(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 551 839 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
16.09.2020 Bulletin 2020/38

(21) Application number: **17822858.1**

(22) Date of filing: **07.12.2017**

(51) Int Cl.:
E21B 36/00 *(2006.01)* ***E21B 36/04*** *(2006.01)*
E21B 43/26 *(2006.01)*

(86) International application number:
PCT/US2017/065003

(87) International publication number:
WO 2018/106857 (14.06.2018 Gazette 2018/24)

(54) **DOWNHOLE WELLBORE HIGH POWER LASER HEATING AND FRACTURING STIMULATION AND METHODS**

BOHRLOCHHOCHLEISTUNGSLASERHEIZUNG IM BOHRLOCH UND FRAKTURIERUNGSSTIMULATION UND VERFAHREN

STIMULATION ET PROCÉDÉS DE FRACTURATION ET DE CHAUFFAGE AU LASER DE HAUTE PUISSANCE DE PUITS DE FORAGE DE FOND DE TROU

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **08.12.2016 US 201615373070**

(43) Date of publication of application:
16.10.2019 Bulletin 2019/42

(73) Proprietor: **Saudi Arabian Oil Company**
Dhahran 31311 (SA)

(72) Inventor: **BATARSEH, Sameeh, Issa**
Dhahran 31311 (SA)

(74) Representative: **Dauncey, Mark Peter**
Marks & Clerk LLP
1 New York Street
Manchester M1 4HD (GB)

(56) References cited:
WO-A1-2016/090229
WO-A1-2016/186690
US-A- 3 977 478
US-A1- 2013 228 372
US-A1- 2014 216 728

- **Muhammad Yaseen ET AL: "The Geo-materials Fracture by Thermal Process", Thirty-Ninth Workshop on Geothermal Reservoir Engineering, 24 February 2014 (2014-02-24), pages 1-6, XP055460344, Stanford, California Retrieved from the Internet: URL:https://pangea.stanford.edu/ERE/pdf/IGAstandard/SGW/2014/Yaseen.pdf [retrieved on 2018-03-16]**

EP 3 551 839 B1

Description

TECHNICAL FIELD

[0001] Disclosed are apparatus and methods for wellbore stimulation. More specifically, embodiments related to apparatus and methods that incorporate lasers for wellbore stimulation applications.

BACKGROUND

[0002] Methods for stimulating a wellbore aim to provide a pathway for fluids to flow from the formation to the wellbore. Hydraulic fracturing is one method for stimulating a wellbore. Conventional hydraulic fracturing injects water at high pressure into the wellbore, which causes fractures of the formation. In conventional hydraulic fracturing, an explosive charge is used to perforate the casing and cementing. An explosive charge is a high impact technology that can cause compaction, deformation of the hole, and sanding and crushing the grains of the rock material. The crushed grains of rock material can be pushed into the formation, blocking the formation and reducing production.

[0003] Additionally, the use of water in conventional hydraulic fracturing is incompatible with certain types of formation, such as shale. Water in shale can cause clay swelling, which blocks flow from the formation to the wellbore.

[0004] WO 2016/186690 A1 discloses a downhole tool system including a downhole tool string configured to couple to a downhole conveyance that extends in a wellbore from a terranean surface through at least a portion of a subterranean zone, the subterranean zone including a geologic formation; and a heating device coupled with the downhole tool string, the heating device, which may be a laser delivery device, configured to transfer heat to the geologic formation in the wellbore at a specified temperature sufficient to adjust a quality of the geologic formation associated with a rock strength of the geologic formation.

SUMMARY OF THE INVENTION

[0005] Disclosed are apparatus and methods for wellbore stimulation. More specifically, embodiments related to apparatus and methods that incorporate lasers for wellbore stimulation applications.

[0006] In a first aspect, a system for fracturing a formation from a wellbore extending into the formation from a surface is provided. The system includes a laser surface unit located on the surface, the laser surface unit configured to generate a laser beam, a fiber optic cable optically connected to a laser delivery device of a thermal shocking tool, the fiber optic cable configured to transmit the laser beam to the laser delivery device to produce a focused laser beam, a power cable electrically connected to a power source on the surface, the power cable configured to transmit electrical energy to a motor, a fluid line connected to a cooling fluid source on the surface, the fluid line configured to supply a cooling fluid to a cooling system of the thermal shocking tool to produce a cooling fluid stream, a protective shaft extending into the wellbore, wherein the fiber optic cable, the power cable, and the fluid line are contained within the protective shaft, the motor configured to rotate a motor shaft, and the thermal shocking tool physically connected to the motor. The thermal shocking tool includes a protective case configured to encompass the laser delivery device and the cooling system, a rotational shaft connected to the motor shaft such that as the motor shaft rotates the rotational shaft rotates, the laser delivery device extending perpendicularly from the rotational shaft, the laser delivery device configured to transform the laser beam to a focused laser beam, wherein the focused laser beam is operable to increase the temperature of the formation to a fracture temperature, and the cooling system extending perpendicularly from the rotational shaft at a position 180 degrees around the axis formed by rotational shaft from the laser delivery device, the cooling system comprising one or more cooling nozzles extending through the protective case such that the one or more cooling nozzles are configured to introduce the cooling fluid stream onto the formation such that the cooling fluid stream reduces the temperature of the formation, where the laser delivery device and the cooling system rotate around the wellbore as the rotational shaft rotates, where rotation of the rotational shaft is configured to alternate between increasing the temperature of the formation and reducing the temperature of the formation such that thermal shocks occur and fractures are formed in the formation.

[0007] In certain aspects, the system further includes a purge nozzle, the purge nozzle positioned between the surface and the motor, where the purge nozzle is configured to keep debris from settling on the motor. In certain aspects, the cooling fluid is selected from the group consisting of nitrogen gas, liquid nitrogen, helium, air, carbon dioxide, and water. In certain aspects, the fracture temperature is 2000 deg. C. In certain aspects, the system further includes an acoustic capability. In certain aspects, the focused laser beam can increase the temperature of the formation to the fracture temperature in less than 1 second. In certain aspects, the laser delivery device can be positioned to introduce the focused laser beam to the formation at a pre-determined angle.

[0008] In a second aspect, a method for fracturing a formation from a wellbore extending into the formation from a surface is provided. The method includes the steps of introducing a focused laser beam to the formation such that the focused laser beam is operable to increase the temperature of the formation to a fracture temperature. The focused laser beam is produced by a laser delivery device extending perpendicularly from a rotational shaft. The method further includes a step of introducing a cooling fluid stream to the formation such that the cooling fluid stream is operable to reduce the temperature of the formation, where the cooling fluid stream is produced by a cooling system. The cooling system extending perpendicularly from the rotational shaft at a position 180 degrees around the axis formed by rotational shaft from the laser delivery device; and rotating the rotational shaft such that the formation is alternately exposed to the focused laser beam and the cooling fluid such that thermal shocks occur and fractures in the formation are formed.

