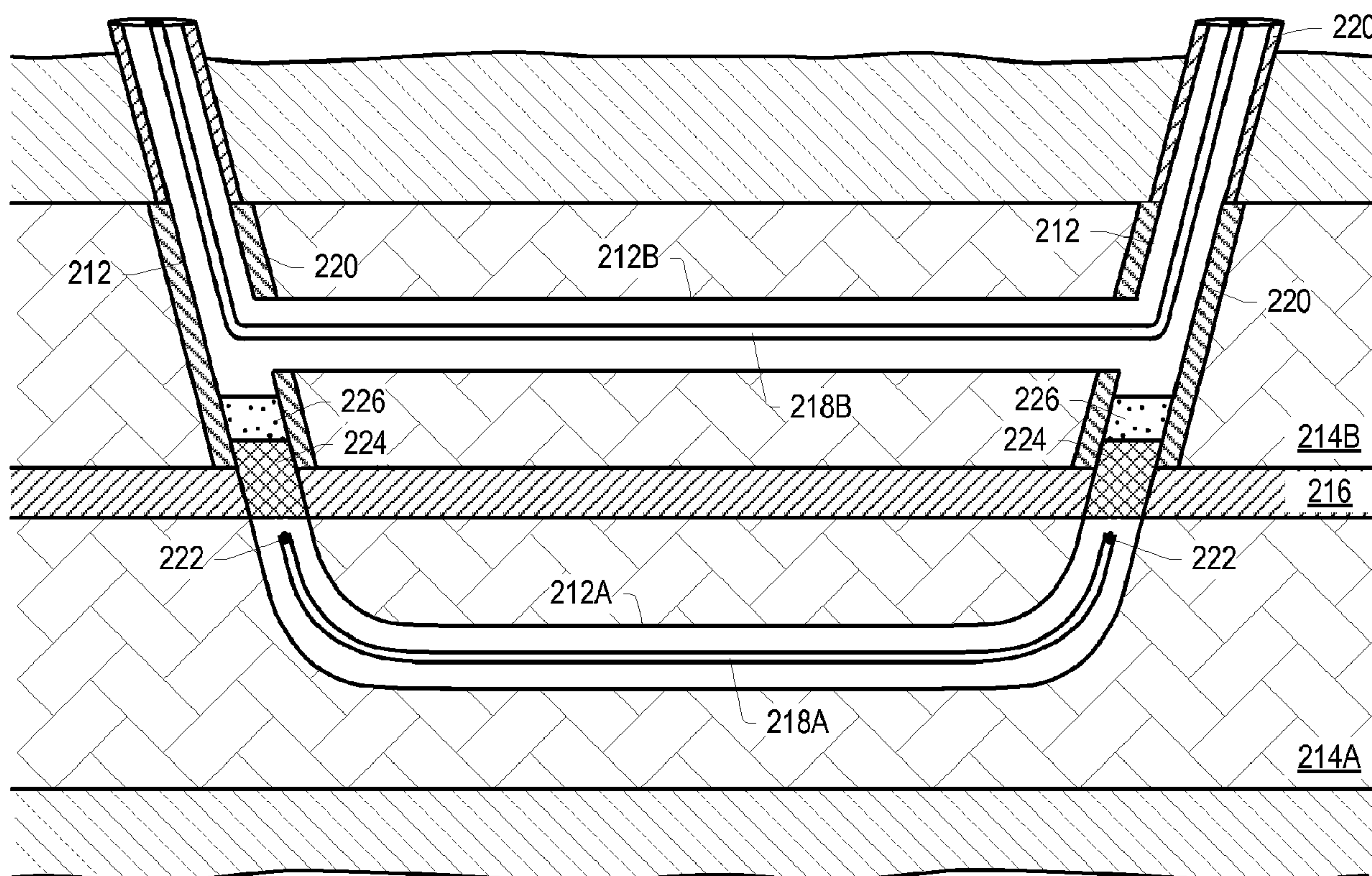




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(54) **Titre : CHAUFFAGE SEQUENCE DE COUCHES MULTIPLES DANS UNE FORMATION CONTENANT DES HYDROCARBURES**
 (54) **Title: TIME SEQUENCED HEATING OF MULTIPLE LAYERS IN A HYDROCARBON CONTAINING FORMATION**



(57) **Abrégé/Abstract:**

A method for treating a hydrocarbon containing formation includes providing heat for a first amount of time to a first hydrocarbon layer in the formation from a first heater located in an opening in the formation. The opening and the first heater have a substantially horizontal or inclined portion located in the first hydrocarbon layer in the formation and at least one connecting portion extending between the substantially horizontal or inclined portion and the surface. At least one connecting portion of the first heater is

(57) Abrégé(suite)/Abstract(continued):

removed from the opening. An isolation material is placed in the opening such that the isolation material at least partially isolates the layer in which the substantially horizontal or inclined portion of the first heater is located. An additional substantially horizontal or inclined opening portion is formed in a second hydrocarbon layer. The additional portion extends from at least one of the connecting portions of the opening. A second heater is placed in the additional substantially horizontal opening portion. Heat is provided from the second heater to the second hydrocarbon layer.

