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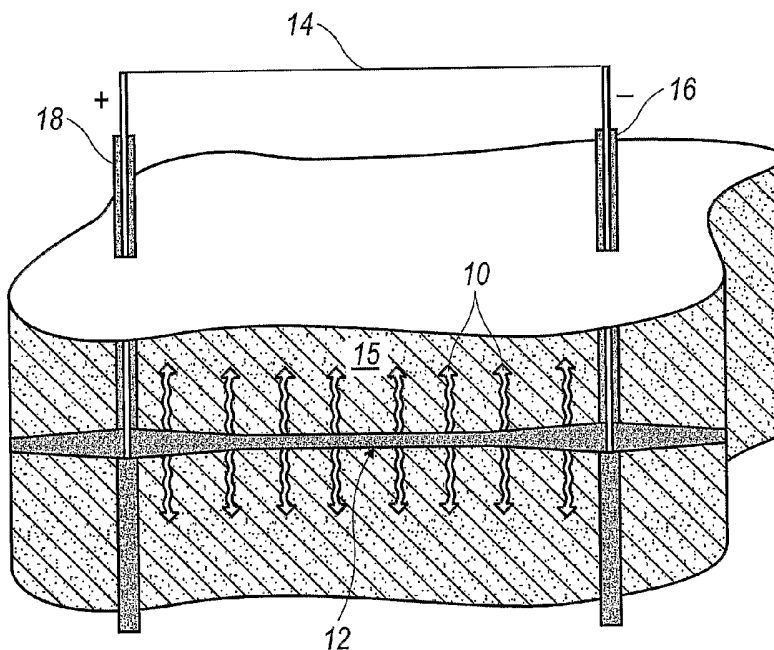
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(54) Title: METHODS OF TREATING A SUBTERRANEAN FORMATION TO CONVERT ORGANIC MATTER INTO PRODUCIBLE HYDROCARBONS



(57) Abstract: Methods are provided that include the steps of providing wells in a formation, establishing one or more fractures (12) in the formation, such that each fracture intersects at least one of the wells (16, 18), placing electrically conductive material in the fractures, and generating electric current through the fractures and through the material such that sufficient heat (10) is generated by electrical resistivity within the material to pyrolyze organic matter in the formation into producible hydrocarbons.



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**METHODS OF TREATING A SUBTERRANEAN FORMATION
TO CONVERT ORGANIC MATTER INTO PRODUCIBLE
HYDROCARBONS**

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FIELD OF THE INVENTION

This invention relates to methods of treating a subterranean formation to convert organic matter into producible hydrocarbons. More particularly, this invention relates to such methods that include the steps of providing wells in the formation, establishing fractures in the formation, such that each fracture intersects at least one of the wells, placing electrically conductive material in the fractures, and generating electric current through the fractures and through the electrically conductive material such that sufficient heat is generated by electrical resistivity within the electrically conductive material to pyrolyze organic matter into producible hydrocarbons.

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BACKGROUND OF THE INVENTION

A Table of References is provided herein, immediately preceding the claims. All REF. numbers referred to herein are identified in the Table of References.

Oil shales, source rocks, and other organic-rich rocks contain kerogen, a solid hydrocarbon precursor that will convert to producible oil and gas upon heating. Production of oil and gas from kerogen-containing rocks presents two primary problems. First, the solid kerogen must be converted to oil and gas that will flow through the rock. When kerogen is heated, it undergoes pyrolysis, chemical reactions that break bonds and form smaller molecules like oil and gas. The second problem with producing hydrocarbons from oil shales and other organic-rich rocks is that these rocks typically have very low permeability. By heating the rock and transforming the kerogen to oil and gas, the permeability is increased.

Several technologies have been proposed for attempting to produce oil and gas from kerogen-containing rocks.

Near-surface oil shales have been mined and retorted at the surface for over a century. In 1862, James Young began processing Scottish oil shales, and that industry lasted for about 100 years. Commercial oil shale retorting has also been conducted in other countries such as Australia, Brazil, China, Estonia, France, Russia, South
5 Africa, Spain, and Sweden. However, the practice has been mostly discontinued in recent years because it proved to be uneconomic or because of environmental constraints on spent shale disposal (REF. 26). Further, surface retorting requires mining of the oil shale, which limits application to shallow formations.

Techniques for in situ retorting of oil shale were developed and pilot tested
10 with the Green River oil shale in the United States. In situ processing offers advantages because it reduces costs associated with material handling and disposal of spent shale. For the in situ pilots, the oil shale was first rubblized and then combustion was carried out by air injection. A rubble bed with substantially uniform fragment size and substantially uniform distribution of void volume was a key success
15 factor in combustion sweep efficiency. Fragment size was of the order of several inches.

Two modified in situ pilots were performed by Occidental and Rio Blanco (REF. 1; REF. 21). A portion of the oil shale was mined out to create a void volume, and then the remaining oil shale was rubblized with explosives. Air was injected at
20 the top of the rubble chamber, the oil shale was ignited, and the combustion front moved down. Retorted oil ahead of the front drained to the bottom and was collected there.

