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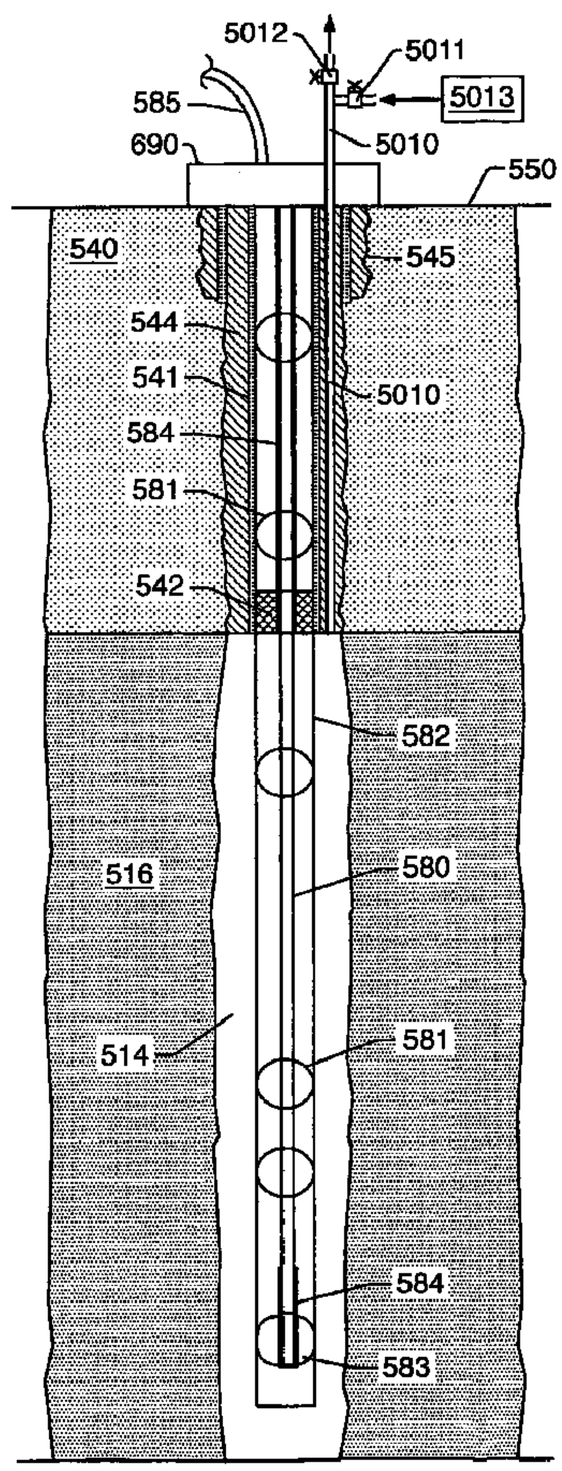

(57) Abrégé/Abstract:
A well heating system comprises an electrical conductor which is suspended within the interior of a conduit and which is configured to transfer heat into a hydrocarbon containing formation surrounding the well in which the conductor-in-conduit heater assembly is arranged.

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(54) Title: ELECTRICAL WELL HEATING SYSTEM AND METHOD

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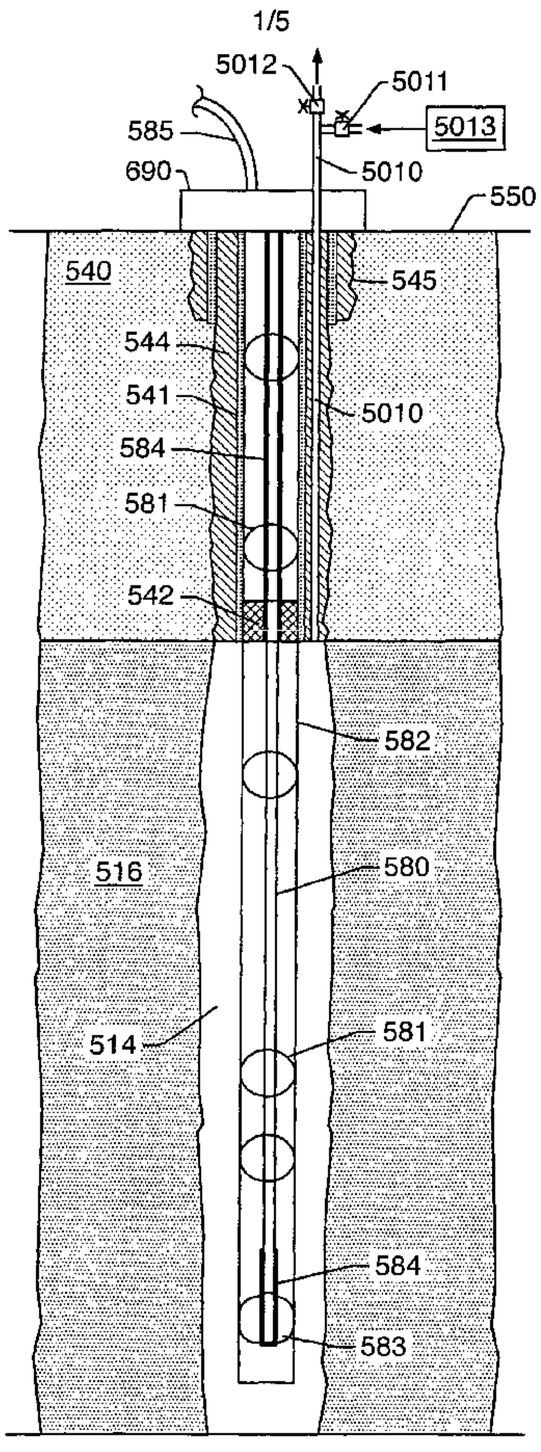

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ELECTRICAL WELL HEATING SYSTEM AND METHOD

Background of the Invention

The invention relates to a method and system for heating a hydrocarbon containing formation, such as a coal layer or an oil shale deposit, surrounding a heat injection well.

Application of heat to oil shale formations is described in U.S. Patent Nos. 2,923,535 to Ljungstrom and 4,886,118 to Van Meurs et al. These prior art references disclose that electrical heaters transmit heat into an oil shale formation to pyrolyze kerogen within the oil shale formation. The heat may also fracture the formation to increase permeability of the formation. The increased permeability may allow formation fluid to travel to a production well where the fluid is removed from the oil shale formation. In some processes disclosed by Ljungstrom, for example, an oxygen containing gaseous medium is introduced to a permeable stratum, preferably while still hot from a preheating step, to initiate combustion.

U.S. Patent No. 2,548,360 describes an electrical heating element placed within a viscous oil within a wellbore. The heater element heats and thins the oil to allow the oil to be pumped from the wellbore. U.S. Patent No. 4,716,960 describes electrically heating a tubing of a petroleum well by passing a relatively low voltage current through the tubing to prevent formation of solids. U.S. Patent No. 5,065,818 to Van Egmond describes an electrical heating element that is cemented into a well borehole without a casing surrounding the heating element.

U.S. Patent No. 6,023,554 to Vinegar et al. describes an electrical heating element that is positioned within a casing. The heating element generates radiant energy that heats the casing. A granular solid fill material may be placed between the casing and the formation. The casing may conductively heat the fill material, which in turn conductively heats the formation.

U.S. Patent No. 4,570,715 to Van Meurs et al. describes an electrical heating element. The heating element has an electrically conductive core, a surrounding layer of insulating material, and a surrounding metallic sheath. The conductive core may have a relatively low resistance at high temperatures. The insulating material may have electrical resistance, compressive strength and heat conductivity properties that are relatively high at high temperatures. The insulating layer may inhibit arcing from the core to the metallic sheath. The metallic sheath may have tensile strength and creep resistance properties that are relatively high at high temperatures.

U.S. Patent No. 5,060,287 to Van Egmond describes an electrical heating element having a copper-nickel alloy core.

The system and method according to the preamble of claims 1 and 11 are known from US patent No. 2,244,255. In this known system electrical current is transmitted through an electrical circuit provided by a steel well casing and production tubing to melt and remove congealed bodies that may clog the well and surrounding formation.