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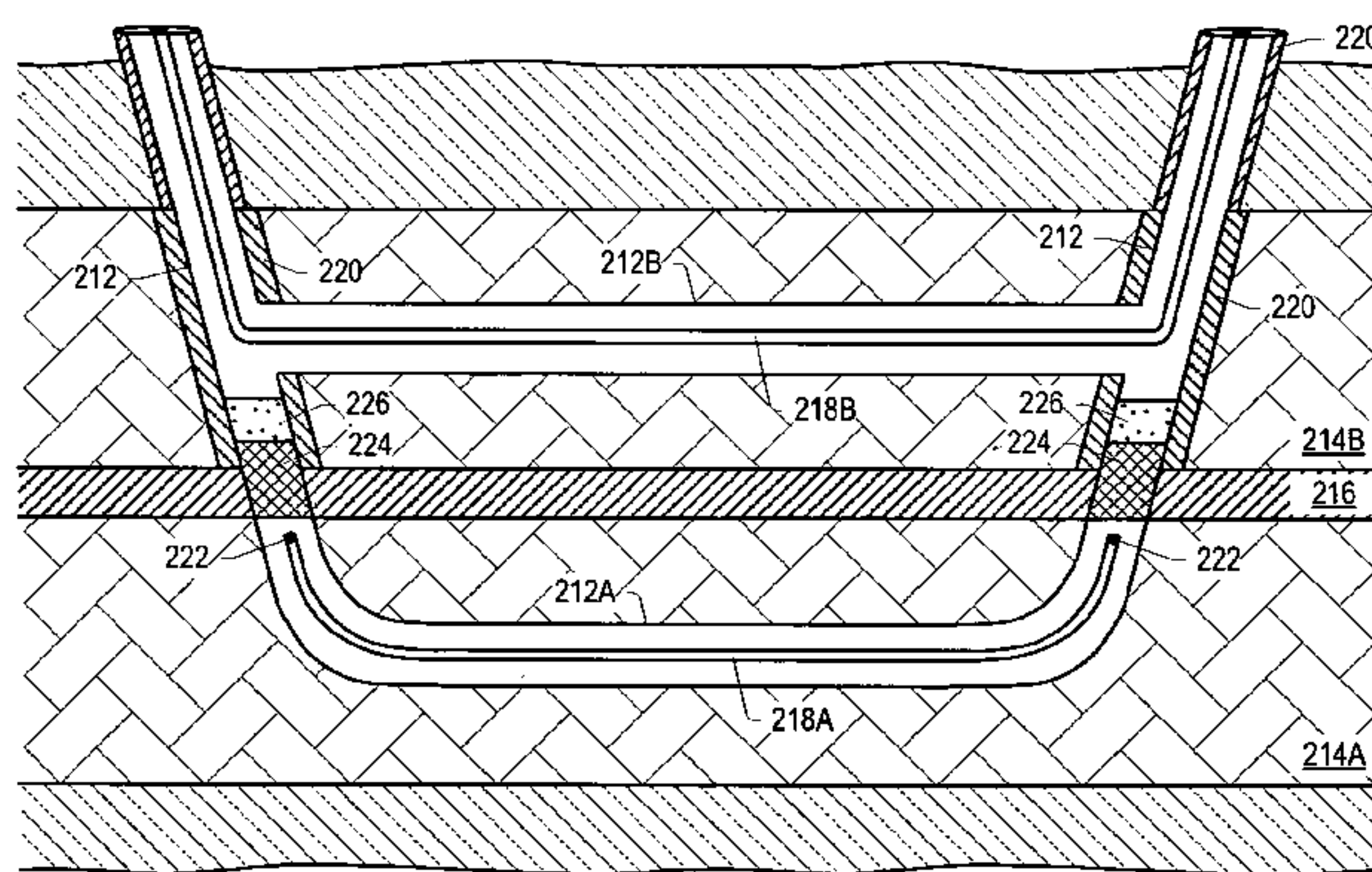


FIG. 3B

(57) Abstract: A method for treating a hydrocarbon containing formation includes providing heat for a first amount of time to a first hydrocarbon layer in the formation from a first heater located in an opening in the formation. The opening and the first heater have a substantially horizontal or inclined portion located in the first hydrocarbon layer in the formation and at least one connecting portion extending between the substantially horizontal or inclined portion and the surface. At least one connecting portion of the first heater is removed from the opening. An isolation material is placed in the opening such that the isolation material at least partially isolates the layer in which the substantially horizontal or inclined portion of the first heater is located. An additional substantially horizontal or inclined opening portion is formed in a second hydrocarbon layer. The additional portion extends from at least one of the connecting portions of the opening. A second heater is placed in the additional substantially horizontal opening portion. Heat is provided from the second heater to the second hydrocarbon layer.