[0009] In certain aspects, the method further includes the steps of generating a laser beam in a laser surface unit, and transmitting the laser beam from the laser surface unit to the laser delivery device through a fiber optic cable. In certain aspects, the method further includes the steps of transmitting electrical energy from a power source to a motor through a power cable, and transforming the electrical energy to mechanical energy in the motor, such that the mechanical energy rotates a motor shaft, wherein the motor shaft is connected to the rotational shaft such that as the motor shaft rotates the rotational shaft rotates. In certain aspects, the method further includes the step of measuring the sound emitted by an acoustic capability.

BRIEF DESCRPTION OF THE DRAWINGS

[0010]

FIG. 1 is a plan view of an embodiment of the laser fracturing tool.
FIG. 2 is a plan view of the laser fracturing tool including the motor and the thermal shocking tool.
FIG. 3 is a plan view of an embodiment of the thermal shocking tool.
FIG. 4 is a pictorial representation of core samples fractured by laser.

DETAILED DESCRIPTION OF THE INVENTION

[0011] Described are an apparatus and methods for fracturing a formation with a laser fracturing tool. The laser fracturing tool can be used to establish fluid communication between the wellbore and the formation to improve production of formation fluids. Advantageously, the laser fracturing tool can provide a targeted method of fracturing the formation as compared to a conventional hydraulic fracturing. The laser fracturing tool can be used to target the location of the fracture, such as targeting the angle and depth of the fracture. In addition, the laser can be located along fault lines. Advantageously, the rotation of the laser fracturing tool means the method of fracturing can be implemented around the entire circumference of the wellbore without the need to reposition the tool. Advantageously, the laser fracturing tool in the absence of a hydraulic fracturing step. The absence of hydraulic fracturing has environmental advantages as hydraulic fracturing consumes and pollutes large quantities of water. The laser fracturing tool produces less damage to the rock material of a formation than conventional hydraulic fracturing.

[0012] FIG. 1 is an elevation view of laser fracturing tool 100. Laser fracturing tool 100 is deployed in wellbore 10 of formation 40. Surface 30 is the surface of the earth from which wellbore 10 extends. Wellbore 10 extends from surface 30 into formation 40. Formation 40 can be any type of formation composed of any type of rock material. In at least one embodiment, formation 40 contains limestone. In at least one embodiment, formation 40 contains sandstone. In at least one embodiment, formation 40 contains shale. Wellbore 10 can be finished with casing 20 and cement 25 for reinforcement.

[0013] Laser surface unit 50 can be located on surface 30 near wellbore 10. Laser surface unit 50 can be in optical communication with laser fracturing tool 100 via fiber optic cable 55. Laser surface unit 50 can be configured to excite energy to a level above the sublimation point of formation 40 to form a laser beam (not shown). The sublimation point of formation 40 can be determined based on the rock material contained in formation 40, where the rock material controls the sublimation point which then controls the excitation energy of the laser beam. In at least one embodiment, laser surface unit 50 can be tuned to excite energy to different excitation levels as can be required for different formations. Laser surface unit 50 can by any type of laser unit capable of generating a laser beam and introducing said laser beam into a fiber optic cable. Examples of laser surface unit 50 include lasers of ytterbium, erbium, neodymium, dysprosium, praseodymium, and thulium ions. In at least one embodiment, laser surface unit 50 can be a 5.34-kW ytterbium doped multiclad fiber laser.

[0014] Fiber optic cable 55 can be any cable containing an optical fiber capable of transmitting a laser beam from laser surface unit 50 to laser fracturing tool 100. Fiber optic cable 55 can include one or more optical fibers. In an alternate embodiment, one or more fiber optic cables can provide electrical communication between laser surface unit 50 and laser fracturing tool 100. In at least one embodiment, fiber optic cable 55 provides a path for light from laser surface unit 50 to laser fracturing tool 100. In at least one embodiment, fiber optic cable 55 can conduct a raw laser beam from laser surface unit 50 to laser fracturing tool 100. A "raw laser beam" as used herein refers to a laser beam that has not been passed through lenses or otherwise focused.

[0015] Power source 60 can be located on surface 30 near wellbore 10. Power source 60 can be in electrical communication with laser fracturing tool 100 via power cable 65. Power source 60 can be any apparatus capable of generating electrical energy. Power cable 65 can be any type of cable capable of transmitting electrical energy to laser fracturing tool 1 00.

[0016] Cooling fluid source 70 can be located on surface 30 near wellbore 10 and can provide a cooling fluid to laser fracturing tool 100. Cooling fluid source 70 is in fluid communication with laser fracturing tool 100 via fluid line 75, such that the cooling fluid is delivered to laser fracturing tool 100 from cooling fluid source 70. Fluid line 75 can be any type of tube capable of supplying a fluid to laser fracturing tool 100. The cooling fluid can include nitrogen gas, liquid nitrogen, helium, air, carbon dioxide, and water. The cooling fluid can be selected based on the rock material of formation 40 and the thermal properties of the rock material. The temperature gradient desired between the fracture temperature and the cooled temperature, the rotation period of the thermal shocking tool, and the efficiency of the cooling fluid in reducing the temperature of the rock material. In at least one embodiment, one or more fluid lines 75 can be in fluid communication with cooling fluid source 70 and laser fracturing tool 100.

[0017] Fiber optic cable 55, power cable 65, and fluid line 75 can be encompassed in protective shaft 80. Protective shaft 80 can be any material of construction suitable for use in a downhole environment without experiencing mechanical or chemical failure. As used here, "downhole environment" refers to the high operating pressure, high operating temperature, and fluid conditions that can be found in a wellbore extending into a formation.

[0018] FIG. 2 is a section view in elevation of one embodiment of laser fracturing tool 100 as understood with reference to FIG. 1. Laser fracturing tool 100 includes motor 200 and thermal shocking tool 300. Power cable 65 is in electrical communication with motor 200, such that power cable 65 transmits electrical energy to motor 200. Motor 200 is physically connected to motor shaft 210. Motor 200 can be any motor capable of converting electrical energy transmitted by power cable 65 into mechanical energy to rotate motor shaft 210 in a downhole environment. Motor shaft 210 is physically connected to rotational shaft 310 of thermal shocking tool 300.

[0019] Fiber optic cable 55 is in optical communication with thermal shocking tool 300. Cooling fluid line 75 is in fluid communication with thermal shocking tool 300.