It is an object of the present invention to provide an improved inexpensive and durable downhole heating method and system which are able to transmit a controlled

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amount of heat in a uniform manner into an underground formation over a long period of time.

Summary of the Invention

According to one aspect of the present invention, there is provided a system configured to heat a carbon containing formation, comprising: a first electrical conductor disposed in a first conduit, which first conduit is disposed within a heater well traversing the formation, wherein the first conductor is configured to provide heat to at least a portion of the formation during use and the system is configured to allow heat to transfer from the first conductor to a section of the formation during use, wherein the first conduit is substantially freely suspended within the heater well and that an annular space is present between the first conduit and the formation; a second conductor is disposed within a second conduit and a third conductor is disposed within a third conduit, wherein the first conduit, the second conduit and the third conduit are disposed in different openings of the formation, wherein the first conductor is electrically coupled to the second conductor and the third conductor, and the first, second and third conductors are configured to operate in a 3 phase Y configuration during use.

Advantages of the heating system according to the invention are that it can be made in any desired length and that it is suitable for use in horizontal or inclined heat injection wells.

In a preferred embodiment of the system according to the invention the first conductor is centralized within the first conduit by a series of ceramic centralisers. A sliding electrical connector may be electrically coupled to the first conductor and to the first conduit near a lower end of the first conductor and/or first conduit to create an electrical circuit. Furthermore a

pressurized fluid may be disposed within the first conduit to maintain a pressure within the first conduit to substantially prevent deformation of the first conduit during use. Another tube may be disposed within the heater well external and co-axial or external and strapped to the first conduit, wherein the tube is configured to remove vapour produced from at least the heated portion of the formation such that a pressure balance is maintained between the first conduit and the surrounding heater well and/or formation to substantially prevent deformation of the first conduit during use. Furthermore the additional tube may be used as a means to control the pressure in the reservoir. Control of the pressure may be required to bring about pyrolysis conditions that will favourably modify the hydrocarbon product composition. Furthermore the additional tube may be used at certain times during the process to adjust the pressure so as to increase the support of the overlying layers of rock and thus mitigate compaction and subsidence.

Preferably, the first conductor is configured to generate during use radiant heat of 0.6 to 1.5 KW per meter length of the first conductor.

In addition to the first conductor and conduit a second conductor may be disposed within a second conduit and a third conductor may be disposed within a third conduit within a first, second and third heater well traversing the hydrocarbon containing formation, wherein the first, second and third conductors are coupled to a 3-phase electrical supply of power at the surface and wherein the first second and third conduits may be coupled electrically to operate the three wells in what is called a "four wire" configuration.

According to another aspect of the present invention, there is provided an in situ method for heating a hydrocarbons containing formation, comprising: applying an electrical current to a first conductor to provide heat to at least a portion of the formation, wherein the first conductor is disposed in a first conduit, and wherein the first conduit is disposed within a heater well traversing the formation; and allowing the heat to transfer from the first conductor to a section of the formation; wherein: the first conduit is substantially freely suspended within the heater well; an annular space is present between the first conduit and the formation; a second conductor is disposed within a second conduit and a third conductor is disposed within a third conduit; the second conduit and the third conduit are disposed in different openings of the formation; the first conductor is electrically coupled to the second conductor and the third conductor, and the first, second and third conductors are configured to operate in a 3-phase Y configuration.

Preferably between 10 and 40 percent of the heat generated in an electrical circuit formed by the first conductor and first conduit and a sliding electrical contact between a lower portion of the first conductor and first conduit is generated by the first conductor conduit. Said electrical circuit provided by the first conductor and the first conduit may irradiate in use an amount of heat between 0.6 and 1.5 KW per meter length of the heater well into the hydrocarbon containing formation such that hydrocarbons within the hydrocarbon containing formation are heated to a temperature above 300°C and are pyrolyzed.

Preferably in use an elevated pressure is maintained in the interior of the first conduit and/or an annular space between the first conduit and the formation to substantially prevent deformation of the first conduit.

Said elevated pressure may be maintained by pumping an oxidizing fluid from an oxidizing fluid source into the first conduit during use such that the fluid flow substantially prevents deposition of heated hydrocarbons on or proximate to at least the first conductor.

The first conduit may comprise openings through which the oxidising fluid, such as air, is injected into an annular space surrounding the first conduit in which space hydrocarbons released by the hydrocarbon containing formation and/or hydrocarbons injected into said annular space are combusted.

A temperature distribution in thc first electrical conductor and/or the first electrical conduit may be monitored continuously or intermittently using an electromagnetic signal provided to the first electrical conductor and/or the first electrical conduit.

Description of preferred embodiments

The invention will be described in more detail and by way of example with reference to the accompanying drawings, in which

FIGS. 1-3 depict several embodiments of an electrical conductor heat source within a conduit in a heater well;

FIG. 4 and FIGS. 5a-5b depict several embodiments of a centralizer for centralizing the electrical conductor within the conduit; and

FIG. 6 depicts an embodiment of an electrical conductor-in-conduit heat source in a formation.

FIG. 1 illustrates an embodiment of an electrical conductor-in-conduit heater configured to heat a section of a hydrocarbon containing formation. Conductor 580 may be disposed in conduit 582. Conductor 580 may be a rod

or conduit of electrically conductive material. A conductor 580 may have a low resistance section 584 at both the top and the bottom of the conductor 580 in order to generate less heating in these sections 584. The substantially low resistance section 584 may be due to a greater cross-sectional area of conductor 580 in that section. For example, conductor 580 may be a 304 or 310 stainless steel rod with a diameter of approximately 2.8 cm. The diameter and wall thickness of conductor 580 may vary, however, depending on, for example, a desired heating rate of the hydrocarbon containing formation. Conduit 582 may include an electrically conductive material. For example, conduit 582 may be a 304 or 310 stainless steel pipe having a diameter of approximately 7.6 cm and a thickness of approximately schedule 40. Conduit 582 may be disposed in opening 514 in formation 516. Opening 514 may have a diameter of at least approximately 5 cm. The diameter of the opening may vary, however, depending on, for example, a desired heating rate in the formation and/or a diameter of conduit 582. For example, a diameter of the opening may be from about 10 cm to about 13 cm. Larger diameter openings may also be used. For example, a larger opening may be used if more than one conductor is to be placed within a conduit.

Conductor 580 may be centred in conduit 582 through centralizer 581. Centralizer 581 may electrically isolate conductor 580 from conduit 582. In addition, centralizer 581 may be configured to locate conductor 580 within conduit 582. Centralizer 581 may be made of a ceramic material or a combination of ceramic and metallic materials. More than one centralizer 581 may be configured to substantially inhibit deformation of conductor 580 in conduit 582 during use. More than one centralizer 581 may be spaced at intervals between

approximately 0.5 m and approximately 3 m along conductor 580. Centralizer 581 may be made of ceramic and 304 and 310 stainless steel. Centralizer 581 may be configured as shown in FIG. 4 and/or Figs. 5a and 5b.

As depicted in FIG. 2, sliding connector 583 may couple an end of conductor 580 disposed proximate a lowermost surface of conduit 582. Sliding connector 583 allows for differential thermal expansion between conductor 580 and conduit 582. Sliding connector 583 is attached to a conductor 580 located at the bottom of the well at a low resistance section 584 which may have a greater cross-sectional area. The lower resistance of section 584 allows the sliding connector to operate at temperatures no greater than about 90 °C. In this manner, corrosion of the sliding connector components is minimized and therefore contact resistance between sliding connector 583 and conduit 582 is also minimized. Sliding connector 583 may be configured as shown in FIG. 20 and as described in any of the embodiments herein.