In another pilot, the "true" in situ GEOKINETICS process produced a rubblized volume with carefully designed explosive placement that lifted a 12-meter overburden (REF. 23). Air was injected via wellbores at one end of the rubblized
25 volume, and the combustion front moved horizontally. The oil shale was retorted ahead of the burn; oil drained to the bottom of the rubblized volume and to production wells at one end.

Results from these in situ combustion pilots indicated technical success, but the methods were not commercialized because they were deemed uneconomic. Oil shale rubblization and air compression were the primary cost drivers.

A few authors and inventors have proposed in situ combustion in fractured oil
5 shales, but field tests, where performed, indicated a limited reach from the wellbore (REF. 10; REF. 11; REF. 17).

An in situ retort by thermal conduction from heated wellbores approach was invented by Ljungstrom in 1940 and pioneered by the Swedish Shale Oil Co. with a full scale plant that operated from 1944 into the 1950's (REF. 19; REF. 24). The
10 process was applied to a permeable oil shale at depths of 6 to 24 m near Norrtorp, Sweden. The field was developed with hexagonal patterns, with six heater wells surrounding each vapor production well. Wells were 2.2 m apart. Electrical resistance heaters in wellbores provided heat for a period of five months, which raised the temperature at the production wells to about 400°C. Hydrocarbon vapor
15 production began when the temperature reached 280°C and continued beyond the heating period. The vapors condensed to a light oil product having a specific gravity of 0.87.

Van Meurs and others further developed the approach of conductive heating from wellbores (REF. 24). They patented a process to apply the approach to
20 impermeable oil shales with heater wells at 600°C and well spacings greater than 6 m. They propose that the heat-injection wells may be heated either by electrical resistance heaters or by gas-fired combustion heaters. The inventors performed field tests in an outcropping oil shale formation with wells 6 to 12 m deep and 0.6 m apart. After three months, temperatures reached 300°C throughout the test area. Oil yields
25 were 90% of Fischer Assay. The inventors observed that permeability increased between the wellbores, and they suggest that it may be a result of horizontal fractures formed by the volume expansion of the kerogen to hydrocarbon reaction.

Because conductive heating is limited to distances of several meters, conductive heating from wellbores must be developed with very closely spaced wells.

This limits economic application of the process to very shallow oil shales (low well costs) and/or very thick oil shales (higher yield per well).

Covell and others proposed retorting a rubblized bed of oil shale by gasification and combustion of an underlying coal seam (REF. 5). Their process
5 named Total Resource Energy Extraction (TREE), called for upward convection of hot flue gases (727°C) from the coal seam into the rubblized oil shale bed. Models predicted an operating time of 20 days, and an estimated oil yield of 89% of Fischer Assay. Large-scale experiments with injection of hot flue gases into beds of oil shale blocks showed considerable coking and cracking, which reduced oil recovery to 68%
10 of Fischer Assay. As with the in situ oil shale retorts, the oil shale rubblization involved in this process limits it to shallow oil shales and is expensive.

Passey et al. describe a process to produce hydrocarbons from organic-rich rocks by carrying out in situ combustion of oil in an adjacent reservoir (REF. 16). The organic-rich rock is heated by thermal conduction from the high temperatures
15 achieved in the adjacent reservoir. Upon heating to temperatures in excess of 250°C, the kerogen in the organic-rich rocks is transformed to oil and gas, which are then produced. The permeability of the organic-rich rock increases as a result of the kerogen transformation. This process is limited to organic-rich rocks that have an oil reservoir in an adjacent formation.

20 In an in situ retort by electromagnetic heating of the formation, electromagnetic energy passes through the formation, and the rock is heated by electrical resistance or by the absorption of dielectric energy. To our knowledge it has not been applied to oil shale, but field tests have been performed in heavy oil formations.

25 The technical capability of resistive heating within a subterranean formation has been demonstrated in a heavy-oil pilot test where "electric preheat" was used to flow electric current between two wells to lower viscosity and create communication channels between wells for follow-up with a steam flood (REF. 4). Resistive heating within a subterranean formation has been patented and applied commercially by

running alternating current or radio frequency electrical energy between stacked conductive fractures or electrodes in the same well (REF. 14; REF. 6; REF. 15; REF. 12). REF. 7 includes a description of resistive heating within a subterranean formation by running alternating current between different wells. Others have
5 described methods to create an effective electrode in a wellbore (REF. 20; REF. 8). REF. 27 describes a method by which electric current is flowed through a fracture connecting two wells to get electric flow started in the bulk of the surrounding formation; heating of the formation occurs primarily due to the bulk electrical resistance of the formation.

10 Resistive heating of the formation with low-frequency electromagnetic excitation is limited to temperatures below the in situ boiling point of water to maintain the current-carrying capacity of the rock. Therefore, it is not applicable to kerogen conversion where much higher temperatures are required for conversion on production timeframes.

15 High-frequency heating (radio or microwave frequency) offers the capability to bridge dry rock, so it may be used to heat to higher temperatures. A small-scale field experiment confirmed that high temperatures and kerogen conversion could be achieved (REF. 2). Penetration is limited to a few meters (REF. 25), so this process would require many wellbores and is unlikely to yield economic success.