[0020] In at least one embodiment, purge nozzle 220 can be located between motor 200 and surface 30, such that purge nozzle 220 is configured to deliver a fluid to the wellbore. In at least one embodiment, purge nozzle 220 can be located between motor 200 and surface 30 near motor 200 such that purge nozzle 220 is operable to deliver the fluid near motor 200. In at least one embodiment, purge nozzle 220 delivers the fluid such that the fluid is operable to clean motor 200, such that the purge fluid from purge nozzle 220 can keep dust and debris from settling on motor 200. In at least one embodiment, purge nozzle 220 delivers the fluid such that the fluid is operable to direct the produced fluid in wellbore 10. As used here, "produced fluid" refers to the fluid that flows from the formation into the wellbore due to fracturing of the formation by laser fracturing tool 100. In at least one embodiment, one or more purge nozzles 220 can be configured in a purge nozzle configuration (not shown) such that the purge nozzle configuration is configured to deliver the fluid to multiple points in wellbore 10. The purge fluid can be any fluid capable of cleaning the motor and directing fluid. Examples of purge fluid can include air and nitrogen gas. The purge fluid can be at the ambient temperature of the purge fluid source (not shown). In an alternate embodiment, the purge fluid is from cooling fluid source 70.

[0021] FIG. 3 is a section view in elevation of a thermal shocking tool 300 with reference to features described in FIG. 2. Thermal shocking tool 300 includes protective case 305, rotational shaft 310, cooling system 320, and laser delivery device 330.

[0022] Protective case 305 surrounds rotational shaft 310, cooling system 320, and laser delivery device 330. Protective case 305 can be formed from any materials capable of withstanding the downhole environment without suffering mechanical failure. Cooling system 320 and laser delivery device 330 can extend into and through protective case 305.

[0023] Rotational shaft 310 connected to motor shaft 210 extends through protective case 305. Rotational shaft 310 rotates as motor shaft 210 rotates as driven by motor 200. Rotational shaft 310 provides an axis around which cooling system 320 and laser delivery device 330 rotate. Rotational shaft 310 can provide physical support, such as an anchor to cooling system 320 and laser delivery device 330. Cooling system 320 and laser delivery device 330 are mounted to rational shaft 310 such that cooling system 320 is opposite laser delivery device 330. As used herein, "opposite" refers to a position 180 degrees around the axis formed by rotational shaft 310, such that if cooling system 320 extends perpendicularly from rotational shaft 310 at zero (0) degrees, laser delivery device extends perpendicularly from rotational shaft 310 at one-hundred eighty (180) degrees. Rotational shaft 310 can be any material of construction suitable for use in a downhole environment that is rigid enough to provide physical support to cooling system 320 and laser delivery device 330.

[0024] Cooling system 320 can include one or more cooling nozzles 325 as shown in FIG. 3. Cooling nozzles 325 are fluidly connected to fluid line 75, such that the cooled purge fluid is delivered from cooling fluid source 70. Cooling system 320 can be configured to introduce the cooling fluid to formation 40 as a cooling fluid stream. The cooling fluid stream is operable to reduce the temperature formation 40.

[0025] Laser delivery device 330 is optically connected to fiber optic cable 55. Laser delivery device 330 can be configured to focus the laser beam from fiber optic cable 55 to produce a focused beam. In one embodiment, laser delivery device 330 can incorporate the features and details set forth in U.S. Pat. No. 9,217,291.

[0026] The focused laser beam is operable to increase the temperature of formation 40. The focused laser beam can be directed to sublimate the casing and the cement prior to contact formation 40. Advantageously, the focused laser beam can precisely cut the casing and the cement. The focused laser beam can increase the temperature of formation 40 in less than one second to a fracture temperature. The fracture temperature can reach 2,000 degrees Celsius (deg C). The less than one second increase in temperature to the fracture temperature can cause thermal shocks in formation 40 which results in fractures, microfractures and cracks in the rock material of formation 40. As used here, "microfractures" refers to fractures in the range from a millimeter to a few centimeters that can be used for initiating fractures. As used here, "thermal shocks" refers to the expansion and contraction of the formation rock over a time period on the order of seconds. As thermal shocking tool 300 rotates, laser delivery device 330 continuously causes an increase in temperature of formation 40 around the wellbore. While laser delivery device 330 increases the temperature of formation 40, cooling system 320 decreases the temperature. The cooling fluid stream can be directed at formation 40, such that the cooling fluid stream can reduce the temperature of the formation to a cooled temperature. The cooled temperature depends on the fluid used as the cooling fluid stream.

[0027] The laser delivery device can include acoustic capability to monitor and record the fracturing sound due to the thermal shocking tool. Acoustic capability can include transducers or geophones. Fracturing sound can be used to indicate the fracture length and size. The acoustic capability can be placed above the motor, below the thermal shocking tool, or both above the motor and below the thermal shocking tool. Power can be supplied to the acoustic capability from power source 60 (not shown). The acoustic capability can transmit the measurements directly to the surface or can be stored and retrieved after the laser fracturing.

EXAMPLE

[0028] Example 1. A dry core sample measuring 5.1 cm x 5.1 cm (2" x 2") of Berea and limestone was obtained. A 3 kW power laser was used to produce a continuous laser beam of 0.9 cm (0.35 inches).
The laser beam was turned on for four (4) seconds before being switched off. Fractures immediately formed in the core sample. Air , at room temperature, was used as the cooling fluid stream on one side of the core sample to orient the fractures. As can be seen in FIG. 4, fractures formed in the core sample.

Claims

1. A system for fracturing a formation (40) from a wellbore (10) extending into the formation (40) from a surface (30), the system comprising:

    a laser surface unit (50), the laser surface unit (50) located on the surface (30), the laser surface unit (50) configured to generate a laser beam;

    a fiber optic cable (55), the fiber optic cable (55) optically connected to a laser delivery device (330) of a thermal shocking tool (300), the fiber optic cable (55) configured to transmit the laser beam to the laser delivery device (330) to produce a focused laser beam;

    a power cable (65), the power cable (65) electrically connected to a power source (60) on the surface (30), the power cable (65) configured to transmit electrical energy to a motor (200);

    a fluid line (75), the fluid line (75) connected to a cooling fluid source (70) on the surface (30), the fluid line (75) configured to supply a cooling fluid to a cooling system (320) of the thermal shocking tool (300) to produce a cooling fluid stream;

    a protective shaft (80), the protective shaft (80) extending into the wellbore (10), wherein the fiber optic cable (55), the power cable (65), and the fluid line (75) are contained within the protective shaft (80);

    the motor (200), the motor (200) configured to rotate a motor shaft (210); and

    the thermal shocking tool (300) physically connected to the motor (200), the thermal shocking tool (300) comprising:

        a protective case (305), the protective case (305) configured to encompass the laser delivery device (330) and the cooling system (320),

        a rotational shaft (310), the rotational shaft (310) connected to the motor shaft (210) such that as the motor shaft (210) rotates the rotational shaft (310) rotates,

        the laser delivery device (330) extending perpendicularly from the rotational shaft (310), the laser delivery device (330) configured to transform the laser beam to a focused laser beam, wherein the focused laser beam is operable to increase the temperature of the formation (40) to a fracture temperature, and

        the cooling system (320), the cooling system (320) extending perpendicularly from the rotational shaft (310) at a position 180 degrees around the axis formed by rotational shaft (310) from the laser delivery device (330), the cooling system (320) comprising one or more cooling nozzles (325) extending through the protective case (305) such that the one or more cooling nozzles (325) are configured to introduce the cooling fluid stream onto the formation (40) such that the cooling fluid stream reduces the temperature of the formation (40),

        wherein the laser delivery device (330) and the cooling system (320) rotate around the

wellbore (10) as the rotational shaft (310) rotates,
wherein rotation of the rotational shaft (310) is configured to alternate between increasing the temperature of the formation (40) and reducing the temperature of the formation (40) such that thermal shocks occur and fractures are formed in the formation (40).

