 17 percent by weight, with the bitumen portion thereof varying from about 2 percent to around 16 percent by weight.

One of the characteristics of tar sand deposits which distinguish them from conventional hydrocarbon deposits is the absence of a consolidated mineral matrix; the sand grains are in grain to grain contact but are not cemented together. The API gravity of bitumen ranges from about 6° to about 8°, and the specific gravity at 60°F. is from about 1.006 to about 1.027. Approximately 50 percent of the bitumen is distillable without cracking, and the sulfur content ranges from 4 to 5 percent by weight. The bituminous petroleum is so viscous that even when a recovery technique is successful in producing bitumen separated from the sand, some onsite refining of the produced petroleum must be undertaken in order to reduce the viscosity of the petroleum to a sufficiently low level that it may be pumped in a pipeline.

Bitumen may be recovered from tar sand deposits by strip mining or in situ processes. Most of the recovery to date has been by means of strip mining, although this is presently limited by economics to formations having a ratio of the overburden thickness to tar sand deposit thickness around one or less. In situ processes which have been applied to tar sand deposits to date are thermal, such as fire flooding or steam flooding, and emulsification drive processes which may also employ steam in combination with an alkaline material and an emulsifier. Generation of thermal heat necessary to mobilize the bitumen by means of a subterranean atomic explosion has also been proposed, although this has not been employed to date.

Many in situ recovery processes depend on reduction of the viscosity of the bituminous petroleum by thermal means, the heat being supplied by in situ combustion or by steam injection. While the bituminous petroleum contained in tar sand deposits may be rendered sufficiently mobile by heating to move through a subterranean deposit by application of an adequate pressure differential, conventional throughput processes have encountered problems associated with cooling of bituminous materials some distance away from the point of injection of the heating fluid; the viscosity of bitumen increases sharply as it cools until it approaches in appearance an amorphous solid. Even though additional hot fluid is being introduced into the formation, the heat transfer from hot fluids to the fluids which have cooled in the forward part of the front is by conduction, which is extremely slow. When the thermally mobilized bituminous petroleum loses sufficient heat to become semi-solid, a plug is formed which restricts or prevents movement of petroleum past the point where the bitumen became immobile. This phenomena is especially troublesome when it occurs in the immediate vicinity of the production wellbore, since the cross-sectional area through which fluids must flow decreases dramatically as the distance to the production wellbore decreases.

This problem has been recognized by persons skilled in the art, and in U.S. Pat. No. 3,279,538 there is described a method for treating production wells which have become plugged by a push-pull treatment with an aqueous caustic solution. The solution is pumped into the formation through the production well and then the fluid and bitumen contacted thereby flows back into the well. This remedial method requires discontinuing the production of petroleum from the well and is quite time consuming. For this and numerous reasons it has not always been entirely satisfactory.

In view of the foregoing discussion, it can be appreciated that there is a substantial need in in situ recovery methods applicable to tar sands or bituminous sand deposits, for a method of preventing formation of or removing these deposited bituminous, immobile hydrocarbon materials from the formation, to permit continued, uninterrupted recovery of petroleum from the formation. The need is especially acute for removing such immobile hydrocarbon materials which plug formations in the immediate vicinity of the production wellbore.

SUMMARY OF THE INVENTION

We have discovered, and this constitutes our invention, that the production and recovery of viscous petroleum or bitumen from subterranean viscous petroleum-containing formations including tar sand deposits, may be improved by employment of a method which permits contacting immobile hydrocarbon deposits in the formation in the vicinity of the production well so as to facilitate removal thereof from the formation. In the practice of one embodiment of our invention, at least one production well is completed so as to provide a separate flow path from the surface, so that a treating fluid may be introduced into a portion of the petroleum formation, said fluid being capable of removing at least a portion of the immobile hydrocarbon materials. In one especially preferred embodiment, the annular space between the production tubing and the well casing is utilized for the separate flow path for introducing the treating fluid into the formation. Heated, aqueous fluid such as hot water or steam or superheated steam, which melts the immobile, solid-like hydrocarbon materials so that they will flow into the production wellbore and be produced to the surface of the earth are introduced via the flow path. The aqueous heating fluid may be injected into the portion of the formation adjacent to the production well on a timed program basis, or only when the production rate has decreased, indicating the presence of immobile hydrocarbon materials obstructing the flow of petroleum from the formation. Continuous injection of the aqueous heating fluid into the formation may also be employed in order to prevent deposition of obstructing hydrocarbon materials.