The substantially low resistance section 584 of the conductor 580 may couple conductor 580 to wellhead 690 as depicted in FIG. 1. Wellhead 690 may be configured as shown in FIG. 3 and as described in any of the embodiments herein. Electrical current may be applied to conductor 580 from power cable 585 through a low resistance section 584 of the conductor 580. Electrical current may pass from conductor 580 through sliding connector 583 to conduit 582. Conduit 582 may be electrically insulated from overburden casing 541 and from wellhead 690 to return electrical current to power cable 585. Heat may be generated in conductor 580 and conduit 582. The generated heat may radiate within conduit 582 and opening 514 to heat at least a portion of formation 516. As an example, a voltage of about 330 volts and a current of about 795 amps may be supplied

to conductor 580 and conduit 582 in a 229 m (750 ft) heated section to generate about 1150 watts/meter of conductor 580 and conduit 582.

Overburden conduit 541 may be disposed in overburden 540 of formation 516. Overburden conduit 541 may in some embodiments be surrounded by materials that may substantially inhibit heating of overburden 540. A substantially low resistance section 584 of a conductor 580 may be placed in overburden conduit 541. The substantially low resistance section 584 of conductor 580 may be made of, for example, carbon steel. The substantially low resistance section 584 may have a diameter between about 2 cm to about 5 cm or, for example, a diameter of about 4 cm. A substantially low resistance section 584 of conductor 580 may be centralized within overburden conduit 541 using centralizers 581. Centralizers 581 may be spaced at intervals of approximately 6 m to approximately 12 m or, for example, approximately 9 m along substantially low resistance section 584 of conductor 580. A substantially low resistance section 584 of conductor 580 may be coupled to conductor 580 using any method known in the art such as arc welding. A substantially low resistance section 584 may be configured to generate little and/or substantially no heat in overburden conduit 541. Packing material 542 may be placed between overburden casing 541 and opening 514. Packing material 542 may be configured to substantially inhibit fluid from flowing from opening 514 to surface 550 or to inhibit most heat carrying fluids from flowing from opening 514 to surface 550.

Overburden conduit may include, for example, a conduit of carbon steel having a diameter of about 7.6 cm and a thickness of about schedule 40 pipe. Cement 544 may include, for example, slag or silica flour, or a

mixture thereof (e.g., about 1.58 grams per cubic centimetre slag/silica flour). Cement 544 may extend radially a width of about 5 cm to about 25 cm. Cement 544 may also be made of material designed to inhibit flow of heat into formation 516.

Surface conductor 545 and overburden casing 541 may enclose cement 544 and may couple to wellhead 690. Surface conductor 545 may have a diameter of about 10 cm to about 30 cm and more preferably a diameter of about 22 cm. Electrically insulating sealing flanges may be configured to mechanically couple substantially low resistance section 584 of conductor 580 to wellhead 690 and to electrically couple lower resistance section 584 to power cable 585. The electrically insulating sealing flanges may be configured to couple lead-in conductor 585 to wellhead 690. For example, lead-in conductor 585 may include a copper cable, wire, or other elongated member. Lead-in conductor 585 may include, however, any material having a substantially low resistance. The lead-in conductor may be clamped to the bottom of the low resistivity conductor to make electrical contact.

In an embodiment, heat may be generated in or by conduit 582. In this manner, about 10% to about 30%, or, for example, about 20%, of the total heat generated by the heater may be generated in or by conduit 582. Both conductor 580 and conduit 582 may be made of stainless steel. Dimensions of conductor 580 and conduit 582 may be chosen such that heat of approximately 650 watts per meter of conductor 580 and conduit 582 to approximately 1650 watts per meter of conductor 580 and conduit 582 may be generated. In this manner, a temperature in conduit 582 may be approximately 480 °C to approximately 815 °C and a temperature in conductor 580 may be approximately 500 °C to 840 °C. Substantially uniform heating of a hydrocarbon containing formation may be provided along a

length of conduit 582 greater than about 300 m or, maybe, greater than about 600 m. A length of conduit 582 may vary, however, depending on, for example, a type of hydrocarbon containing formation, a depth of an opening in the formation, and/or a length of the formation desired for treating.

The generated heat may be configured to heat at least a portion of a hydrocarbon containing formation. Heating of at least the portion may occur substantially by radiation of the generated heat within an opening in the formation and to a lesser extent by gas conduction. In this manner, a cost associated with filling the opening with a filling material to provide conductive heat transfer between the insulated conductor and the formation may be eliminated. In addition, heat transfer by radiation is generally more efficient than by conduction so the heaters will generally operate at lower temperatures in an open wellbore. Still another advantage is that the heating assembly will be free to undergo thermal expansion. Yet another advantage is that the heater may be replaceable.

The conductor-in-conduit heater, as described in any of the embodiments herein, may be installed in opening 514. In an embodiment, the conductor-in-conduit heater may be installed into a well by sections. For example, a first section of the conductor-in-conduit heater may be disposed into the well. The section may be about 12 m in length. A second section (e.g., of substantially similar length) may be coupled to the first section in the well. The second section may be coupled by welding the second section to the first section and/or with threads disposed on the first and second section. An orbital welder disposed at the wellhead may be configured to weld the second section to the first section. This process may be repeated with subsequent

sections coupled to previous sections until a heater of desired length may be disposed in the well. In some embodiments, three sections may be coupled prior to being disposed in the well. The three sections may be coupled by welding. The three sections may have a length of about 12.2 m each. The resulting 37 m section may be lifted vertically by a crane at the wellhead. The three sections may be coupled to three additional sections in the well as described herein. Welding the three sections prior to being disposed in the well may reduce a number of leaks and/or faulty welds and may decrease a time required for installation of the heater.

In an alternate embodiment, the conductor-in-conduit heater may be spooled onto a spooling assembly. The spooling assembly may be mounted on a transportable structure. The transportable structure may be transported to a well location. The conductor-in-conduit heater may be un-spooled from the spooling assembly into the well.

FIG. 2 illustrates an embodiment of a sliding connector. Sliding connector 583 may include scraper 593 that may abut an inner surface of conduit 582 at point 595. Scraper 593 may include any metal or electrically conducting material (e.g., steel or stainless steel). Centralizer 591 may couple to conductor 580. In some embodiments, conductor 580 may have a substantially low resistance section 584, due to an increased thickness, substantially around a location of sliding connector 583. Centralizer 591 may include any electrically conducting material (e.g., a metal or metal alloy). Centralizer 591 may be coupled to scraper 593 through spring bow 592. Spring bow 592 may include any metal or electrically conducting material (e.g., copper-beryllium alloy). Centralizer 591, spring bow 592, and/or scraper 593 may be coupled through any

welding method known in the art. Sliding connector 583 may electrically couple the substantially low resistance section 584 of conductor 580 to conduit 582 through centralizer 591, spring bow 592, and/or scraper 593. During heating of conductor 580, conductor 580 may expand at a substantially different rate than conduit 582. For example, point 594 on conductor 580 may move relative to point 595 on conduit 582 during heating of conductor 580. Scraper 593 may maintain electrical contact with conduit 582 by sliding along surface of conduit 582. Several sliding connectors may be used for redundancy and to reduce the current at each scraper. In addition, a thickness of conduit 582 may be increased for a length substantially adjacent to sliding connector 583 to substantially reduce heat generated in that portion of the conduit 582. The length of conduit 582 with increased thickness may be, for example, approximately 6 m.

FIG. 3 illustrates an embodiment of a wellhead. Wellhead 690 may be coupled to electrical junction box 690a by flange 690n or any other suitable mechanical device. Electrical junction box 690a may be configured to control power (current and voltage) supplied to an electric heater. The electric heater may be a conductor-in-conduit heater as described herein. Flange 690n may include, for example, stainless steel or any other suitable sealing material. Conductor 690b may be disposed in flange 690n and may electrically couple overburden casing 541 to electrical junction box 690a. Conductor 690b may include any metal or electrically conductive material (e.g., copper). Compression seal 690c may seal conductor 690b at an inner surface of electrical junction box 690a.