2. The system of claim 1 further comprises a purge nozzle (220), the purge nozzle (220) positioned between the surface (30) and the motor (200), where the purge nozzle (220) is configured to keep debris from settling on the motor (200).

3. The system of claims 1 or 2, wherein the cooling fluid is selected from the group consisting of nitrogen gas, liquid nitrogen, helium, air, carbon dioxide, and water.

4. The system of any of claims 1-3, wherein the fracture temperature is 2000 deg. C.

5. The system of any of claims 1-4 further comprising an acoustic capability.

6. The system of any of claims 1-5, wherein the focused laser beam can increase the temperature of the formation (40) to the fracture temperature in less than 1 second.

7. The system of any of claims 1-6, wherein the laser delivery device (330) can be positioned to introduce the focused laser beam to the formation (40) at a pre-determined angle.

8. A method for fracturing a formation (40) from a wellbore (10) extending into the formation (40) from a surface (30), the method comprising the steps of:

introducing a focused laser beam to the formation (40) such that the focused laser beam is operable to increase the temperature of the formation (40) to a fracture temperature, wherein the focused laser beam is produced by a laser delivery device (330), the laser delivery device (330) extending perpendicularly from a rotational shaft (310);
introducing a cooling fluid stream to the formation (40) such that the cooling fluid stream is operable to reduce the temperature of the formation (40), wherein the cooling fluid stream is produced by a cooling system (320), the cooling system (320) extending perpendicularly from the rotational shaft (310) at a position 180 degrees around the axis formed by rotational shaft (310) from the laser delivery device (330); and
rotating the rotational shaft (310) such that the formation (40) is alternately exposed to the focused laser beam and the cooling fluid such that thermal shocks occur and fractures in the formation (40) are formed.

9. The method of claim 8, further comprising the steps of:

generating a laser beam in a laser surface unit (50); and
transmitting the laser beam from the laser surface unit (50) to the laser delivery device (330) through a fiber optic cable (55).

10. The method of claims 8 or 9, further comprising the steps of:

transmitting electrical energy from a power source (60) to a motor (200) through a power cable (65); and
transforming the electrical energy to mechanical energy in the motor (200), such that the mechanical energy rotates a motor shaft (210), wherein the motor shaft (210) is connected to the rotational shaft (310) such that as the motor shaft (210) rotates the rotational shaft (310) rotates.

11. The method of any of claims 8-10, wherein the cooling fluid is selected from the group consisting of nitrogen gas, liquid nitrogen, helium, air, carbon dioxide, and water.

12. The method of any of claims 8-11, wherein the fracture temperature is 2000 deg. C.

13. The method of any of claims 8-12 further comprising the step of measuring the sound emitted by an acoustic capability.

14. The method of any of claims 8-13, wherein the focused laser beam can increase the temperature of the formation (40) to the fracture temperature in less than 1 second; and/or wherein the laser delivery device (330) can be positioned to introduce the focused laser beam to the formation (40) at a pre-determined angle.

Patentansprüche

1. System zum Frakturieren einer Formation (40) aus einem Bohrloch (10), welches sich in die Formation (40) aus einer Oberfläche (30) erstreckt, wobei das System umfasst:

eine Laseroberflächeneinheit (50), wobei die Laseroberflächeneinheit (50) an der Oberfläche (30) angeordnet ist, wobei die Laseroberflä-

cheneinheit (50) konfiguriert ist, um einen Laserstrahl zu erzeugen;
ein Glasfaserkabel (55), wobei das Glasfaserkabel (55) mit einer Laserausgabevorrichtung (330) eines Thermoschockwerkzeuges (300) optisch verbunden ist, wobei das Glasfaserkabel (55) konfiguriert ist, um den Laserstrahl an die Laserausgabevorrichtung (330) zu übertragen, um einen fokussierten Laserstrahl zu erzeugen;
ein Stromkabel (65), wobei das Stromkabel (65) mit einer Stromquelle (60) an der Oberfläche (30) elektrisch verbunden ist, wobei das Stromkabel (65) konfiguriert ist, um elektrische Energie an einen Motor (200) zu übertragen;
eine Fluidleitung (75), wobei die Fluidleitung (75) mit einer Kühlfluidquelle (70) an der Oberfläche (30) verbunden ist, wobei die Fluidleitung (75) konfiguriert ist, um ein Kühlfluid an ein Kühlsystem (320) des Thermoschockwerkzeuges (300) zuzuführen, um eine Kühlfluidströmung zu erzeugen;
einen Schutzschacht (80), wobei der Schutzschacht (80) sich in das Bohrloch (10) erstreckt, wobei das Glasfaserkabel (55), das Stromkabel (65) und die Fluidleitung (75) innerhalb des Schutzschachtes (80) enthalten sind;
den Motor (200), wobei der Motor (200) konfiguriert ist, um eine Motorwelle (210) zu drehen; und
wobei das Thermoschockwerkzeug (300) mit dem Motor (200) physisch verbunden ist, wobei das Thermoschockwerkzeug (300) umfasst:

ein Schutzgehäuse (305), wobei das Schutzgehäuse (305) konfiguriert ist, um die Laserausgabevorrichtung (330) und das Kühlsystem (320) aufzunehmen,
eine Drehwelle (310), wobei die Drehwelle (310) mit der Motorwelle (210) derart verbunden ist, dass wenn sich die Motorwelle (210) dreht, sich auch die Drehwelle (310) dreht,
wobei die Laserausgabevorrichtung (330) sich senkrecht von der Drehwelle (310) erstreckt, wobei die Laserausgabevorrichtung (330) konfiguriert ist, um den Laserstrahl in einen fokussierten Laserstrahl zu verwandeln, wobei der fokussierte Laserstrahl betreibbar ist, um die Temperatur der Formation (40) bis zu einer Frakturierungstemperatur zu erhöhen, und
das Kühlsystem (320), wobei das Kühlsystem (320) sich senkrecht von der Drehwelle (310) an einer Stelle erstreckt, welche relativ zur Laserausgabevorrichtung (330) um 180 Grad um die Achse (310) versetzt ist, welche durch die Drehwelle (310) gebildet ist, wobei das Kühlsystem (320) eine oder mehrere Kühldüsen (325) umfasst, welche sich durch das Schutzgehäuse (305) derart erstrecken, dass die eine oder die mehreren Kühldüsen (325) konfiguriert sind, um die Kühlfluidströmung auf die Formation (40) einzuführen, sodass die Kühlfluidströmung die Temperatur der Formation (40) reduziert,
wobei die Laserausgabevorrichtung (330) und das Kühlsystem (320) sich um das Bohrloch (10) drehen, während sich die Drehwelle (310) dreht,
wobei die Drehung der Drehwelle (310) konfiguriert ist, um zwischen einer Temperaturerhöhung der Formation (40) und einer Temperaturreduzierung der Formation (40) zu wechseln, sodass Temperaturschocks stattfinden und sich Frakturen innerhalb der Formation (40) bilden.