20 In these methods that utilize an electrode to deliver electrical excitation directly to the formation, electrical energy passes through the formation and is converted to heat. One patent proposes thermal heating of a gas hydrate from an electrically conductive fracture proppant in only one well, with current flowing into the fracture and presumably to ground (REF. 9).

25 Even in view of currently available and proposed technologies, it would be advantageous to have improved methods of treating subterranean formations to convert organic matter into producible hydrocarbons.

Therefore, an object of this invention is to provide such improved methods. Other objects of this invention will be made apparent by the following description of the invention.

SUMMARY OF THE INVENTION

5 Methods of treating a subterranean formation that contains solid organic matter are provided. In one embodiment, a method according to this invention comprises the steps of: (a) providing one or more wells that penetrate a treatment interval within the subterranean formation; (b) establishing at least one fracture from at least one of said wells, whereby said fracture intersects at least one of said wells; (c) placing electrically
10 conductive material in said fracture; and (d) passing electric current through said fracture such that said current passes through at least a portion of said electrically conductive material and sufficient heat is generated by electrical resistivity within said portion of said electrically conductive material to pyrolyze at least a portion of said solid organic matter into producible hydrocarbons. In one embodiment, said electrically conductive
15 material comprises a proppant. In one embodiment, said electrically conductive material comprises a conductive cement. In one embodiment, one or more of said fractures intersects at least two of said wells. In one embodiment, said subterranean formation comprises oil shale. In one embodiment, said well is substantially vertical. In one embodiment, said well is substantially horizontal. In one embodiment, said fracture is
20 substantially horizontal. In one embodiment, said fracture is substantially vertical. In one embodiment, said fracture is substantially longitudinal to the well from which it is established.

 In one embodiment of this invention, a method of treating a subterranean formation that contains solid organic matter is provided wherein said method comprises
25 the steps of: (a) providing one or more wells that penetrate a treatment interval within the subterranean formation; (b) establishing at least one fracture from at least one of said wells, whereby said fracture intersects at least one of said wells; (c) placing electrically conductive proppant material in said fracture; and (d) passing electric current through said fracture such that said current passes through at least a portion of said electrically
30 conductive proppant material and sufficient heat is generated by electrical resistivity

within said portion of said electrically conductive proppant material to pyrolyze at least a portion of said solid organic matter into producible hydrocarbons.

In another embodiment, a method of treating a subterranean formation that contains solid organic matter is provided wherein said method comprises the steps of: (a) providing two or more wells that penetrate a treatment interval within the subterranean formation; (b) establishing at least one fracture from at least one of said wells, whereby said fracture intersects at least two of said wells; (c) placing electrically conductive material in said fracture; and (d) passing electric current through said fracture such that said current passes through at least a portion of said electrically conductive material and sufficient heat is generated by electrical resistivity within said portion of said electrically conductive material to pyrolyze at least a portion of said solid organic matter into producible hydrocarbons.

In another embodiment, a method of treating a subterranean formation that contains solid organic matter is provided wherein said method comprises the steps of: (a) providing two or more wells that penetrate a treatment interval within the subterranean formation; (b) establishing at least one fracture from at least one of said wells, whereby said fracture intersects at least two of said wells; (c) placing electrically conductive proppant material in said fracture; and (d) passing electric current through said fracture such that said current passes through at least a portion of said electrically conductive proppant material and sufficient heat is generated by electrical resistivity within said portion of said electrically conductive proppant material to pyrolyze at least a portion of said solid organic matter into producible hydrocarbons.

In another embodiment, a method of treating a heavy oil or tar sand subterranean formation containing hydrocarbons is provided wherein said method comprises the steps of: (a) providing one or more wells that penetrate a treatment interval within the subterranean formation; (b) establishing at least one fracture from at least one of said wells, whereby said fracture intersects at least one of said wells; (c) placing electrically conductive material in said fracture; and (d) passing electric current through said fracture such that said current passes through at least a portion of said electrically conductive material and sufficient heat is generated by electrical resistivity

within said portion of said electrically conductive material to reduce the viscosity of at least a portion of said hydrocarbons.

This invention uses an electrically conductive material as a resistive heater. Electrical current flows primarily through the resistive heater comprised of the electrically conductive material. Within the resistive heater, electrical energy is converted to thermal energy, and that energy is transported to the formation by thermal conduction.