Flange 690n may be sealed with metal o-ring 690d. Conduit 690f, which may be, e.g., a pipe, may couple

flange 690n to flange 690m. Flange 690m may couple to overburden casing 541. Flange 690m may be sealed with o-ring 690g (e.g., metal o-ring or steel o-ring). The substantially low resistance section 584 of the conductor (e.g., conductor 580) may couple to electrical junction box 690a. The substantially low resistance section 584 may be passed through flange 690n and may be sealed in flange 690n with o-ring assembly 690p. Assemblies 690p are designed to insulate the substantially low resistance section 584 of conductor 580 from flange 690n and flange 690m. O-ring assembly 690c may be designed to electrically insulate conductor 690b from flange 690m and junction box 690a. Centralizer 581 may couple to low resistance section 584. Electrically insulating centralizer 581 may have characteristics as described in any of the embodiments herein. Thermocouples 690i may be coupled to thermocouple flange 690q with connectors 690h and wire 690j. Thermocouples 690i may be enclosed in an electrically insulated sheath (e.g., a metal sheath). Thermocouples 690i may be sealed in thermocouple flange 690q with compression seals 690k. Thermocouples 690i may be used to monitor temperatures in the heated portion downhole.

FIG. 4 illustrates an embodiment of a centralizer in, e.g., conduit 582. Electrical insulator 581a may be disposed on conductor 580. Insulator 581a may be made of, for example, aluminium oxide or any other electrically insulating material that may be configured for use at high temperatures. A location of insulator 581a on the conductor 580 may be maintained by disc 581d. Disc 581d may be welded to conductor 580. Spring bow 581c may be coupled to insulator 581a by disc 581b. Spring bow 581c and disc 581b may be made of metals such as 310 stainless steel and any other thermally conducting material that may be configured for use at high

temperatures. Centralizer 581 may be arranged as a single cylindrical member disposed on conductor 580. Centralizer 581 may be arranged as two half-cylindrical members disposed on conductor 580. The two half-cylindrical members may be coupled to conductor 580 by band 581e. Band 581e may be made of any material configured for use at high temperatures (e.g., steel).

FIG. 5a illustrates a longitudinal sectional view of an embodiment of a centralizer 581e disposed on conductor 580. FIG. 5b illustrates a cross-sectional view of the embodiment shown in FIG. 5a. Centralizer 581e may be made of any suitable electrically insulating material that may substantially withstand high voltage at high temperatures. Examples of such materials may be aluminium oxide and/or Macor. Discs 581d may maintain positions of centralizer 581e relative to conductor 580. Discs 581d may be metal discs welded to conductor 580. Discs 581d may be tack-welded to conductor 580. Centralizer 581e may substantially electrically insulate conductor 580 from conduit 582.

In an embodiment, a conduit may be pressurized with a fluid to balance a pressure in the conduit with a pressure in the surrounding wellbore. In this manner, deformation of the conduit may be substantially inhibited. A thermally conductive fluid may be configured to pressurize the conduit. The thermally conductive fluid may increase heat transfer within the conduit. The thermally conductive fluid may include a gas such as helium, nitrogen, air, or mixtures thereof. A pressurized fluid may also be configured to pressurize the conduit such that the pressurized fluid may inhibit arcing between the conductor and the conduit. If air and/or air mixtures are used to pressurize the conduit, the air and/or air mixtures may react with materials of the conductor and the conduit to form an oxide on a

surface of the conductor and the conduit such that the conductor and the conduit are at least somewhat more resistant to corrosion.

An emissivity of a conductor and/or a conduit may be increased. For example, a surface of the conductor and/or the conduit may be roughened to increase the emissivity. Blackening the surface of the conductor and/or the conduit may also increase the emissivity. Alternatively, oxidation of the conductor and/or the conduit prior to installation may be configured to increase the emissivity. The conductor and/or the conduit may also be oxidized by heating the conductor and/or the conduit in the presence of an oxidizing fluid in the conduit and/or in an opening in a hydrocarbon containing formation. Another alternative for increasing the emissivity may be to anodize the conductor and/or the conduit such that the surface may be roughened and/or blackened.

In another embodiment, a perforated tube may be placed in the opening formed in the hydrocarbon containing formation proximate to and external the first conduit. The perforated tube may be configured to remove fluids formed in the opening. In this manner, a pressure may be maintained in the opening such that deformation of the first conduit may be substantially inhibited and the pressure in the formation near the heaters may be reduced. The perforated tube may also be used to increase or decrease pressure in the formation by addition or removal of a fluid or fluids from the formation. This may allow control of the pressure in the formation and therefore control produced hydrocarbons quality as described in above embodiments. This may also allow control of the pressure at certain times during the process in order to provide additional support of the overlying formation and thus mitigate compaction and

subsidence. Perforated tubes may be used for pressure control in all described embodiments of heat sources using an open hole configuration. The perforated tube may also be configured to inject gases to upgrade hydrocarbon properties in situ; for example, hydrogen gas may be injected under elevated pressure.

FIG. 6 illustrates an alternative embodiment of a conductor-in-conduit heater configured to heat a section of a hydrocarbon containing formation. Second conductor 586 may be disposed in conduit 582 in addition to conductor 580. Conductor 580 may be configured as described herein. Second conductor 586 may be coupled to conductor 580 using connector 587 located near a lowermost surface of conduit 582. Second conductor 586 may be configured as a return path for the electrical current supplied to conductor 580. For example, second conductor 586 may return electrical current to wellhead 690 through second substantially low resistance conductor 588 in overburden casing 541. Second conductor 586 and conductor 580 may be configured of an elongated conductive material. Second conductor 586 and conductor 580 may be, for example, a stainless steel rod having a diameter of approximately 2.4 cm. Connector 587 may be flexible. Conduit 582 may be electrically isolated from conductor 580 and second conductor 586 using centralizers 581. Overburden casing 541, cement 544, surface conductor 545, and packing material 542 may be configured as described in the embodiment shown in FIG. 1. Advantages of this embodiment include the absence of a sliding contactor, which may extend the life of the heater, and the isolation of all applied power from formation 516.

In another embodiment, a second conductor may be disposed in a second conduit, and a third conductor may be disposed in a third conduit. The second opening may

be different from the opening for the first conduit. The third opening may be different from the opening for the first conduit and the second opening. For example, each of the first, second, and third openings may be disposed in substantially different well locations of the formation and may have substantially similar dimensions. The first, second, and third conductors may be configured as described herein. The first, second, and third conductors may be electrically coupled in a 3-phase Y electrical configuration. The outer conduits may be connected together or may be connected to the ground. The 3-phase Y electrical configuration may provide a safer, more efficient method to heat a hydrocarbon containing formation than using a single conductor. The first, second, and/or third conduits may be electrically isolated from the first, second, and third conductors, respectively. Dimensions of each conductor and each conduit may be configured such that each conductor may generate heat of approximately 650 watts per meter of conductor to approximately 1650 watts per meter of conductor. In an embodiment, a first conductor and a second conductor in a conduit may be coupled by a flexible connecting cable. The bottom of the first and second conductor may be enlarged to create low resistance sections, and thus generate less heat. In this manner, the flexible connector may be made of, for example, stranded copper covered with rubber insulation.

In an embodiment, a first conductor and a second conductor may be coupled to at least one sliding connector within a conduit. The sliding connector may be configured as described herein. For example, such a sliding connector may be configured to generate less heat than the first conductor or the second conductor. The conduit may be electrically isolated from the first conductor, second conductor, and/or the sliding

connector. The sliding connector may be placed in a location within the first conduit where substantially less heating of the hydrocarbon containing formation may be required.

In an embodiment, a thickness of a section of a conduit may be increased such that substantially less heat may be transferred (e.g., radiated) along the section of increased thickness. The section with increased thickness may preferably be formed along a length of the conduit where less heating of the hydrocarbon containing formation may be required.

In an embodiment, the conductor may be formed of sections of various metals that are welded together. The cross-sectional area of the various metals may be selected to allow the resulting conductor to be long, to be creep resistant at high operating temperatures, and/or to dissipate substantially the same amount of heat per unit length along the entire length of the conductor. For example a first section may be made of a creep resistant metal (such as, but not limited to Inconel 617 or HR120) and a second section of the conductor may be made of 304 stainless steel. The creep resistant first section may help to support the second section. The cross-sectional area of the first section may be larger than the cross-sectional area of the second section. The larger cross-sectional area of the first section may allow for greater strength of the first section. Higher resistivity properties of the first section may allow the first section to dissipate the same amount of heat per unit length as the smaller cross-sectional area second section.