2. System nach Anspruch 1, ferner umfassend eine Spüldüse (220), wobei die Spüldüse (220) zwischen der Oberfläche (30) und dem Motor (200) angeordnet ist, wo die Spüldüse (220) konfiguriert ist, um zu verhindern, dass Trümmer sich auf dem Motor (200) absetzen.

3. System nach Anspruch 1 oder 2, wobei das Kühlfluid aus der Gruppe ausgewählt ist, bestehend aus Stickstoffgas, flüssigem Stickstoff, Helium, Luft, Kohlendioxid und Wasser.

4. System nach einem der Ansprüche 1 bis 3, wobei die Frakturierungstemperatur 2000° C beträgt.

5. System nach einem der Ansprüche 1 bis 4, ferner umfassend eine akustische Funktion.

6. System nach einem der Ansprüche 1 bis 5, wobei der fokussierte Laserstrahl die Temperatur der Formation (40) bis zur Frakturierungstemperatur in weniger als 1 Sekunde erhöhen kann.

7. System nach einem der Ansprüche 1 bis 6, wobei die Laserausgabevorrichtung (330) positionierbar ist, um den fokussierten Laserstrahl in die Formation (40) in einem vorbestimmten Winkel einzuführen.

8. Verfahren zum Frakturieren einer Formation (40) aus einem Bohrloch (10), welches sich in die Formation (40) aus einer Oberfläche (30) erstreckt, wobei das Verfahren folgende Schritte umfasst:

Einführen eines fokussierten Laserstrahls in die Formation (40) derart, dass der fokussierte Laserstrahl betreibbar ist, um die Temperatur der Formation (40) bis zu einer Frakturierungstemperatur zu erhöhen, wobei der fokussierte Laserstrahl durch eine Laserausgabevorrichtung (330) erzeugt wird, wobei die Laserausgabevorrichtung (330) sich senkrecht von einer Drehwelle (310) erstreckt;

Einführen einer Kühlfluidströmung in die Formation (40), derart, dass die Kühlfluidströmung betreibbar ist, um die Temperatur der Formation (40) zu reduzieren, wobei die Kühlfluidströmung durch ein Kühlsystem (320) erzeugt wird, wobei das Kühlsystem (320) sich senkrecht von der Drehwelle (310) 180 Grad um die Achse (310), welche durch die Drehwelle (310) und die Laserausgabevorrichtung (330) gebildet ist, erstreckt; und

Drehen der Drehwelle (310) derart, dass die Formation (40) abwechselnd dem fokussierten Laserstrahl und dem Kühlfluid ausgesetzt ist, sodass Temperaturschocks stattfinden und sich Frakturen in der Formation (40) bilden.

9. Verfahren nach Anspruch 8, ferner umfassend die folgenden Schritte:

Erzeugen eines Laserstrahls in einer Laseroberflächeneinheit (50); und

Übertragen des Laserstrahls von der Laseroberflächeneinheit (50) an die Laserausgabevorrichtung (330) durch ein Glasfaserkabel (55).

10. Verfahren nach Anspruch 8 oder 9, ferner umfassend die folgenden Schritte:

Übertragen von elektrischer Energie von einer Stromquelle (60) an einen Motor (200) durch ein Stromkabel (65); und

Umwandeln der elektrischen Energie in mechanische Energie in dem Motor (200), derart, dass die mechanische Energie eine Motorwelle (210) dreht, wobei die Motorwelle (210) mit der Drehwelle (310) so verbunden ist, dass, wenn sich die Motorwelle (210) dreht, sich auch die Drehwelle (310) dreht.

11. Verfahren nach einem der Ansprüche 8 bis 10, wobei das Kühlfluid ausgewählt ist, aus der Gruppe bestehend aus Stickstoffgas, flüssigem Stickstoff, Helium, Luft, Kohlendioxid und Wasser.

12. System nach einem der Ansprüche 8 bis 11, wobei die Frakturierungstemperatur 2000° C beträgt.

13. System nach einem der Ansprüche 8 bis 12, ferner umfassend den Schritt des Messens des Schalls, welcher von einem akustischen Mittel emittiert wird.

14. Verfahren nach einem der Ansprüche 8 bis 13, wobei der fokussierte Laserstrahl die Temperatur der Formation (40) bis zur Frakturierungstemperatur in weniger als 1 Sekunde erhöhen kann; und/oder wobei die Laserausgabevorrichtung (330) positionierbar ist, um den fokussierten Laserstrahl in die Formation (40) in einem vorbestimmten Winkel einzuführen.

Revendications

1. Système de fracturation d'une formation (40) depuis un trou de forage (10) s'étendant dans la formation (40) depuis une surface (30), le système comprenant:

une unité de surface laser (50), l'unité de surface laser (50) localisée sur la surface (30), l'unité de surface laser (50) configurée pour générer un faisceau laser;

un câble à fibres optiques (55), le câble à fibres optiques (55) optiquement connecté à un dispositif d'émission laser (330) d'un outil à choc thermique (300), le câble à fibres optiques (55) configuré pour transmettre le faisceau laser au dispositif d'émission laser (330) pour produire un faisceau laser focalisé;

un câble d'alimentation (65), le câble d'alimentation (65) électriquement connecté à une source d'énergie (60) sur la surface (30), le câble d'alimentation (65) configuré pour transmettre de l'énergie électrique à un moteur (200);

une conduite de liquide (75), la conduite de liquide (75) raccordée à une source de liquide de refroidissement (70) sur la surface (30), la conduite de liquide (75) configurée pour alimenter un liquide de refroidissement à un système de refroidissement (320) de l'outil à choc thermique (300) pour produire un jet de liquide de refroidissement;

un puits de protection (80), le puits de protection (80) s'étendant dans le trou de forage (10), le câble à fibres optiques (55), le câble d'alimentation (65), et la conduite de liquide (75) étant contenus à l'intérieur du puits de protection (80);