Broadly, the invention is a process that generates hydrocarbons from organic-rich rocks (i.e., source rocks, oil shale). The process utilizes electric heating of the organic-rich rocks. An in situ electric heater is created by delivering electrically conductive material into a fracture in the organic matter containing formation in which the process is applied. In describing this invention, the term "hydraulic fracture" is used. However, this invention is not limited to use in hydraulic fractures. The invention is suitable for use in any fracture, created in any manner considered to be suitable by one skilled in the art. In one embodiment of this invention, as will be described along with the drawings, the electrically conductive material may comprise a proppant material; however, this invention is not limited thereto. FIG. 1 shows an example application of the process in which heat 10 is delivered via a substantially horizontal hydraulic fracture 12 propped with essentially sand-sized particles of an electrically conductive material (not shown in FIG. 1). A voltage 14 is applied across two wells 16 and 18 that penetrate the fracture 12. An AC voltage 14 is preferred because AC is more readily generated and minimizes electrochemical corrosion, as compared to DC voltage. However, any form of electrical energy, including without limitation, DC, is suitable for use in this invention. Propped fracture 12 acts as a heating element; electric current passed through it generates heat 10 by resistive heating. Heat 10 is transferred by thermal conduction to organic-rich rock 15 surrounding fracture 12. As a result, organic-rich rock 15 is heated sufficiently to convert kerogen contained in rock 15 to hydrocarbons. The generated hydrocarbons are then produced using well-known production methods. FIG. 1 depicts the process of this invention with a single horizontal hydraulic fracture 12 and one pair of vertical wells 16, 18. The process of this invention is not limited to the embodiment shown in

FIG. 1. Possible variations include the use of horizontal wells and/or vertical fractures. Commercial applications might involve multiple fractures and several wells in a pattern or line-drive formation. The key feature distinguishing this invention from other treatment methods for formations that contain organic matter is that an in situ heating element is created by the delivery of electric current through a fracture containing electrically conductive material such that sufficient heat is generated by electrical resistivity within the material to pyrolyze at least a portion of the organic matter into producible hydrocarbons.

Any means of generating the voltage/current through the electrically conductive material in the fractures may be employed, as will be familiar to those skilled in the art. Although variable with organic-rich rock type, the amount of heating required to generate producible hydrocarbons, and the corresponding amount of electrical current required, can be estimated by methods familiar to those skilled in the art. Kinetic parameters for Green River oil shale, for example, indicate that for a heating rate of 100°C (180°F) per year, complete kerogen conversion will occur at a temperature of about 324°C (615°F). Fifty percent conversion will occur at a temperature of about 291°C (555°F). Oil shale near the fracture will be heated to conversion temperatures within months, but it is likely to require several years to attain thermal penetration depths required for generation of economic reserves.

During the thermal conversion process, oil shale permeability is likely to increase. This may be caused by the increased pore volume available for flow as solid kerogen is converted to liquid or gaseous hydrocarbons, or it may result from the formation of fractures as kerogen converts to hydrocarbons and undergoes a substantial volume increase within a confined system. If initial permeability is too low to allow release of the hydrocarbons, excess pore pressure will eventually cause fractures.

The generated hydrocarbons may be produced via the same wells by which the electric power is delivered to the conductive fracture, or additional wells may be used. Any method of producing the producible hydrocarbons may be used, as will be familiar to those skilled in the art.

DESCRIPTION OF THE DRAWINGS

The advantages of the present invention will be better understood by referring to the following detailed description and the attached drawings in which:

FIG. 1 illustrates one embodiment of this invention;

5 FIG. 2 illustrates another embodiment of this invention; and

FIG. 3, FIG. 4, and FIG. 5, illustrate a laboratory experiment conducted to test a method according to this invention.

While the invention will be described in connection with its preferred embodiments, it will be understood that the invention is not limited thereto. On the
10 contrary, the invention is intended to cover all alternatives, modifications, and equivalents which may be included within the spirit and scope of the present disclosure, as defined by the appended claims.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to FIG. 2, a preferred embodiment of this invention is
15 illustrated. FIG. 2 shows an example application of the process in which heat is delivered via a plurality of substantially vertical hydraulic fractures **22** propped with particles of an electrically conductive material (not shown in FIG. 2). Each hydraulic fracture **22** is longitudinal to the well from which it is established. A voltage **24** is applied across two or more wells **26**, **28** that penetrate the fractures **22**. In this
20 embodiment, wells **26** are substantially horizontal and wells **28** are substantially vertical. An AC voltage **24** is preferred because AC is more readily generated and minimizes electrochemical corrosion, as compared to DC voltage. However, any form of electrical energy, including without limitation, DC, is suitable for use in this invention. As shown in FIG. 2, in this embodiment the positive ends of the electrical
25 circuits generating voltage **24** are at wells **26** and the negative ends of the circuits are at wells **28**. Propped fractures **22** act as heating elements; electric current passed through propped fractures **22** generate heat by resistive heating. This heat is transferred by thermal conduction to organic-rich rock **25** surrounding fractures **22**.

As a result, organic-rich rock **25** is heated sufficiently to convert kerogen contained in rock **25** to hydrocarbons. The generated hydrocarbons are then produced using well-known production methods. Using this embodiment of the invention, as compared to the embodiment illustrated in FIG. 1, a greater volume of organic-rich rock can be heated and the heating can be made more uniform, causing a smaller volume of organic-rich rock to be heated in excess of what is required for complete kerogen conversion. The embodiment illustrated in FIG. 2 is not intended to limit any aspect of this invention.

Fractures into which conductive material is placed may be substantially vertical or substantially horizontal. Such a fracture may be, but is not required to be, substantially longitudinal to the well from which it is established.