BRIEF DESCRIPTION OF THE DRAWING

The attached drawing illustrates in cross-sectional view a tar sand deposit and a production wellbore completed therein permitting employment of at least one embodiment of our invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

I. The Process

The process of our invention may best be understood by a reference to the illustrative embodiment shown in the attached drawing, in which a subterranean tar sand deposit **1** is penetrated by a production well **2**. The production well **2** contains production tubing **3** in which is contained rod **4** for activating pump **5** in the lower portion of the production tubing. The well further contains casing **6** and in this embodiment fluid communication is established by means of perforations **7** and a porous, sand restraining gravel pack **8** near the bottom of the tar sand deposit. A packer **9** isolates the portion of the casing in fluid communication with the open bottom end of the tubing from the upper portion of the annular space **10** between the production tubing and the casing. Fluid communication means **11** such as perforations and unconsolidated sand restraining, porous material **8** establish fluid flow communication between annular space **10** and the upper portion of tar sand deposit **1** which is separate from the production string.

On the surface, production tubing **3** is in fluid communication with separation tank **12**, wherein the produced fluid which may comprise a mixture or an emulsion of the injected fluid and the petroleum recovered from the formation, is subjected to separation so that the injected fluid may be recycled by reinjecting it into the formation via the treating fluid injection means. Separation may be accomplished by natural gravity separation of the immiscible aqueous heating fluid and petroleum in tank **12**. The aqueous fluid is recycled through line **13** through heater **15** into storage vessel **16**, where it is reinjected into the annular space **10** by pump **17** either continually or intermittently on a regular basis or when required in order to stimulate production of petroleum from tar sand deposit **1**. Line **18** completes the circuit, connecting pump **17** with annular space **10**. The produced formation petroleum from which the injected treating fluid has been separated in tank **12** is pumped to storage or surface refining facilities.

In the practice of the process of our invention, the treating fluid to be injected into the formation is stored in tank **16** and pumped as desired via pump **17** and line **18** into the annular space **10** of the production well. The treating fluid flows down the annular space and out into the formation through the fluid communication means, in this particular embodiment this being perforations **11** and gravel pack **8**. The injected fluid moves away from the point of injection, contacting the immobile hydrocarbon materials which are plugging the formation, and dissolves or melts the materials so that they flow into the lower portion of the production well via perforations **7**, from which they are pumped to the surface of the earth by pump **5**. The fluid which enters perforations **7** and is pumped to the surface by pump **5** is an emulsion or mixture of the injected aqueous heating fluid, formation petroleum, and the bituminous or other immobile hydrocarbon materials which have been melted or mobilized by the injected aqueous heating fluid. Since the aqueous heating fluid is insoluble in the solidified deposited material, the nature of the fluid being produced to the surface of the earth may be a mixture or an emulsion. Many of the bituminous materials in which our invention will be most suitable for application readily form oil-in-water emulsions and the viscosity of such emulsions is generally much less than the viscosity of the hydrocarbon portion thereof, so it is quite readily pumpable to the surface of the earth.

There are several methods of applying our process, and the choice may well be determined by the severity of the problem sought to be corrected. In formations where the deposition of immobile hydrocarbon materials occurs only infrequently, it may be desirable to inject the treating material only when it is necessary to do so in order to continuue production of petroleum from the subterranean formation. This can be done under human control when necessary, or one may utilize automatic production rate and/or pressure monitoring devices which automatically initiate injection of aqueous heating fluid when necessary as indicated by a drop in petroleum production rate or pressure. In severe cases, particularly in application to tar sand deposits, it is frequently preferable to inject the aqueous heating fluid continually, so that no deposition or solidification of plugging materials occurs near the production wellbore. Injection of fluid may also be on the basis of preselected time interval, which may be responsive to human control or to an automatic timing device.