In some embodiments, the cross-sectional area and/or the metal used for a particular section may be chosen so that a particular section provides greater (or lesser) heat dissipation per unit length than an adjacent

section. More or less heat dissipation may be required in some areas to slow down or accelerate certain physicochemical processes in the formation. More heat may be provided near an interface between a hydrocarbon layer and a non-hydrocarbon layer (e.g., the overburden and the hydrocarbon containing formation) to counteract end effects and allow for more uniform heat dissipation into the hydrocarbon containing formation. A higher heat dissipation may also be located at a lower end of an elongated member to counteract end effects and allow for more uniform heat dissipation.

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CLAIMS:

1. A system configured to heat a carbon containing formation, comprising:

a first electrical conductor disposed in a first conduit, which first conduit is disposed within a heater well traversing the formation, wherein the first conductor is configured to provide heat to at least a portion of the formation during use and the system is configured to allow heat to transfer from the first conductor to a section of the formation during use, wherein the first conduit is substantially freely suspended within the heater well and that an annular space is present between the first conduit and the formation;

a second conductor is disposed within a second conduit and a third conductor is disposed within a third conduit, wherein the first conduit, the second conduit and the third conduit are disposed in different openings of the formation, wherein the first conductor is electrically coupled to the second conductor and the third conductor, and the first, second and third conductors are configured to operate in a 3 phase Y configuration during use.

2. The system of claim 1, wherein the first conduit is removably suspended in a fluid filled section of the heater well and the system is configured to pyrolyse at least some hydrocarbon material within the formation.

3. The system of claim 1, wherein the first conductor is substantially freely suspended in the first conduit and one or more centralizers maintain at least a section of the first conductor substantially centrally within the first conduit.

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4. The system of claims 2 and 3, wherein the first conduit is filled with a fluid.

5. The system of claim 1, further comprising a lead-in cable coupled to an upper end of the first conductor, wherein the lead-in cable comprises a low resistance conductor configured to generate substantially no heat.

6. The system of claim 1, further comprising a sliding electrical connector which is electrically coupled to the first conductor and first conduit near a lower end of the first conductor and/or first conduit and a power source is connectable between an upper end of the first conductor and first conduit to form an electrical circuit.

7. The system of claim 4, wherein the fluid disposed within the first conduit is configured to maintain a pressure within the first conduit to substantially prevent deformation of the first conduit during use.

8. The system of claim 7, further comprising a tube disposed within the heater well external to the first conduit, wherein the tube is configured to remove vapour produced from at least the heated portion of the formation such that a pressure balance is maintained between the first conduit and the opening to substantially prevent deformation of the first conduit during use.

9. The system of claim 1, wherein the system is configured to generate during use radiant heat of 0.6 to 1.5 KW per meter length of the first conductor a second conductor is disposed within a second conduit and a third conductor is disposed within a third conduit, wherein first conduit, the second conduit and the third conduit are disposed in different openings of the formation, wherein the first conductor is electrically coupled to the second

conductor and the third conductor, and wherein the first, second, and third conductors are configured to operate in a 3-phase Y configuration during use.

10. An in situ method for heating a hydrocarbons containing formation, comprising:

applying an electrical current to a first conductor to provide heat to at least a portion of the formation, wherein the first conductor is disposed in a first conduit, and wherein the first conduit is disposed within a heater well traversing the formation; and allowing the heat to transfer from the first conductor to a section of the formation; wherein:

the first conduit is substantially freely suspended within the heater well;

an annular space is present between the first conduit and the formation;

a second conductor is disposed within a second conduit and a third conductor is disposed within a third conduit; the second conduit and the third conduit are disposed in different openings of the formation; the first conductor is electrically coupled to the second conductor and the third conductor, and the first, second and third conductors are configured to operate in a 3-phase Y configuration.

11. The method of claim 10, wherein the first conductor and the first conduit comprise a stainless steel pipe.

12. The method of claim 10 or 11, wherein the first conduit is removably suspended in a fluid filled section of the heater well.

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13. The method of claim 10, further comprising centralizing the first conductor within the first conduit with at least one centralizer and coupling a sliding electrical connector to the first conductor and the first conduit near the lower ends thereof.

14. The method of claim 13, wherein the first conduit comprises an electrical lead configured to complete an electrical circuit with the first conductor.

15. The method of claim 14, wherein between 10 and 40 percent of the heat generated in the electrical circuit formed by the first conductor and first conduit is generated by the first conduit.

16. The method of claim 15, wherein the electrical circuit provided by the first conductor and the first conduit generates in use between 0.6 and 1.5 KW per meter length of the heater well in which the first conductor and first conduit are arranged.

17. The method of claim 10, further comprising maintaining a fluid at an elevated pressure with in the first conduit and maintaining a sufficient elevated pressure between the first conduit and the formation to restrict deformation of the first conduit.

18. The method of claim 10, further comprising heating at least the portion of the formation to substantially pyrolyze at least some carbon containing material within the formation.

19. The method of claim 17, further comprising: pumping an oxidizing fluid from an oxidizing fluid source through the first conduit during use to substantially prevent deposition

of heated hydrocarbons on or proximate to at least the first conductor.

20. The method of claim 19, wherein the first conduit comprises openings through which the oxidising fluid is injected into an annular space surrounding the first conduit in which space hydrocarbons released by the hydrocarbon containing formation and/or hydrocarbons injected into said annular space are combusted.

21. The method of any one of claims 10 to 20, further comprising determining a temperature distribution in the first electrical conductor and/or the first electrical conduit using an electromagnetic signal provided to the first electrical conductor and/or the first electrical conduit.

22. The method of any one of claims 10 to 21, further comprising heating at least the portion of the formation surrounding the heater well to a temperature above 300°C to substantially pyrolyze at least some hydrocarbon material within the hydrocarbon containing formation.

SMART & BIGGAR

OTTAWA, CANADA

PATENT AGENTS

Fig.1.

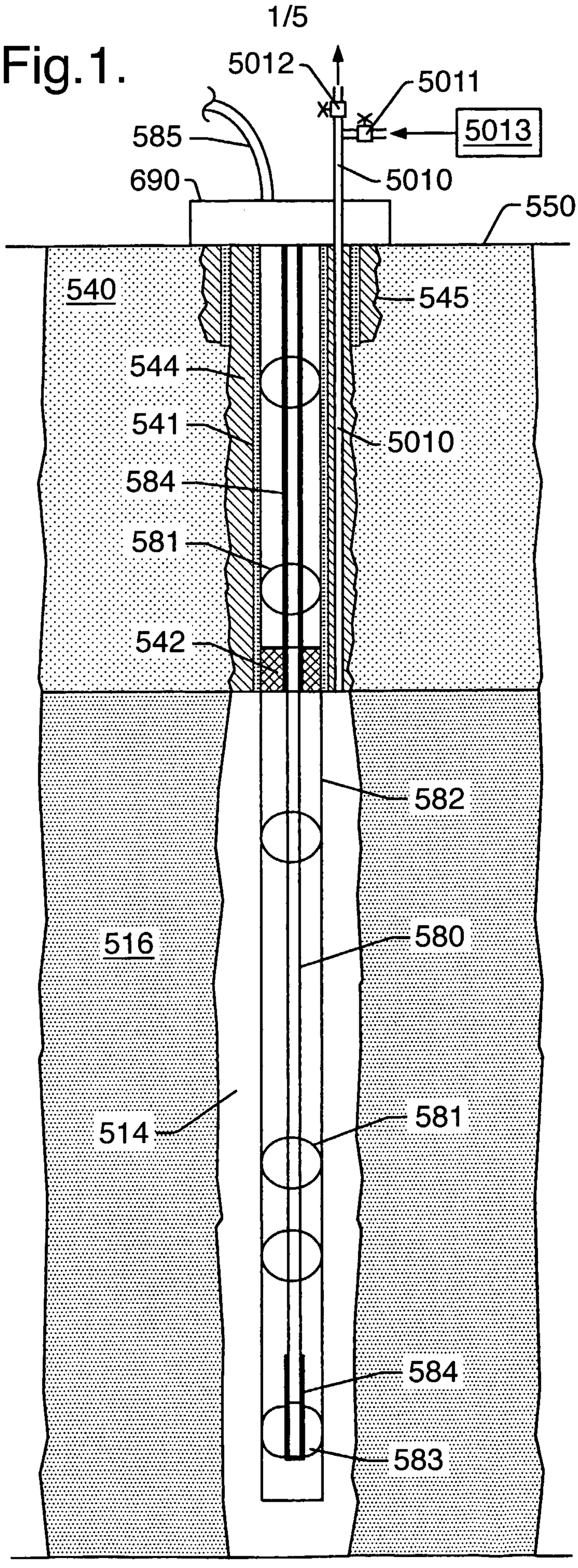
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Fig.2.