Any suitable materials may be used as the electrically conducting fracture proppant. To be suitable, a candidate material preferably meets several criteria, as will be familiar to those skilled in the art. The electrical resistivity of the proppant bed under anticipated in situ stresses is preferably high enough to provide resistive heating while also being low enough to conduct the planned electric current from one well to another. The proppant material also preferably meets the usual criteria for fracture proppants: e.g., sufficient strength to hold the fracture open, and a low enough density to be pumped into the fracture. Economic application of the process may set an upper limit on acceptable proppant cost. Any suitable proppant material or electrically conductive material may be used, as will be familiar to those skilled in the art. Three suitable classes of proppant comprise (i) thinly metal-coated sands, (ii) composite metal/ceramic materials, and (iii) carbon based materials. A suitable class of non-proppant electrically conductive material comprises conductive cements. More specifically, green or black silicon carbide, boron carbide, or calcined petroleum coke may be used as a proppant. One skilled in the art has the ability to select a suitable proppant or non-proppant electrically conductive material for use in this invention. The electrically conductive material is not required to be homogeneous, but may comprise a mixture of two or more suitable electrically conductive materials.

30 EXAMPLE

A laboratory test was conducted and the test results show that this invention successfully transforms kerogen in a rock into producible hydrocarbons in the laboratory. Referring now to FIG. 3 and FIG. 4, a core sample 30 was taken from a kerogen-containing subterranean formation. As illustrated in FIG. 3, core sample 30 was cut into two portions 32 and 34. A tray 36 having a depth of about .25 mm (1/16 inch) was carved into sample portion 32 and a proxy proppant material 38 (#170 cast steel shot having a diameter of about .1 mm (0.02 inch)) was placed in tray 36. As illustrated, a sufficient quantity of proppant material 38 to substantially fill tray 36 was used. Electrodes 35 and 37 were placed in contact with proppant material 38, as shown. As shown in FIG. 4, sample portions 32 and 34 were placed in contact, as if to reconstruct core sample 30, and placed in a stainless steel sleeve 40 held together with three stainless steel hose clamps 42. The hose clamps 42 were tightened to apply stress to the proxy proppant (not seen in FIG. 4), just as the proppant would be required to support in situ stresses in a real application. A thermocouple (not shown in the FIGs.) was inserted into core sample 30 about mid-way between tray 36 and the outer diameter of core sample 30. The resistance between electrodes 35 and 37 was measured at 822 ohms before any electrical current was applied.

The entire assembly was then placed in a pressure vessel (not shown in the FIGs.) with a glass liner that would collect any generated hydrocarbons. The pressure vessel was equipped with electrical feeds. The pressure vessel was evacuated and charged with Argon at 500 psi to provide a chemically inert atmosphere for the experiment. Electrical current in the range of 18 to 19 amps was applied between electrodes 35 and 37 for 5 hours. The thermocouple in core sample 30 measured a temperature of 268°C after about 1 hour and thereafter tapered off to about 250°C. Using calculation techniques that are well known to those skilled in the art, the high temperature reached at the location of tray 36 was from about 350°C to about 400°C.

After the experiment was completed and the core sample 30 had cooled to ambient temperature, the pressure vessel was opened and 0.15 ml of oil was recovered from the bottom of the glass liner within which the experiment was conducted. The core sample 30 was removed from the pressure vessel, and the resistance between

electrodes **35** and **37** was again measured. This post-experiment resistance measurement was 49 ohms.

FIG. 5 includes (i) chart **52** whose ordinate **51** is the electrical power, in watts, consumed during the experiment, and whose abscissa **53** shows the elapsed time in minutes during the experiment; (ii) chart **62** whose ordinate **61** is the temperature in degrees Celsius measured at the thermocouple in the core sample **30** (FIGS. 3 and 4) throughout the experiment, and whose abscissa **63** shows the elapsed time in minutes during the experiment; and (iii) chart **72** whose ordinate **71** is the resistance in ohms measured between electrodes **35** and **37** (FIGS. 3 and 4) during the experiment, and whose abscissa **73** shows the elapsed time in minutes during the experiment. Only resistance measurements made during the heating experiment are included in chart **72**, the pre-experiment and post-experiment resistance measurements (822 and 49 ohms) are omitted.

After the core sample **30** cooled to ambient temperature, it was removed from the pressure vessel and disassembled. The proxy proppant **38** was observed to be impregnated in several places with tar-like hydrocarbons or bitumen, which were generated from the oil shale during the experiment. A cross section was taken through a crack that developed in the core sample **30** because of thermal expansion during the experiment. A crescent shaped section of converted oil shale adjacent to the proxy proppant **38** was observed.

Although this invention is applicable to transforming solid organic matter into producible hydrocarbons in oil shale, this invention may also be applicable to heavy oil reservoirs, or tar sands. In these instances, the electrical heat supplied would serve to reduce hydrocarbon viscosity. Additionally, while the present invention has been described in terms of one or more preferred embodiments, it is to be understood that other modifications may be made without departing from the scope of the invention, which is set forth in the claims below.