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TIME SEQUENCED HEATING OF MULTIPLE LAYERS IN A
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GOVERNMENT INTEREST

5 The U.S. Government has certain rights in this invention pursuant to Agreement No. ERD-05-2516 between UT-Battelle, LLC, operating under prime contract No. DE-ACO5-00OR22725 for the US Department of Energy and Shell Exploration and Production Company.

10 **BACKGROUND**

1. Field of the Invention

The present invention relates generally to methods and systems for production of hydrocarbons, hydrogen, and/or other products from various subsurface formations such as hydrocarbon containing formations. In particular, certain embodiments relate to treating multiple layers in a hydrocarbon containing formation in a time sequenced method.

2. Description of Related Art

Hydrocarbons obtained from subterranean formations are often used as energy resources, as feedstocks, and as consumer products. Concerns over depletion of available hydrocarbon resources and concerns over declining overall quality of produced hydrocarbons have led to development of processes for more efficient recovery, processing and/or use of available hydrocarbon resources. In situ processes may be used to remove hydrocarbon materials from subterranean formations. Chemical and/or physical properties of hydrocarbon material in a subterranean formation may need to be changed to allow hydrocarbon material to be more easily removed from the subterranean formation. The chemical and physical changes may include in situ reactions that produce removable fluids, composition changes, solubility changes, density changes, phase changes, and/or viscosity changes of the hydrocarbon material in the formation. A fluid may be, but is not limited to, a gas, a liquid, an emulsion, a slurry, and/or a stream of solid particles that has flow characteristics similar to liquid flow.

30 Large deposits of heavy hydrocarbons (heavy oil and/or tar) contained in relatively permeable formations (for example in tar sands) are found in North America, South America, Africa, and Asia. Tar can be surface-mined and upgraded to lighter hydrocarbons such as crude oil, naphtha, kerosene, and/or gas oil. Surface milling

processes may further separate the bitumen from sand. The separated bitumen may be converted to light hydrocarbons using conventional refinery methods. Mining and upgrading tar sand is usually substantially more expensive than producing lighter hydrocarbons from conventional oil reservoirs.

5 In situ production of hydrocarbons from tar sand may be accomplished by heating and/or injecting a gas into the formation. U.S. Patent Nos. 5,211,230 to Ostapovich et al. and 5,339,897 to Leaute describe a horizontal production well located in an oil-bearing reservoir. A vertical conduit may be used to inject an oxidant gas into the reservoir for in situ combustion.

10 U.S. Patent No. 2,780,450 to Ljungstrom describes heating bituminous geological formations in situ to convert or crack a liquid tar-like substance into oils and gases.

U.S. Patent No. 4,597,441 to Ware et al. describes contacting oil, heat, and hydrogen simultaneously in a reservoir. Hydrogenation may enhance recovery of oil from the reservoir.

15 U.S. Patent No. 5,046,559 to Glandt and 5,060,726 to Glandt et al. describe preheating a portion of a tar sand formation between an injector well and a producer well. Steam may be injected from the injector well into the formation to produce hydrocarbons at the producer well.

20 As outlined above, there has been a significant amount of effort to develop methods and systems to economically produce hydrocarbons, hydrogen, and/or other products from hydrocarbon containing formations. At present, however, there are still many hydrocarbon containing formations from which hydrocarbons, hydrogen, and/or other products cannot be economically produced. Thus, there is still a need for improved methods and systems for production of hydrocarbons, hydrogen, and/or other products from various hydrocarbon
25 containing formations. Specifically, there is a need for one or more methods to treat formations with two or more hydrocarbon layers separated by impermeable layers. Producing the layers in a time sequenced method may increase the economic viability of treating such formations.

30 SUMMARY

Embodiments described herein generally relate to systems, methods, and heaters for treating a subsurface formation. Embodiments described herein also generally relate to

heaters that have novel components therein. Such heaters can be obtained by using the systems and methods described herein.

In certain embodiments, the invention provides one or more systems, methods, and/or heaters. In some embodiments, the systems, methods, and/or heaters are used for
5 treating a subsurface formation.

In certain embodiments, the invention provides a method for treating a hydrocarbon containing formation, comprising: providing heat for a first amount of time to a first hydrocarbon layer in the formation from a first heater located in an opening in the formation, the opening and the first heater having a substantially horizontal or inclined
10 portion located in the first hydrocarbon layer in the formation and at least one connecting portion extending between the substantially horizontal or inclined portion and the surface; removing at least one connecting portion of the first heater from the opening; placing an isolation material in the opening such that the isolation material at least partially isolates the layer in which the substantially horizontal or inclined portion of the first heater is
15 located; forming an additional substantially horizontal or inclined opening portion in a second hydrocarbon layer, the additional portion extending from at least one of the connecting portions of the opening; placing a second heater in the additional substantially horizontal opening portion; and providing heat from the second heater to the second hydrocarbon layer.