The produced fluid will frequently be an emulsion of bitumen-in-water, and so the surface separation facilities should include equipment capable of breaking the produced emulsion. This can be accomplished by using separation equipment and techniques commonly employed in oil field production operations such as the so-called "heater treater" type of emulsion breaking device. More sophisticated emulsifying means may also be utilized for separation of the injected heated aqueous treating fluid from the petroleum.

II. The Treating Fluid

Immobile or solidified hydrocarbon deposits may be rendered mobile by heating and/or emulsification with a heated aqueous treating fluid. For example, steam, either saturated or superheated, or hot water may be injected into the formation through the treating fluid injection means in order to raise the temperature of the immobile hydrocarbon materials plugging the formation in the vicinity of the production well. The pressure gradient present in the vicinity or in the formation will result in the movement of these heated hydrocarbon materials into the production well where they are transported to the surface.

It is known that some asphaltic materials spontaneously emulsify, forming an oil-in-water emulsion having a viscosity substantially less than the viscosity of the petroleum. In some deposits of bituminous petroleum the emulsification process may be increased significantly by incorporating a small amount of an alkaline material such as sodium hydroxide in the steam or hot water treating fluid. Accordingly, another embodiment of our invention incorporates the injection of steam or hot water having dissolved therein a small amount of basic material such as sodium hydroxide, in order to enhance the tendency for the viscous formation petroleum to form an oil-in-water emulsion. A small amount of a surfactant emulsifier may also be incorporated in the injected steam. For example, steam having dissolved therein a small but effective amount of sodium hydroxide and a surfactant such as petroleum sulfonate may be injected into the formation to emulsify and remove the solidified hydrocarbon material.

III. Field Example

Our invention is best understood by referring to the following pilot field example, which is offered only as an illustrative embodiment of our invention and is not intended to be limitative or restrictive thereof.

A tar sand deposit having an overburden thickness of **200** feet has a formation thickness of **90** feet is to be exploited. It is determined that the petroleum is a highly bituminous, viscous hydrocarbon which is essentially immobile at reservoir conditions, and so the material is unrecoverable by conventional, primary recovery techniques. An injection well is drilled into the formation and fluid communication means in the form of perforations are formed over a substantial portion of the tar sand interval. A production well is drilled **50** feet from the injection well, and casing is set to the bottom of the tar sand interval. Perforations in the casing are formed in both the upper and lower sections of the oil saturated interval, to establish fluid communication between the annular space between the production tubing string (to be run later) and the casing with the upper and lower portion of the tar sand formation. A production tubing string is run to a point near the bottom of the casing, and a packer is set above the end of the production tubing between the two sets of perforations in the casing for the purpose of isolating the annular space above the packer from the annular space therebelow which is in fluid communication with the production tubing string. A pump is located in the lower portion of the production string, said pump being activated by a sucker rod which connects to a lifting device on the surface of the earth. The upper portion of the production tubing is connected to a tank for separation of the produced fluid, which may at times be a mixture of the injected aqueous heating fluid and petroleum from the tar sand formation. The aqueous heating fluid which is separated from petroleum is pumped into the annular space so that treating fluids may be recycled into the top perforations in the casing into the upper portion of the tar sand interval.

Steam is injected into the injection well at the maximum rate possible, the limitation being that the pressure must not exceed **200** pounds per square inch since it is essential that the overburden not be fractured or lifted. Fracturing of the overburden would make it impossible to continue the injection of any type of fluid into the formation. Steam injection continues, with the steam temperature being **300°F**. The initial gas receptivity of the formation is quite adequate, and **350,000** pounds of water in the form of steam are injected into the formation per **24** hour period.

After several weeks of steam injection, the steam injection pressure begins to increase and injection rate decreases without any appreciable quantity of bitumen being produced at the production well. It is determined that the bitumen has been heated sufficiently that it has begun to move toward the production well, but as the bitumen moves into cooler regions of the formation, it loses heat and the viscosity increases rapidly, forming a bitumen plug somewhere in the formation near the production well. It is determined that in order to stimulate production of bitumen from the production well, it will be necessary to initiate injection of treating fluid into the injection means provided near the production well for that purpose.