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We Claim:

1. A method of treating a subterranean formation that contains solid organic matter, said method comprising:
 - (a) providing one or more wells that penetrate a treatment interval within the subterranean formation;
 - (b) establishing at least one fracture from at least one of said wells, whereby said fracture intersects at least one of said wells;
 - (c) placing electrically conductive material in said fracture; and
 - (d) passing electric current through said fracture such that said current passes through at least a portion of said electrically conductive material and sufficient heat is generated by electrical resistivity within said portion of said electrically conductive material to pyrolyze at least a portion of said solid organic matter into producible hydrocarbons.
2. The method of claim 1 wherein said subterranean formation comprises oil shale.
3. The method of claim 1 wherein said wells are substantially vertical.
4. The method of claim 1 wherein said wells are substantially horizontal.
5. The method of claim 1 wherein said fracture is substantially horizontal.
6. The method of claim 1 wherein said fracture is substantially vertical.
7. The method of claim 1 wherein said fracture is substantially longitudinal to the well from which it is established.
8. The method of claim 1 wherein said electrically conductive material comprises a proppant material.

9. The method of claim 1 wherein said electrically conductive material comprises a conductive cement.

10. A method of treating a subterranean formation that contains solid organic matter, said method comprising:

- 5 (a) providing one or more wells that penetrate a treatment interval within the subterranean formation;
- (b) establishing at least one fracture from at least one of said wells, whereby said fracture intersects at least one of said wells;
- (c) placing electrically conductive proppant material in said fracture; and
- 10 (d) passing electric current through said fracture such that said current passes through at least a portion of said electrically conductive proppant material and sufficient heat is generated by electrical resistivity within said portion of said electrically conductive proppant material to pyrolyze at least a portion of said solid
- 15 organic matter into producible hydrocarbons.

11. A method of treating a subterranean formation that contains solid organic matter, said method comprising:

- (a) providing two or more wells that penetrate a treatment interval within the subterranean formation;
- 20 (b) establishing at least one fracture from at least one of said wells, whereby said fracture intersects at least two of said wells;
- (c) placing electrically conductive material in said fracture; and
- (d) passing electric current through said fracture such that said current passes through at least a portion of said electrically conductive material
- 25 and sufficient heat is generated by electrical resistivity within said portion of said electrically conductive material to pyrolyze at

least a portion of said solid organic matter into producible hydrocarbons.

12. A method of treating a subterranean formation that contains solid organic matter, said method comprising:

- 5 (a) providing two or more wells that penetrate a treatment interval within the subterranean formation;
- (b) establishing at least one fracture from at least one of said wells, whereby said fracture intersects at least two of said wells;
- (c) placing electrically conductive proppant material in said fracture; and
- 10 (d) passing electric current through said fracture such that said current passes through at least a portion of said electrically conductive proppant material and sufficient heat is generated by electrical resistivity within said portion of said electrically conductive proppant material to pyrolyze at least a portion of said solid
- 15 organic matter into producible hydrocarbons.

13. A method of treating a heavy oil or tar sand subterranean formation containing hydrocarbons, said method comprising:

- (a) providing one or more wells that penetrate a treatment interval within the subterranean formation;
- 20 (b) establishing at least one fracture from at least one of said wells, whereby said fracture intersects at least one of said wells;
- (c) placing electrically conductive material in said fracture; and
- (d) passing electric current through said fracture such that said current passes through at least a portion of said electrically conductive material
- 25 and sufficient heat is generated by electrical resistivity within said

portion of said electrically conductive material to reduce the viscosity of at least a portion of said hydrocarbons.

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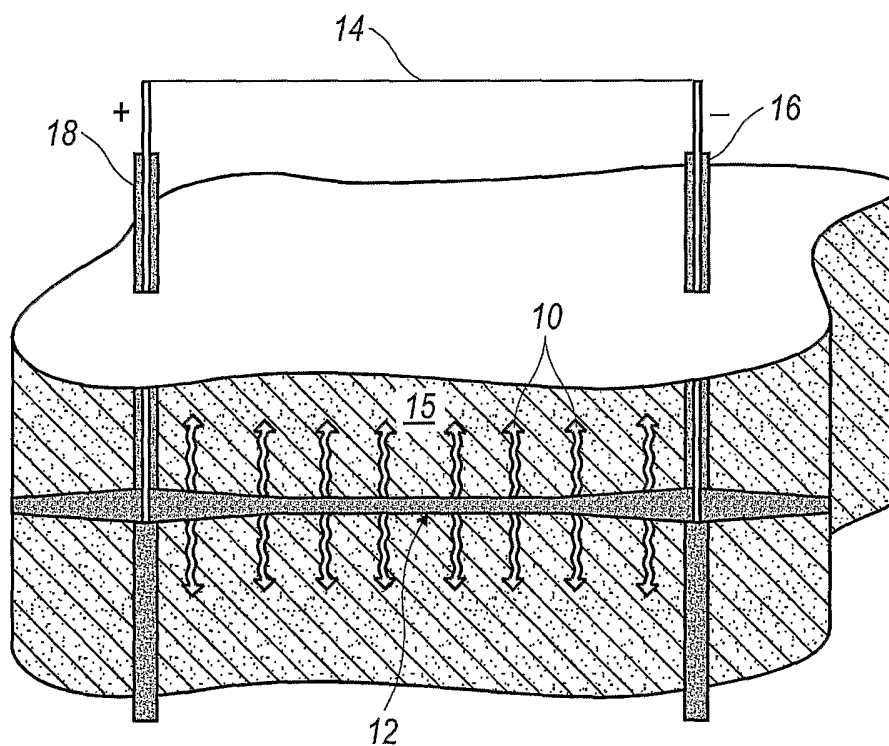