20 In further embodiments, features from specific embodiments may be combined with features from other embodiments. For example, features from one embodiment may be combined with features from any of the other embodiments.

In further embodiments, treating a subsurface formation is performed using any of the methods, systems, or heaters described herein.

25 In further embodiments, additional features may be added to the specific embodiments described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

Advantages of the present invention may become apparent to those skilled in the art
30 with the benefit of the following detailed description and upon reference to the accompanying drawings in which:

FIG. 1 depicts an illustration of stages of heating a hydrocarbon containing formation.

FIG. 2 shows a schematic view of an embodiment of a portion of an in situ heat treatment system for treating a hydrocarbon containing formation.

FIGS. 3A and 3B depict an embodiment for using substantially u-shaped wellbores to time sequence heat two layers in a hydrocarbon containing formation.

5 FIGS. 4A and 4B depict an embodiment for using horizontal wellbores to time sequence heat two layers in a hydrocarbon containing formation.

While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof are shown by way of example in the drawings and may herein be described in detail.

10 The drawings may not be to scale. It should be understood, however, that the drawings and detailed description thereto are not intended to limit the invention to the particular form disclosed, but on the contrary, the intention is to cover all modifications, equivalents and alternatives falling within the spirit and scope of the present invention as defined by the appended claims.

15

DETAILED DESCRIPTION

The following description generally relates to systems and methods for treating hydrocarbons in the formations. Such formations may be treated to yield hydrocarbon products, hydrogen, and other products.

20 A "formation" includes one or more hydrocarbon containing layers, one or more non-hydrocarbon layers, an overburden, and/or an underburden. "Hydrocarbon layers" refer to layers in the formation that contain hydrocarbons. The hydrocarbon layers may contain non-hydrocarbon material and hydrocarbon material. The "overburden" and/or the "underburden" include one or more different types of impermeable materials. For
25 example, the overburden and/or underburden may include rock, shale, mudstone, or wet/tight carbonate. In some embodiments of in situ heat treatment processes, the overburden and/or the underburden may include a hydrocarbon containing layer or hydrocarbon containing layers that are relatively impermeable and are not subjected to temperatures during in situ heat treatment processing that result in significant characteristic
30 changes of the hydrocarbon containing layers of the overburden and/or the underburden. For example, the underburden may contain shale or mudstone, but the underburden is not allowed to heat to pyrolysis temperatures during the in situ heat treatment process. In some cases, the overburden and/or the underburden may be somewhat permeable.

“Formation fluids” refer to fluids present in a formation and may include pyrolyzation fluid, synthesis gas, mobilized hydrocarbon, and water (steam). Formation fluids may include hydrocarbon fluids as well as non-hydrocarbon fluids. The term “mobilized fluid” refers to fluids in a hydrocarbon containing formation that are able to flow as a result of thermal treatment of the formation. “Produced fluids” refer to fluids removed from the formation.

A “heat source” is any system for providing heat to at least a portion of a formation substantially by conductive and/or radiative heat transfer. For example, a heat source may include electric heaters such as an insulated conductor, an elongated member, and/or a conductor disposed in a conduit. A heat source may also include systems that generate heat by burning a fuel external to or in a formation. The systems may be surface burners, downhole gas burners, flameless distributed combustors, and natural distributed combustors. In some embodiments, heat provided to or generated in one or more heat sources may be supplied by other sources of energy. The other sources of energy may directly heat a formation, or the energy may be applied to a transfer medium that directly or indirectly heats the formation. It is to be understood that one or more heat sources that are applying heat to a formation may use different sources of energy. Thus, for example, for a given formation some heat sources may supply heat from electric resistance heaters, some heat sources may provide heat from combustion, and some heat sources may provide heat from one or more other energy sources (for example, chemical reactions, solar energy, wind energy, biomass, or other sources of renewable energy). A chemical reaction may include an exothermic reaction (for example, an oxidation reaction). A heat source may also include a heater that provides heat to a zone proximate and/or surrounding a heating location such as a heater well.

A “heater” is any system or heat source for generating heat in a well or a near wellbore region. Heaters may be, but are not limited to, electric heaters, burners, combustors that react with material in or produced from a formation, and/or combinations thereof.

“Hydrocarbons” are generally defined as molecules formed primarily by carbon and hydrogen atoms. Hydrocarbons may also include other elements such as, but not limited to, halogens, metallic elements, nitrogen, oxygen, and/or sulfur. Hydrocarbons may be, but are not limited to, kerogen, bitumen, pyrobitumen, oils, natural mineral waxes, and asphaltites. Hydrocarbons may be located in or adjacent to mineral matrices in the earth.

Matrices may include, but are not limited to, sedimentary rock, sands, silicilytes, carbonates, diatomites, and other porous media. "Hydrocarbon fluids" are fluids that include hydrocarbons. Hydrocarbon fluids may include, entrain, or be entrained in non-hydrocarbon fluids such as hydrogen, nitrogen, carbon monoxide, carbon dioxide, hydrogen sulfide, water, and ammonia.