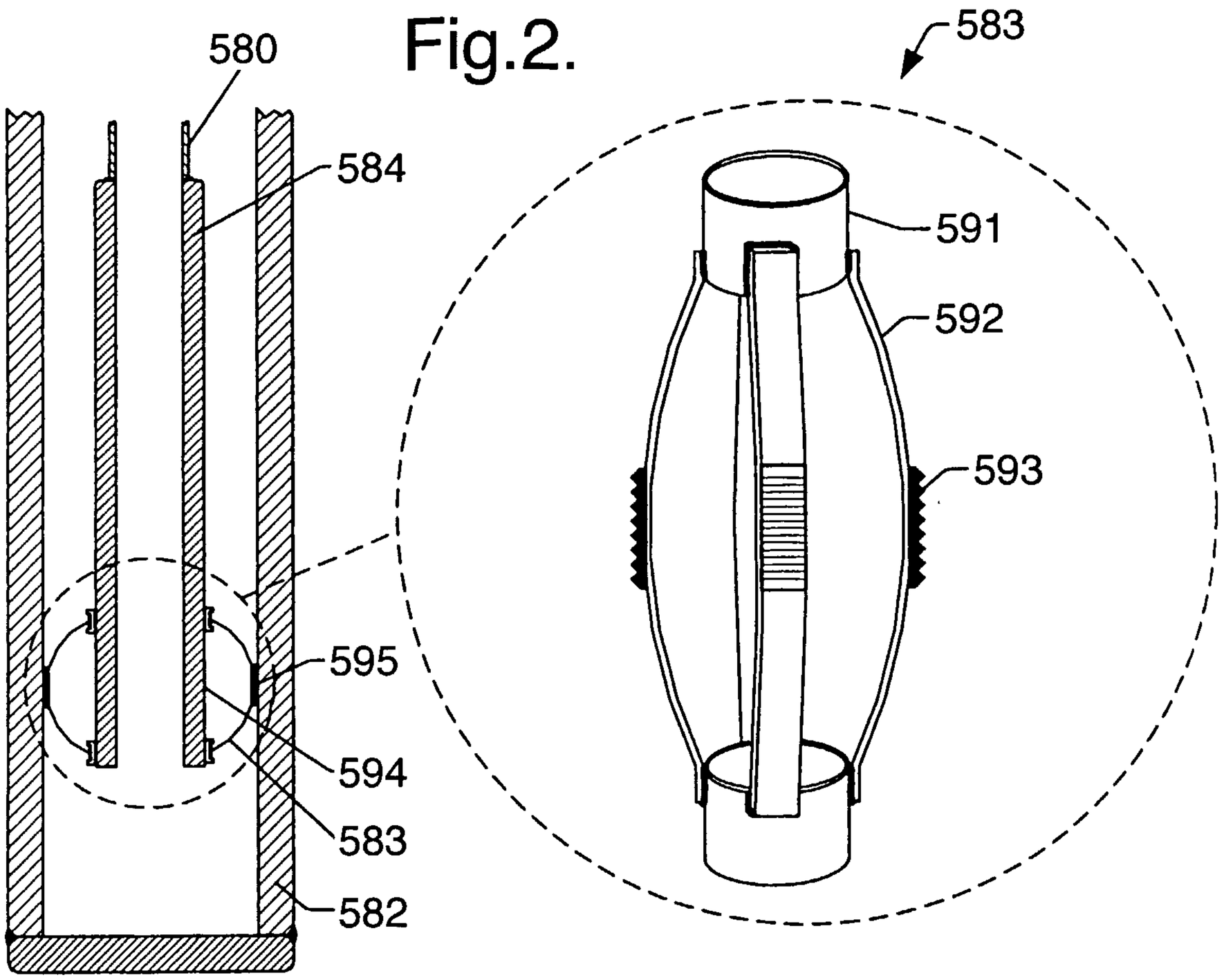
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Fig.4.

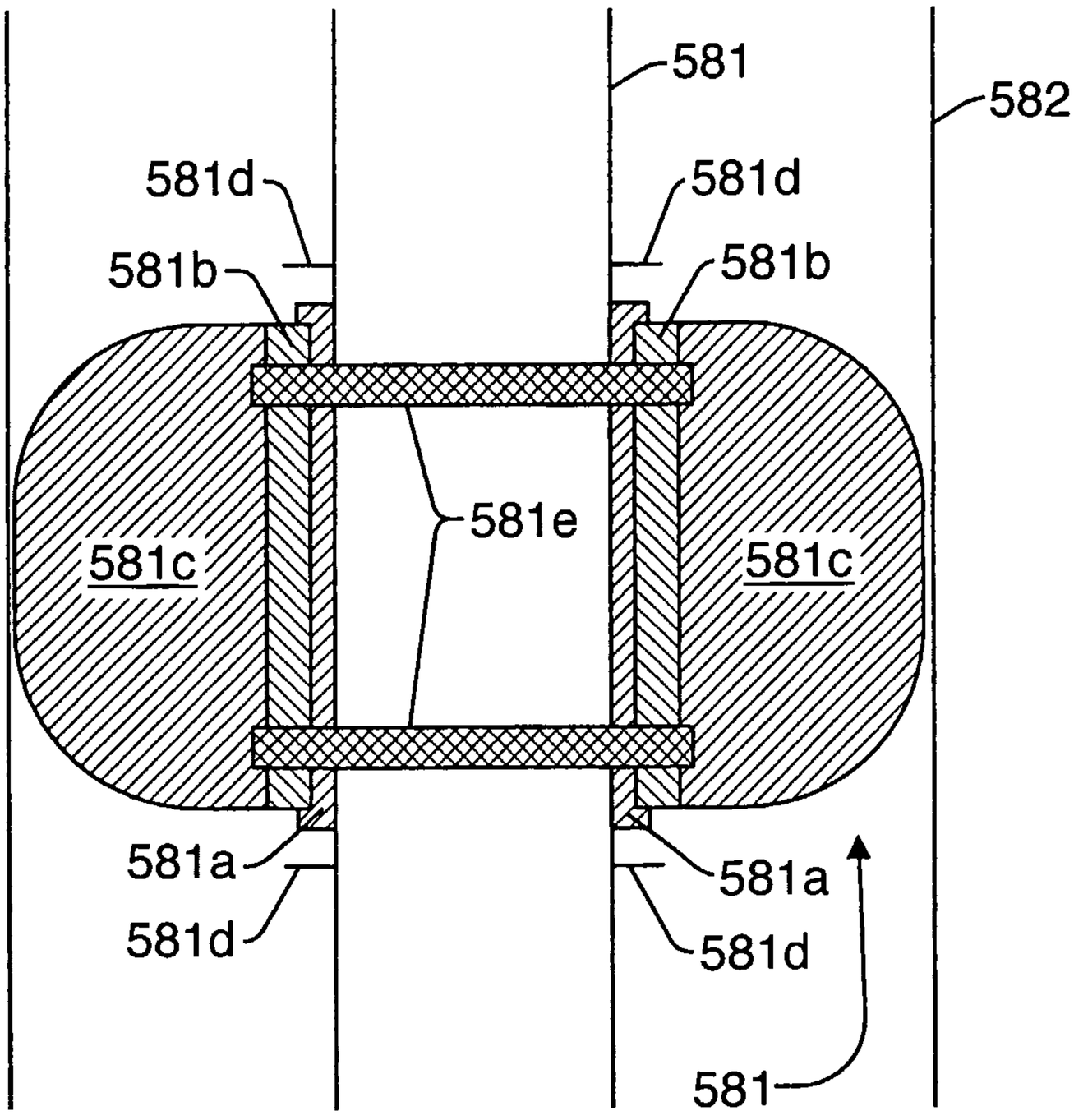
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Fig.3.