le moteur (200), le moteur (200) configuré pour faire tourner un arbre moteur (210); et

l'outil à choc thermique (300) physiquement relié au moteur (200), l'outil à choc thermique (300) comprenant:

un boîtier protecteur (305), le boîtier protecteur (305) configuré pour englober le dispositif d'émission laser (330) et le système de refroidissement (320),

un arbre de rotation (310), l'arbre de rotation (310) relié à l'arbre moteur (210) de sorte que lorsque l'arbre moteur (210) tourne, l'arbre de rotation (310) tourne lui aussi,

le dispositif d'émission laser (330) s'étendant perpendiculairement depuis l'arbre de rotation (310), le dispositif d'émission laser (330) configuré pour transformer le faisceau laser en un faisceau laser focalisé, le faisceau laser focalisé pouvant fonctionner pour accroître la température de la formation (40) à une température de fracture, et le système de refroidissement (320), le système de refroidissement (320) s'étendant perpendiculairement depuis l'arbre de rotation (310) à une position de 180 degrés autour de l'axe formé par l'arbre de rotation (310) depuis le dispositif d'émission laser (330), le système de refroidissement (320) comprenant une ou plusieurs buses de refroidissement (325) s'étendant à travers le boîtier protecteur (305) de sorte que lesdites buses de refroidissement (325) sont configurées pour introduire le jet de liquide de refroidissement sur la formation (40) de sorte que le jet de liquide de refroidissement réduit la température de la formation (40), le dispositif d'émission laser (330) et le système de refroidissement (320) tournant autour du trou de forage (10) lorsque l'arbre de rotation (310) tourne,

la rotation de l'arbre de rotation (310) étant configurée pour alterner entre l'augmentation de la température de la formation (40) et la réduction de la température de la formation (40) de sorte que des chocs thermiques se produisent et que des fractures sont formées dans la formation (40).

2. Système selon la revendication 1, comprenant en outre une buse de purge (220), la buse de purge (220) positionnée entre la surface (30) et le moteur (200), où la buse de purge (220) est configurée pour empêcher les débris de se déposer sur le moteur (200).

3. Système selon les revendications 1 ou 2, le liquide de refroidissement étant sélectionné dans le groupe constitué de l'azote gazeux, de l'azote liquide, de l'hélium, de l'air, du dioxyde de carbone, et de l'eau.

4. Système selon l'une quelconque des revendications 1 à 3, la température de fracture étant de 2 000 deg. C.

5. Système selon l'une quelconque des revendications 1 à 4 comprenant en outre un moyen acoustique.

6. Système selon l'une quelconque des revendications 1 à 5, le faisceau laser focalisé pouvant accroître la température de la formation (40) à la température de fracture en moins d'une seconde.

7. Système selon l'une quelconque des revendications 1 à 6, le dispositif d'émission laser (330) pouvant être positionné de manière à introduire le faisceau laser focalisé dans la formation (40) sous un angle prédéterminé.

8. Procédé de fracturation d'une formation (40) depuis un trou de forage (10) s'étendant dans la formation (40) depuis une surface (30), le procédé comprenant les étapes de:

introduction d'un faisceau laser focalisé dans la formation (40) de manière que le faisceau laser focalisé agit pour accroître la température de la formation (40) à la température de fracture, le faisceau laser focalisé étant produit par un dispositif d'émission laser (330), le dispositif d'émission laser (330) s'étendant perpendiculairement depuis un arbre de rotation (310);

introduction d'un jet de liquide de refroidissement dans la formation (40) de manière que le jet de liquide de refroidissement agit pour réduire la température de la formation (40), le jet de liquide de refroidissement étant produit par un système de refroidissement (320), le système de refroidissement (320) s'étendant perpendiculairement depuis l'arbre de rotation (310) sous une position de 180 degrés autour de l'axe formé par l'arbre de rotation (310) et le dispositif d'émission laser (330); et

rotation de l'arbre de rotation (310) de manière à exposer la formation (40) de manière alternative au faisceau laser focalisé et au liquide de refroidissement de manière à produire des chocs thermiques et à former des fractures dans la formation (40).

9. Procédé selon la revendication 8, comprenant en outre les étapes de:

génération d'un faisceau laser dans une unité de surface laser (50); et

de transmission du faisceau laser de l'unité de surface laser (50) au dispositif d'émission laser (330) à travers un câble à fibres optiques (55).

10. Procédé selon les revendications 8 ou 9, comprenant en outre les étapes de:

transmission d'énergie électrique d'une source d'énergie (60) à un moteur (200) à travers un câble d'alimentation (65); et

transformation de l'énergie électrique en une énergie mécanique dans le moteur (200), de manière que l'énergie mécanique fait tourner un arbre moteur (210), l'arbre moteur (210) étant connecté à l'arbre de rotation (310) de manière que lorsque l'arbre moteur (210) tourne, l'arbre de rotation (310) tourne lui aussi.

11. Procédé selon l'une quelconque des revendications 8 à 10, le liquide de refroidissement étant sélectionné dans le groupe constitué de l'azote gazeux, de l'azote liquide, de l'hélium, de l'air, du dioxyde de carbone, et de l'eau.

12. Procédé selon l'une quelconque des revendications 8 à 11, la température de fracture étant de 2 000 deg. C.

13. Procédé selon l'une quelconque des revendications 8 à 12 comprenant en outre l'étape de mesure du son émis par un moyen acoustique.

14. Procédé selon l'une quelconque des revendications 8 à 13, le faisceau laser focalisé pouvant accroître la température de la formation (40) à la température de fracture en moins d'une seconde; et/ou le dispositif d'émission laser (330) pouvant être positionné pour introduire le faisceau focalisé dans la formation (40) sous un angle prédéterminé.