An "in situ conversion process" refers to a process of heating a hydrocarbon containing formation from heat sources to raise the temperature of at least a portion of the formation above a pyrolysis temperature so that pyrolyzation fluid is produced in the formation.

An "in situ heat treatment process" refers to a process of heating a hydrocarbon containing formation with heat sources to raise the temperature of at least a portion of the formation above a temperature that results in mobilized fluid, visbreaking, and/or pyrolysis of hydrocarbon containing material so that mobilized fluids, visbroken fluids, and/or pyrolyzation fluids are produced in the formation.

A "u-shaped wellbore" refers to a wellbore that extends from a first opening in the formation, through at least a portion of the formation, and out through a second opening in the formation. In this context, the wellbore may be only roughly in the shape of a "v" or "u", with the understanding that the "legs" of the "u" do not need to be parallel to each other, or perpendicular to the "bottom" of the "u" for the wellbore to be considered "u-shaped".

The term "wellbore" refers to a hole in a formation made by drilling or insertion of a conduit into the formation. A wellbore may have a substantially circular cross section, or another cross-sectional shape. As used herein, the terms "well" and "opening," when referring to an opening in the formation may be used interchangeably with the term "wellbore."

Hydrocarbons in formations may be treated in various ways to produce many different products. In certain embodiments, hydrocarbons in formations are treated in stages. FIG. 1 depicts an illustration of stages of heating the hydrocarbon containing formation. FIG. 1 also depicts an example of yield ("Y") in barrels of oil equivalent per ton (y axis) of formation fluids from the formation versus temperature ("T") of the heated formation in degrees Celsius (x axis).

Desorption of methane and vaporization of water occurs during stage 1 heating. Heating of the formation through stage 1 may be performed as quickly as possible. For example, when the hydrocarbon containing formation is initially heated, hydrocarbons in

the formation desorb adsorbed methane. The desorbed methane may be produced from the formation. If the hydrocarbon containing formation is heated further, water in the hydrocarbon containing formation is vaporized. Water may occupy, in some hydrocarbon containing formations, between 10% and 50% of the pore volume in the formation. In other formations, water occupies larger or smaller portions of the pore volume. Water typically is vaporized in a formation between 160 °C and 285 °C at pressures of 600 kPa absolute to 7000 kPa absolute. In some embodiments, the vaporized water produces wettability changes in the formation and/or increased formation pressure. The wettability changes and/or increased pressure may affect pyrolysis reactions or other reactions in the formation. In certain embodiments, the vaporized water is produced from the formation. In other embodiments, the vaporized water is used for steam extraction and/or distillation in the formation or outside the formation. Removing the water from and increasing the pore volume in the formation increases the storage space for hydrocarbons in the pore volume.

In certain embodiments, after stage 1 heating, the formation is heated further, such that a temperature in the formation reaches (at least) an initial pyrolyzation temperature (such as a temperature at the lower end of the temperature range shown as stage 2). Hydrocarbons in the formation may be pyrolyzed throughout stage 2. A pyrolysis temperature range varies depending on the types of hydrocarbons in the formation. The pyrolysis temperature range may include temperatures between 250 °C and 900 °C. The pyrolysis temperature range for producing desired products may extend through only a portion of the total pyrolysis temperature range. In some embodiments, the pyrolysis temperature range for producing desired products may include temperatures between 250 °C and 400 °C or temperatures between 270 °C and 350 °C. If a temperature of hydrocarbons in the formation is slowly raised through the temperature range from 250 °C to 400 °C, production of pyrolysis products may be substantially complete when the temperature approaches 400 °C. Average temperature of the hydrocarbons may be raised at a rate of less than 5 °C per day, less than 2 °C per day, less than 1 °C per day, or less than 0.5 °C per day through the pyrolysis temperature range for producing desired products. Heating the hydrocarbon containing formation with a plurality of heat sources may establish thermal gradients around the heat sources that slowly raise the temperature of hydrocarbons in the formation through the pyrolysis temperature range.

The rate of temperature increase through the pyrolysis temperature range for desired products may affect the quality and quantity of the formation fluids produced from the hydrocarbon containing formation. Raising the temperature slowly through the pyrolysis temperature range for desired products may inhibit mobilization of large chain molecules in the formation. Raising the temperature slowly through the pyrolysis temperature range for desired products may limit reactions between mobilized hydrocarbons that produce undesired products. Slowly raising the temperature of the formation through the pyrolysis temperature range for desired products may allow for the production of high quality, high API gravity hydrocarbons from the formation. Slowly raising the temperature of the formation through the pyrolysis temperature range for desired products may allow for the removal of a large amount of the hydrocarbons present in the formation as hydrocarbon product.