FIG. 1

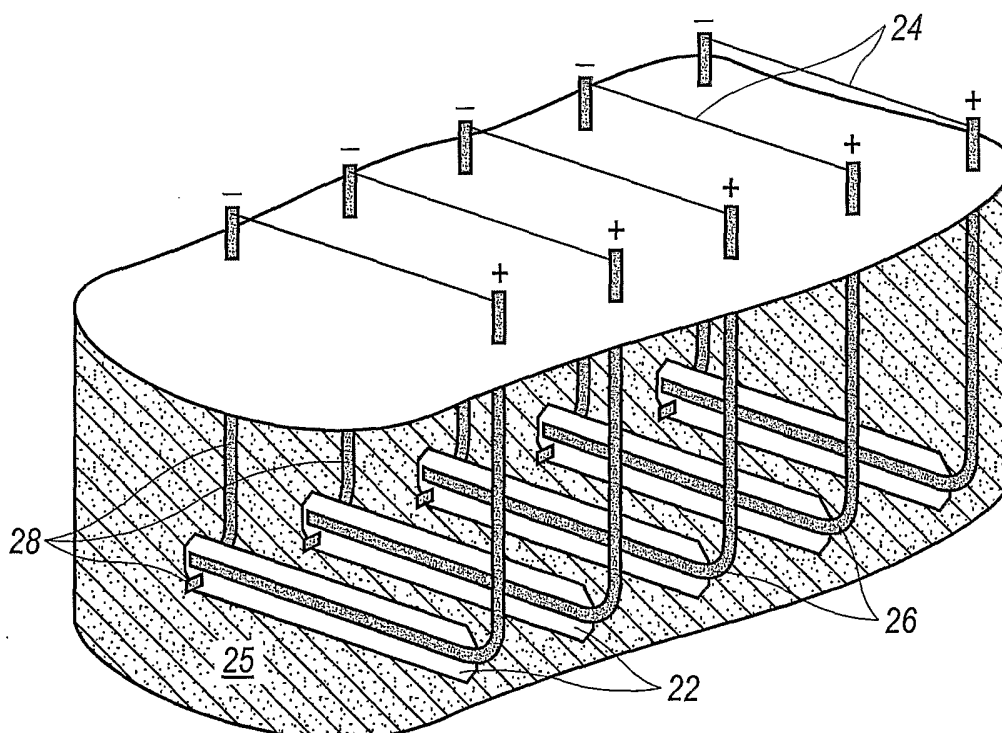


FIG. 2

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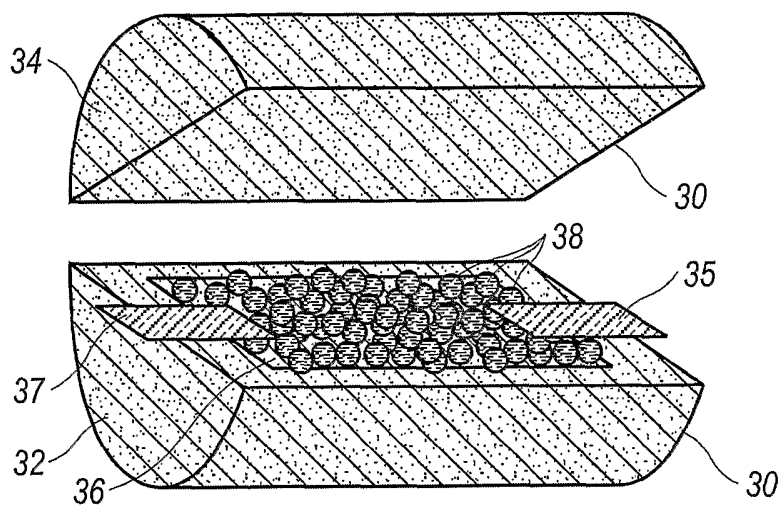