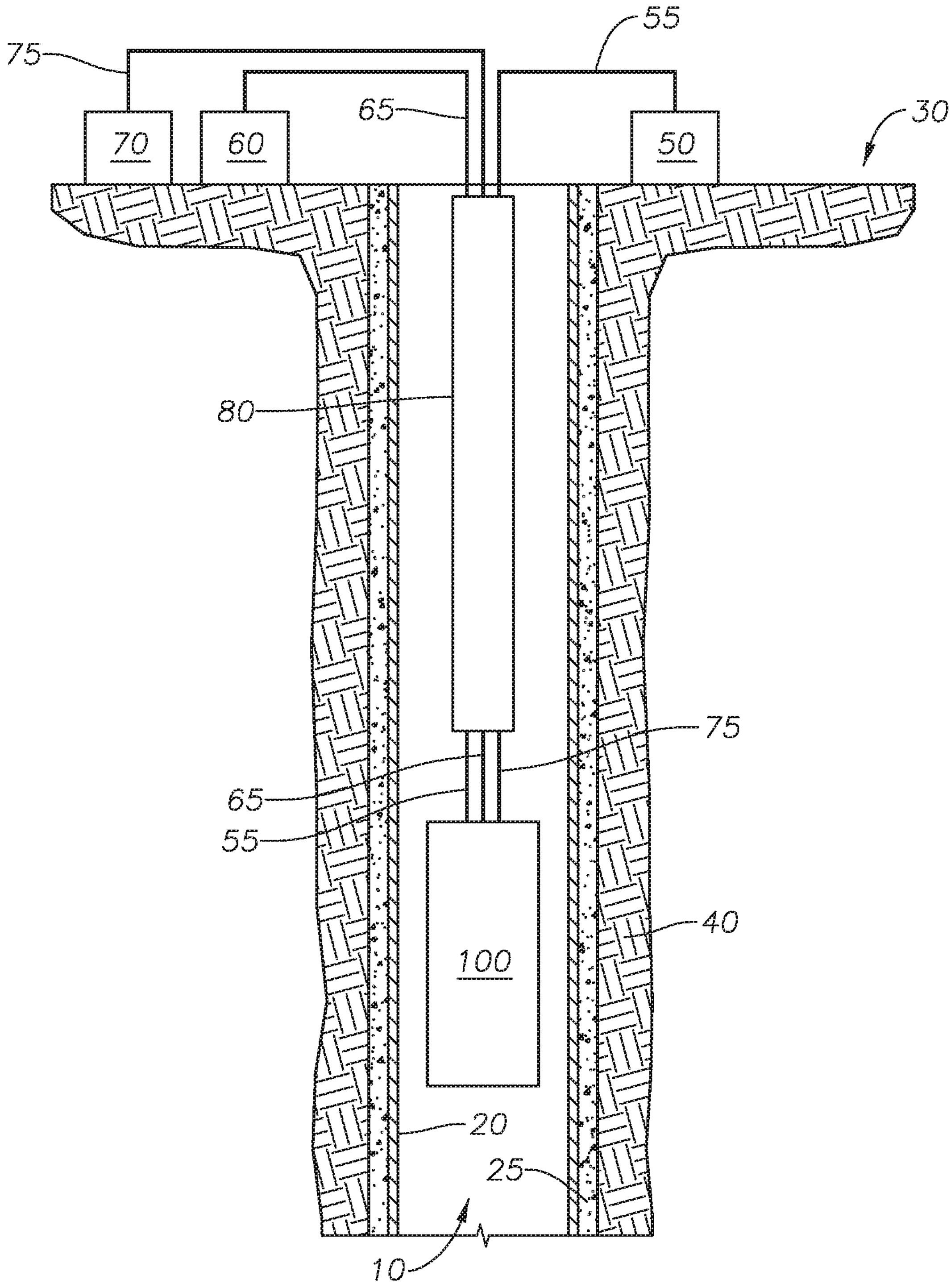

FIG. 1

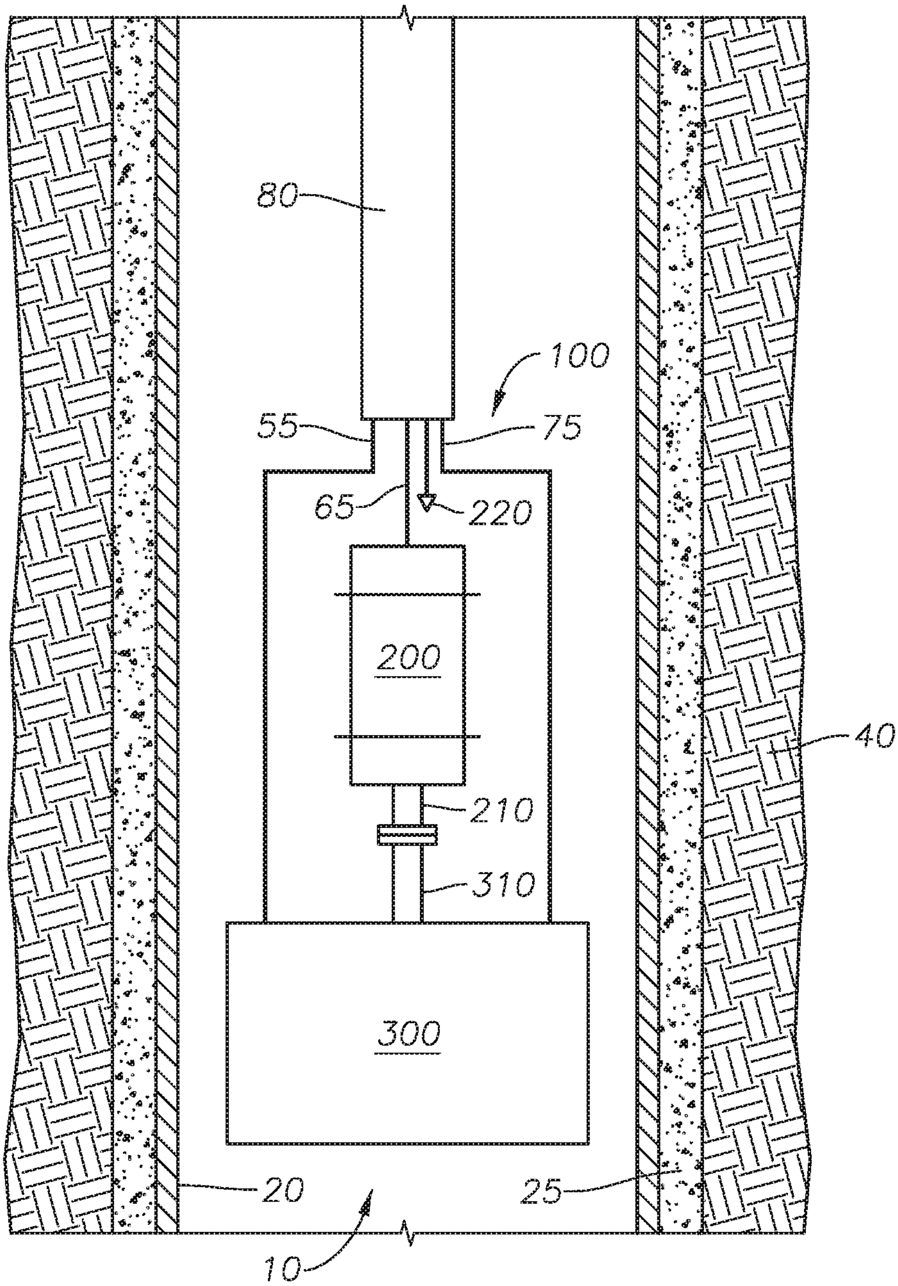

FIG. 2

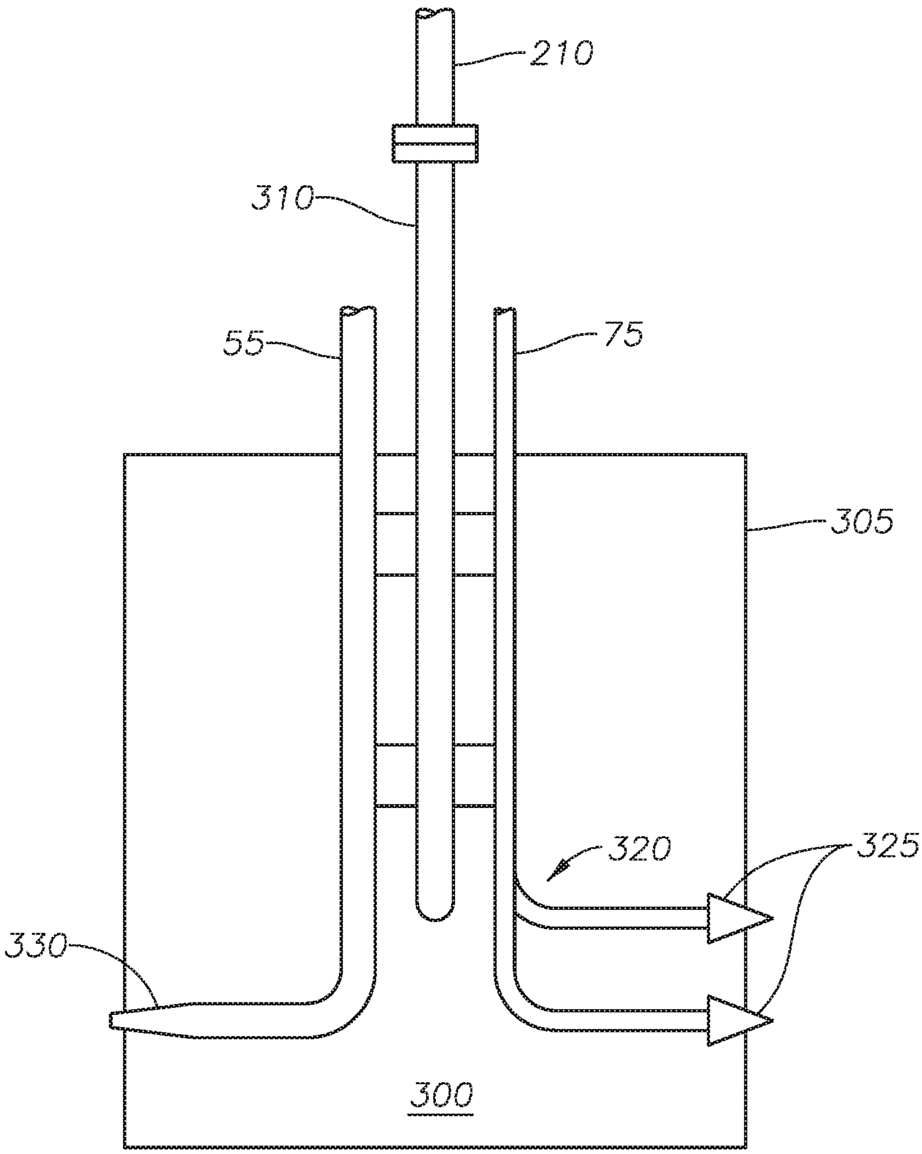

FIG. 3