In some in situ heat treatment embodiments, a portion of the formation is heated to a desired temperature instead of slowly heating the temperature through a temperature range. In some embodiments, the desired temperature is 300 °C, 325 °C, or 350 °C. Other temperatures may be selected as the desired temperature. Superposition of heat from heat sources allows the desired temperature to be relatively quickly and efficiently established in the formation. Energy input into the formation from the heat sources may be adjusted to maintain the temperature in the formation substantially at the desired temperature. The heated portion of the formation is maintained substantially at the desired temperature until pyrolysis declines such that production of desired formation fluids from the formation becomes uneconomical. Parts of the formation that are subjected to pyrolysis may include regions brought into a pyrolysis temperature range by heat transfer from only one heat source.

In certain embodiments, formation fluids including pyrolyzation fluids are produced from the formation. As the temperature of the formation increases, the amount of condensable hydrocarbons in the produced formation fluid may decrease. At high temperatures, the formation may produce mostly methane and/or hydrogen. If the hydrocarbon containing formation is heated throughout an entire pyrolysis range, the formation may produce only small amounts of hydrogen towards an upper limit of the pyrolysis range. After all of the available hydrogen is depleted, a minimal amount of fluid production from the formation will typically occur.

After pyrolysis of hydrocarbons, a large amount of carbon and some hydrogen may still be present in the formation. A significant portion of carbon remaining in the formation can be produced from the formation in the form of synthesis gas. Synthesis gas generation may take place during stage 3 heating depicted in FIG. 1. Stage 3 may include heating a hydrocarbon containing formation to a temperature sufficient to allow synthesis gas generation. For example, synthesis gas may be produced in a temperature range from about 400 °C to about 1200 °C, about 500 °C to about 1100 °C, or about 550 °C to about 1000 °C. The temperature of the heated portion of the formation when the synthesis gas generating fluid is introduced to the formation determines the composition of synthesis gas produced in the formation. The generated synthesis gas may be removed from the formation through a production well or production wells.

Total energy content of fluids produced from the hydrocarbon containing formation may stay relatively constant throughout pyrolysis and synthesis gas generation. During pyrolysis at relatively low formation temperatures, a significant portion of the produced fluid may be condensable hydrocarbons that have a high energy content. At higher pyrolysis temperatures, however, less of the formation fluid may include condensable hydrocarbons. More non-condensable formation fluids may be produced from the formation. Energy content per unit volume of the produced fluid may decline slightly during generation of predominantly non-condensable formation fluids. During synthesis gas generation, energy content per unit volume of produced synthesis gas declines significantly compared to energy content of pyrolyzation fluid. The volume of the produced synthesis gas, however, will in many instances increase substantially, thereby compensating for the decreased energy content.

FIG. 2 depicts a schematic view of an embodiment of a portion of the in situ heat treatment system for treating the hydrocarbon containing formation. The in situ heat treatment system may include barrier wells 200. Barrier wells are used to form a barrier around a treatment area. The barrier inhibits fluid flow into and/or out of the treatment area. Barrier wells include, but are not limited to, dewatering wells, vacuum wells, capture wells, injection wells, grout wells, freeze wells, or combinations thereof. In some embodiments, barrier wells 200 are dewatering wells. Dewatering wells may remove liquid water and/or inhibit liquid water from entering a portion of the formation to be heated, or to the formation being heated. In the embodiment depicted in FIG. 2, the barrier wells 200 are shown extending only along one side of heat sources 202, but the barrier

wells typically encircle all heat sources 202 used, or to be used, to heat a treatment area of the formation.

Heat sources 202 are placed in at least a portion of the formation. Heat sources 202 may include heaters such as insulated conductors, conductor-in-conduit heaters, surface
5 burners, flameless distributed combustors, and/or natural distributed combustors. Heat sources 202 may also include other types of heaters. Heat sources 202 provide heat to at least a portion of the formation to heat hydrocarbons in the formation. Energy may be supplied to heat sources 202 through supply lines 204. Supply lines 204 may be structurally different depending on the type of heat source or heat sources used to heat the
10 formation. Supply lines 204 for heat sources may transmit electricity for electric heaters, may transport fuel for combustors, or may transport heat exchange fluid that is circulated in the formation. In some embodiments, electricity for an in situ heat treatment process may be provided by a nuclear power plant or nuclear power plants. The use of nuclear power may allow for reduction or elimination of carbon dioxide emissions from the in situ
15 heat treatment process.

Production wells 206 are used to remove formation fluid from the formation. In some embodiments, production well 206 includes a heat source. The heat source in the production well may heat one or more portions of the formation at or near the production well. In some in situ heat treatment process embodiments, the amount of heat supplied to
20 the formation from the production well per meter of the production well is less than the amount of heat applied to the formation from a heat source that heats the formation per meter of the heat source. Heat applied to the formation from the production well may increase formation permeability adjacent to the production well by vaporizing and removing liquid phase fluid adjacent to the production well and/or by increasing the
25 permeability of the formation adjacent to the production well by formation of macro and/or micro fractures.