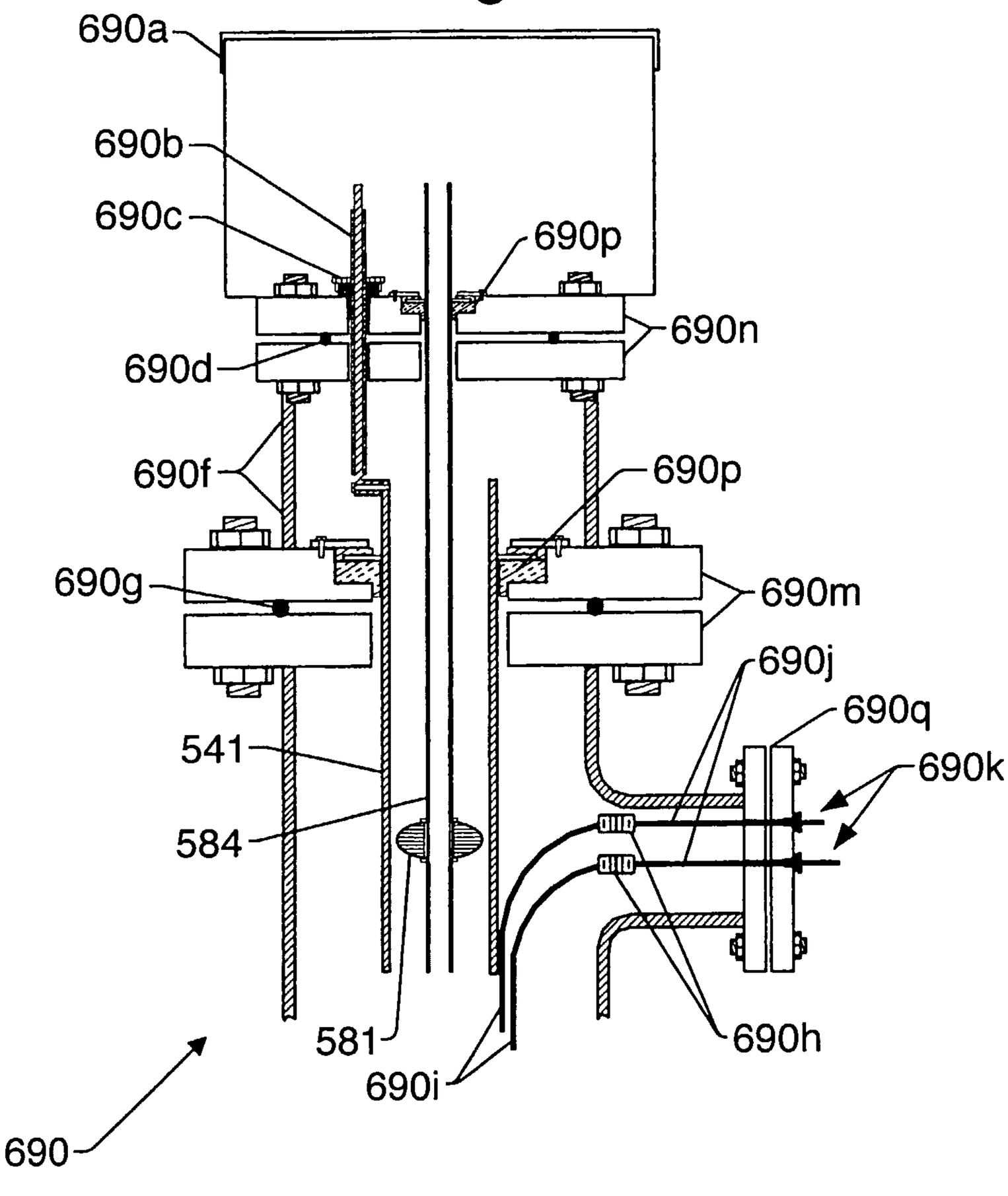
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Fig.5a.

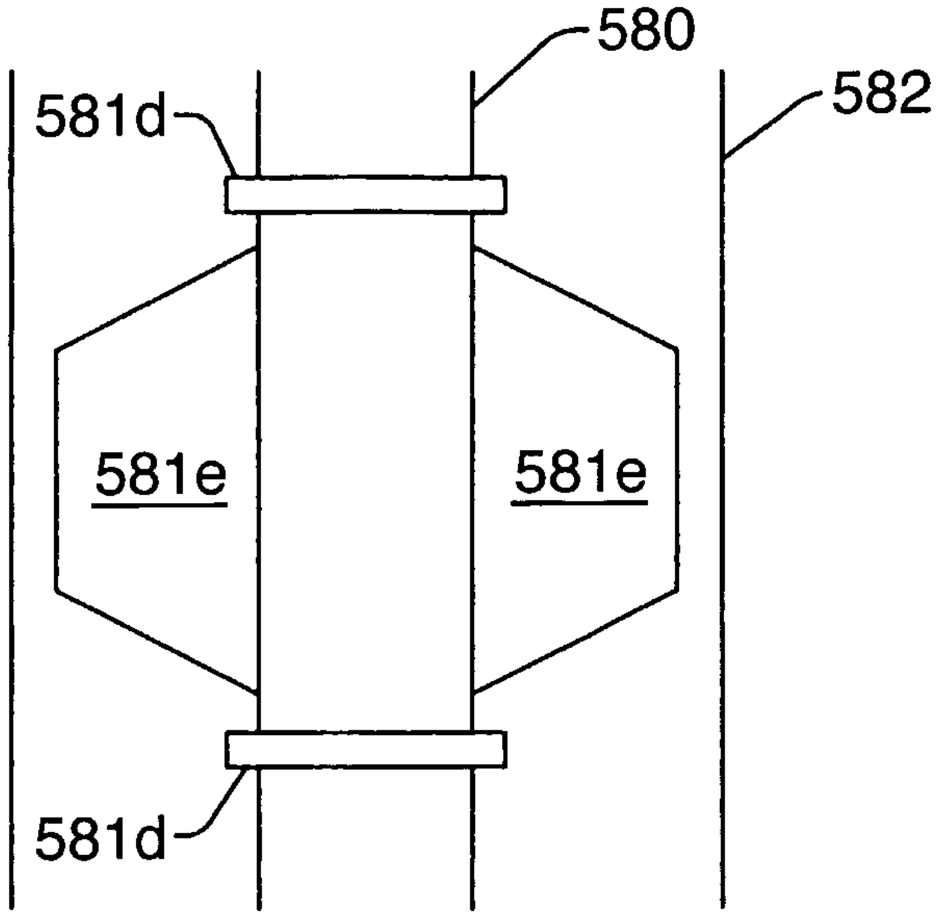


Fig.5b.