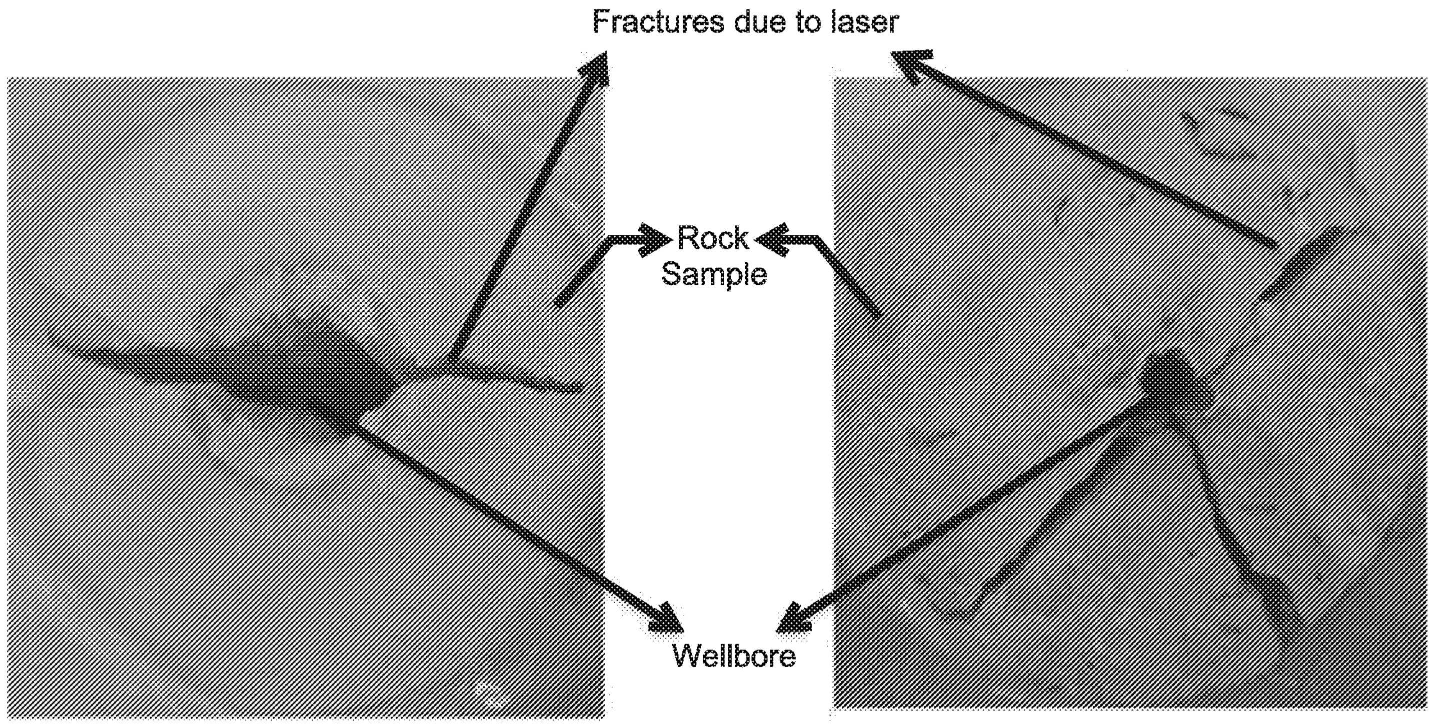

FIG. 4

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- WO 2016186690 A1 **[0004]**
- US 9217291 B **[0025]**