In some embodiments, the heat source in production well 206 allows for vapor phase removal of formation fluids from the formation. Providing heating at or through the production well may: (1) inhibit condensation and/or refluxing of production fluid when
30 such production fluid is moving in the production well proximate the overburden, (2) increase heat input into the formation, (3) increase production rate from the production well as compared to a production well without a heat source, (4) inhibit condensation of

high carbon number compounds (C6 and above) in the production well, and/or (5) increase formation permeability at or proximate the production well.

Subsurface pressure in the formation may correspond to the fluid pressure generated in the formation. As temperatures in the heated portion of the formation increase, the pressure in the heated portion may increase as a result of increased fluid generation and vaporization of water. Controlling rate of fluid removal from the formation may allow for control of pressure in the formation. Pressure in the formation may be determined at a number of different locations, such as near or at production wells, near or at heat sources, or at monitor wells.

In some hydrocarbon containing formations, production of hydrocarbons from the formation is inhibited until at least some hydrocarbons in the formation have been pyrolyzed. Formation fluid may be produced from the formation when the formation fluid is of a selected quality. In some embodiments, the selected quality includes an API gravity of at least about 20°, 30°, or 40°. Inhibiting production until at least some hydrocarbons are pyrolyzed may increase conversion of heavy hydrocarbons to light hydrocarbons. Inhibiting initial production may minimize the production of heavy hydrocarbons from the formation. Production of substantial amounts of heavy hydrocarbons may require expensive equipment and/or reduce the life of production equipment.

After pyrolysis temperatures are reached and production from the formation is allowed, pressure in the formation may be varied to alter and/or control a composition of formation fluid produced, to control a percentage of condensable fluid as compared to non-condensable fluid in the formation fluid, and/or to control an API gravity of formation fluid being produced. For example, decreasing pressure may result in production of a larger condensable fluid component. The condensable fluid component may contain a larger percentage of olefins.

In some in situ heat treatment process embodiments, pressure in the formation may be maintained high enough to promote production of formation fluid with an API gravity of greater than 20°. Maintaining increased pressure in the formation may inhibit formation subsidence during in situ heat treatment. Maintaining increased pressure may facilitate vapor phase production of fluids from the formation. Vapor phase production may allow for a reduction in size of collection conduits used to transport fluids produced from the formation. Maintaining increased pressure may reduce or eliminate the need to compress

formation fluids at the surface to transport the fluids in collection conduits to treatment facilities.

Maintaining increased pressure in a heated portion of the formation may surprisingly allow for production of large quantities of hydrocarbons of increased quality and of relatively low molecular weight. Pressure may be maintained so that formation fluid produced has a minimal amount of compounds above a selected carbon number. The selected carbon number may be at most 25, at most 20, at most 12, or at most 8. Some high carbon number compounds may be entrained in vapor in the formation and may be removed from the formation with the vapor. Maintaining increased pressure in the formation may inhibit entrainment of high carbon number compounds and/or multi-ring hydrocarbon compounds in the vapor. High carbon number compounds and/or multi-ring hydrocarbon compounds may remain in a liquid phase in the formation for significant time periods. The significant time periods may provide sufficient time for the compounds to pyrolyze to form lower carbon number compounds.

Formation fluid produced from production wells 206 may be transported through collection piping 208 to treatment facilities 210. Formation fluids may also be produced from heat sources 202. For example, fluid may be produced from heat sources 202 to control pressure in the formation adjacent to the heat sources. Fluid produced from heat sources 202 may be transported through tubing or piping to collection piping 208 or the produced fluid may be transported through tubing or piping directly to treatment facilities 210. Treatment facilities 210 may include separation units, reaction units, upgrading units, fuel cells, turbines, storage vessels, and/or other systems and units for processing produced formation fluids. The treatment facilities may form transportation fuel from at least a portion of the hydrocarbons produced from the formation. In some embodiments, the transportation fuel may be jet fuel, such as JP-8.

FIGS. 3A and 3B depict an embodiment for using substantially u-shaped wellbores to time sequence heat two layers in a hydrocarbon containing formation. A single heater is shown in the embodiments depicted in FIGS. 3A and 3B, it is to be understood, however, that there are typically several heaters located in a hydrocarbon layer and that only one heater is shown in the drawings for simplicity. In FIG. 3A, opening 212A is formed in hydrocarbon layer 214A extending between openings 212. In certain embodiments, opening 212A is a substantially horizontal opening in hydrocarbon layer 214A. In some embodiments, opening 212A is an inclined opening in hydrocarbon layer 214A (for

example, the layer may be an angled layer and the opening is angled to be substantially horizontal in the layer). Openings 212 are openings (for example, relatively vertical openings) that extend from the surface into hydrocarbon layer 214A. Hydrocarbon layer 214A may be separated from hydrocarbon layer 214B by impermeable zone 216. In
5 certain embodiments, hydrocarbon layer 214B is an upper layer or a layer at a lesser depth than hydrocarbon layer 214A. In some embodiments, hydrocarbon layer 214B is a lower layer or a layer at a greater depth than hydrocarbon layer 214A. In certain embodiments, impermeable zone 216 provides a substantially impermeable seal that inhibits fluid flow between hydrocarbon layer 214A and hydrocarbon layer 214B. In certain embodiments
10 (for example, in an oil shale formation), hydrocarbon layer 214A has a higher richness than hydrocarbon layer 214B.