FIG. 3

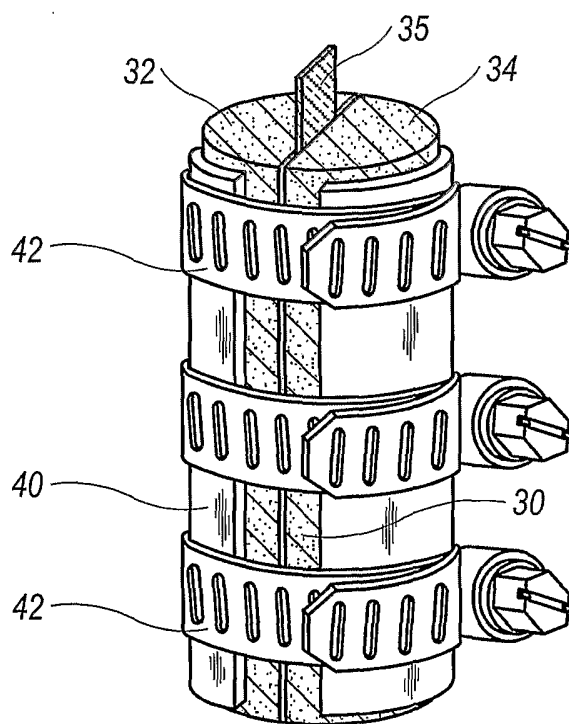


FIG. 4

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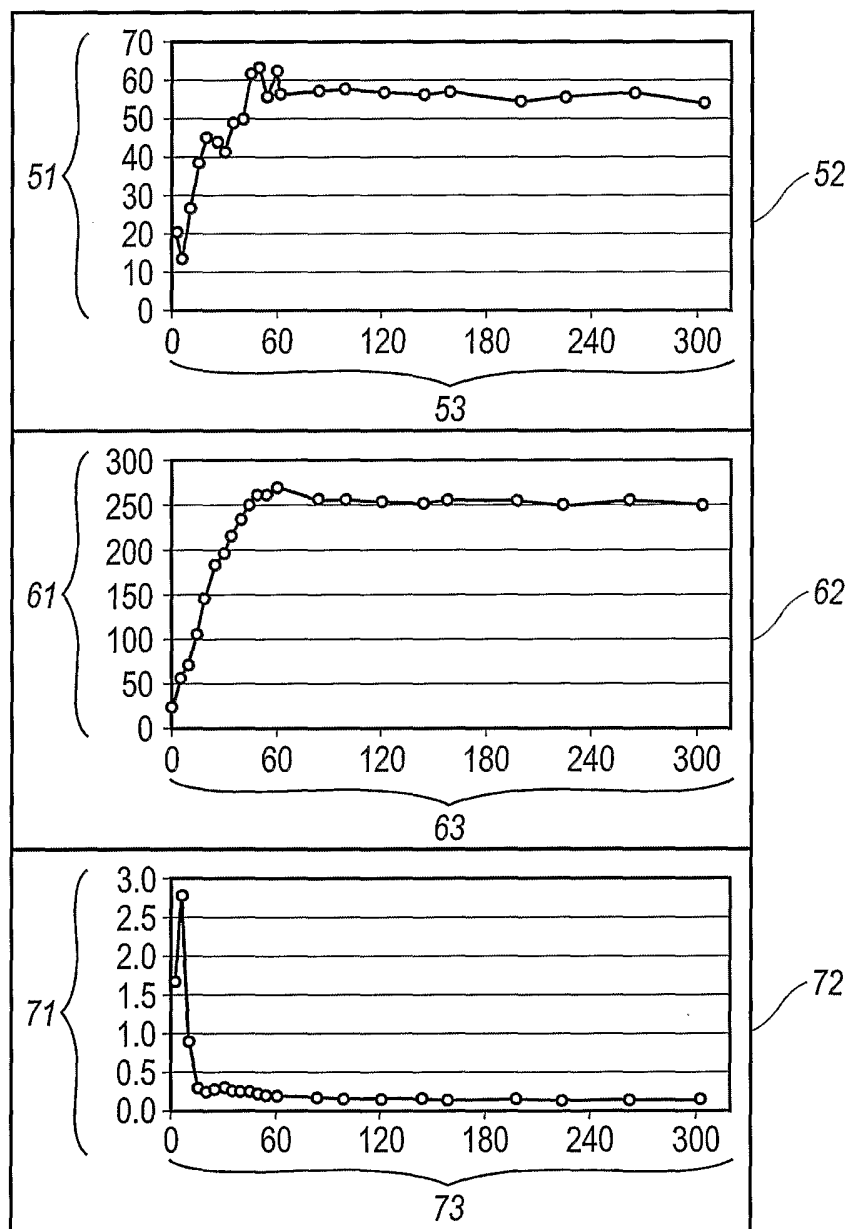


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No

PCT/US04/11508

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) E21B 43/12
 US CL 166/248, 272 1, 272 2

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U S 166/248, 272 1, 272 2, 271, 263, 279, 308

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
 WEST

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No
X --- Y	US 6,148,911 a(Gipson et al) 21 Nov 2000, abstract, Figs 1, 2, Col. 1, lines, 18-48, col. 2, lines 23-35, col 2, lines 55-col 5, line 17	1, 3-8, 10-13 ----- 2, 9
X --- Y	US 5,620,049A(Gipson et al) 15 Apr 1997, abstract, Fig 1, col. 1, lines 8-30; col 2, line 25, col. 4, line 41.	1,3-8, 10-13 ----- 2, 9
Y	US 4,926,941 A (Glandt et al)Fig 2, col 4, line 62-col. 5, line 64	2, 9
A	US 4,412,585A (Bouck) 1 Nov. 1983, entire document	1-13

☐ Further documents are listed in the continuation of Box C☐ See patent family annex

* Special categories of cited documents	
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"E" earlier application or patent published on or after the international filing date	"X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

08 August 2004 (08 08 2004)

Date of mailing of the international search report

05 JAN 2005

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