Eighty percent quality steam at a temperature of **275°F.** and containing **0.2** percent sodium hydroxide is injected via the annular injection means into the upper portion of the formation. The injection pressure is held to **150** pounds per square inch initially, and this pressure is then reduced to approximately **100** pounds per square inch so that the overall pressure gradient within the tar sand formation still induces movement of petroleum from the injection point to the producton point. Since there is essentially no petroleum production initially, the initial injection rate of treating fluid into the formation is **500** gallons per hour. This injection rate is continued until the fluid being produced to the surface of the earth via the production string indicated the presence therein of bituminous material, indicating the block is being dissolved. The injection rate and pressure is then decreased to **200** gallons per hour and aqueous heating fluid is injected into the formation for **2** weeks at this injection rate. During this period, the fluid being produced from the production well is an emulsion of bituminous petroleum in water. The injection of aqueous heating fluid is then discontinued and it is noted that production of bituminous petroleum from the tar sand formation begins declining quite soon thereafter. Thus, it is established that production will continue only so long as injection of aqueous heating fluid is maintained on a more or less continual basis in order to avoid plugging due to solidification of hydrocarbons in the formation near the production well. Injection of **2000** pounds of steam containing **0.15** percent sodium hydroxide every **4** hours allows essentially uninterrupted production of bitumen.

While our invention has been described in terms of a number of specific illustrative embodiments, it should be understood that it is not so limited. Numerous variations of the process of our invention will be apparent to those skilled in the related art without departing from the true spirit and scope of our invention, and it is intended that our invention be limited only by such restrictions and limitations as are imposed in the appended claims.

We claim:

1. In a method of recovering viscous petroleum including bitumen from a subterranean, viscous petroleum-containing formation including tar sand deposits, said formation being penetrated by at least two spaced apart wells, at least one of which is an injection well and at least one of which is a production well in fluid communication with the lower portion of the formation, said process being of the type wherein a fluid is injected via said injection well into the petroleum formation for the purpose of increasing the mobility of the petroleum contained therein, wherein the improvement for removing immobile hydrocarbon deposits from the formation in the vicinity of the production well, which deposits are obstructing the flow of petroleum mobilized by the fluid injected into the formation via the injection well are obstructing the flow of petroleum into the production well comprises:

a. providing a liquid injection flow path from the surface separate from the production flow path of the production well and adjacent thereto, said injection means being in fluid communication with the upper portion of the viscous petroleum-containing formation near the production well;

b. injecting an aqueous heating liquid into the upper portion of the viscous petroleum-containing formation in the vicinity of the production well at a pressure less than the pressure at which fluid is injected into the injection well to mobilize viscous petroleum, said heating liquid being injected via said liquid injection flow path adjacent the production well, said liquid being capable of increasing the mobility of the immobile hydrocarbon materials in the vicinity of the production wellbore; and

c. recovering the injected aqueous heating liquid, mobilizing fluid and formation petroleum from the lower portion of the formation via the production well.

2. A method as recited in claim **1** wherein the aqueous heating liquid is hot water.

3. A method as recited in claim **1** wherein the injected aqueous heating liquid also contains an alkaline material.

4. A method as recited in claim **3** wherein the alkaline material included with the injected aqueous heating liquid is sodium hydroxide.

5. A method as recited in claim **1** wherein the injected aqueous heating liquid also contains a surfactant.

6. A method as recited in claim **1** wherein the viscous petroleum-containing formation is a tar sand deposit.

7. A method as recited in claim **1** wherein the aqueous heating liquid is injected continuously.

8. A method as recited in claim **1** wherein the aqueous heating liquid is injected intermittently.

9. A method as recited in claim **8** comprising the additional step of monitoring the petroleum production rate and initiating injecting the aqueous heating liquid in response to a drop in petroleum production rate below a preselected value.

10. A method as recited in claim **1** wherein the annular space between the casing and the tubing in the production well is used as the separate flow path for injecting the aqueous heating liquid.

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