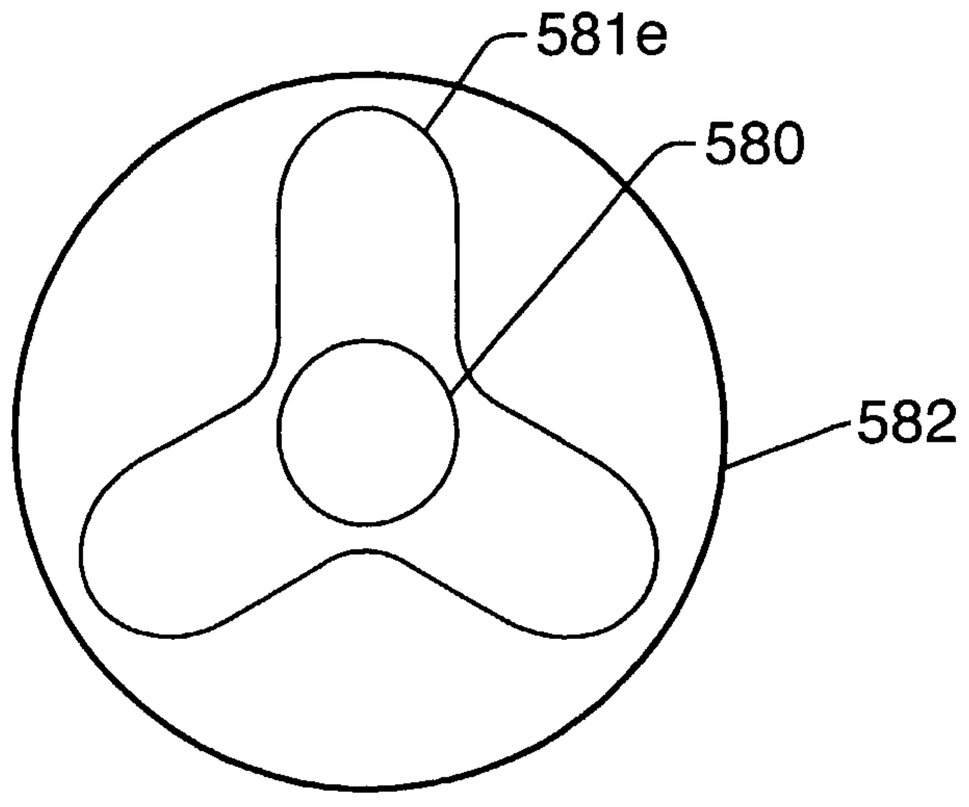
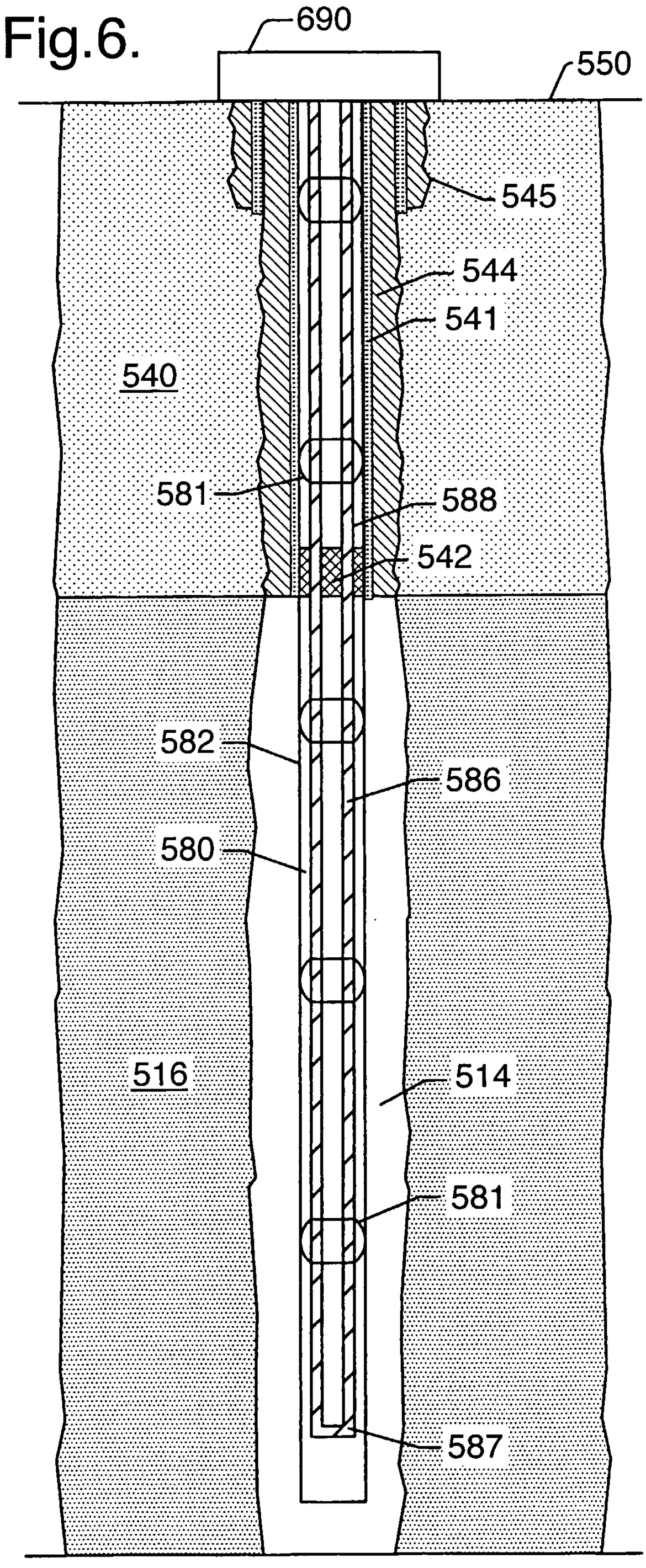
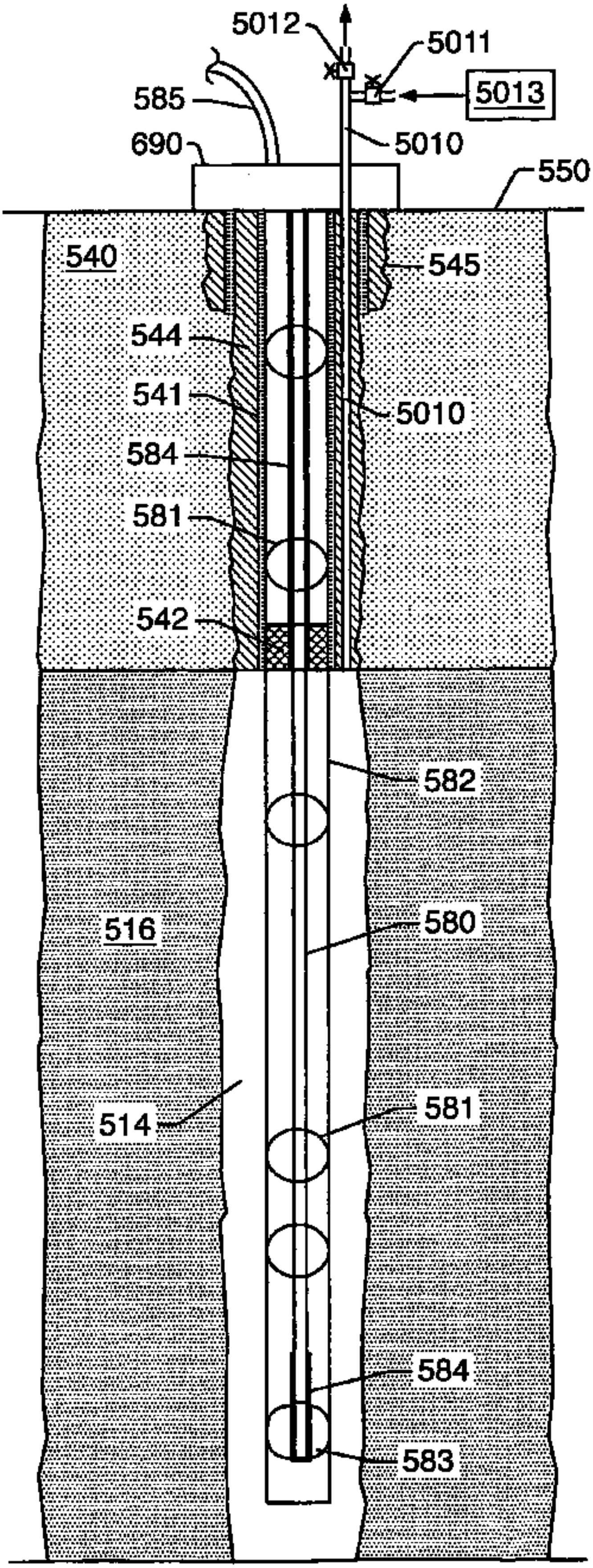


Fig.6.

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