As shown in FIG. 3A, heating element 218A is located in opening 212A in hydrocarbon layer 214A. Overburden casing 220 is placed along the relatively vertical walls of openings 212 in hydrocarbon layer 214B. Overburden casing 220 inhibits heat
15 transfer to hydrocarbon layer 214B while heat is provided to hydrocarbon layer 214A by heating element 218A. Heating element 218A is used to provide heat to hydrocarbon layer 214A. Formation fluids (such as mobilized hydrocarbons, pyrolyzed hydrocarbons, and/or water) may be produced from hydrocarbon layer 214A during and/or after heating of the layer by heating element 218A.

20 Heat may be provided to hydrocarbon layer 214A by heating element 218A for a selected amount of time (for example, a first amount of time). The selected amount of time may be based on a variety of factors including, but not limited to, formation characteristics or properties, present or future economic factors, or capital costs. For example, for an oil shale formation, hydrocarbon layer 214A may have a richness of about 0.12 L/kg (30.5
25 gals/ton) and the layer is heated for about 25 years. Production of formation fluids from hydrocarbon layer 214A may continue from the layer until production slows down to an uneconomical rate.

After hydrocarbon layer 214A is heated for the selected amount of time, heating element 218A is turned down and/or off. After heating element 218A is turned off, the
30 heating element may be pulled firmly (for example, yanked) upwards so that the heating element breaks off at links 222. Both ends of heating element 218A at the surface may be pulled simultaneously so that links 222 break approximately simultaneously. Links 222 may be weak links designed to pull apart when a selected or sufficient amount of pulling

force is applied to the links. For example, links 222 may be breakable mechanical couplings between portions of the heating element. The upper portions of heating element 218A are then pulled out of the formation and the substantially horizontal portion of heating element 218A is left in opening 212A, as shown in FIG. 3B.

5 In some embodiments, only one link 222 may be broken so that the upper portion above the one link can be removed and the remaining portions of the heater can be removed by pulling on the opposite end of the heater. Thus, the entire length of heating element 218A may be removed from the formation.

After upper portions of heating element 218A are removed from openings 212,
10 plugs 224 may be placed into openings 212 at a selected location in hydrocarbon layer 214B, as depicted in FIG. 3B. In certain embodiments, plugs 224 are placed into openings 212 at or near impermeable zone 216. Plugs 224 may include isolation materials such as substantially impermeable materials or other materials that inhibit fluid flow between the hydrocarbon layers in the formation in openings 212 (for example, the plugs may isolate
15 hydrocarbon layer 214A). In some embodiments, packing 226 is placed into openings 212 above plugs 224. In some embodiments, packing 226 is placed in openings 212 without plugs in the openings. Packing 226 may include substantially impermeable materials or other materials to inhibit fluid flow.

After plugs 224 and/or packing 226 is set into place in openings 212, substantially
20 horizontal opening 212B may be formed in hydrocarbon layer 214B. Opening 212B may be formed by punching (for example, drilling) through casing 220 on the wall of opening 212. In certain embodiments, opening 212B is a substantially horizontal opening in hydrocarbon layer 214B. In some embodiments, opening 212B is an inclined opening in hydrocarbon layer 214B (for example, the layer may be an angled layer and the opening is
25 angled to be substantially horizontal in the layer). Heating element 218B is then placed into opening 212B. Heating element 218B may be used to provide heat to hydrocarbon layer 214B. Formation fluids, such as pyrolyzed hydrocarbons and/or mobilized hydrocarbons, may be produced from hydrocarbon layer 214B during and/or after heating of the layer by heating element 218B.

30 In certain embodiments, opening 212 is a single-ended horizontal opening in hydrocarbon layer 214A (for example, the opening has only one end open at the surface of the formation). FIGS. 4A and 4B depict an embodiment for using single-ended horizontal wellbores to time sequence heat two layers in a hydrocarbon containing formation. A

single heater is shown in the embodiments depicted in FIGS. 4A and 4B, it is to be understood, however, that there are typically several heaters located in a hydrocarbon layer and that only one heater is shown in the drawings for simplicity.

In FIG. 4A, opening 212A is formed in hydrocarbon layer 214A extending from opening 212. In certain embodiments, opening 212A is a substantially horizontal opening in hydrocarbon layer 214A that terminates in the layer. In some embodiments, opening 212A is an inclined opening in hydrocarbon layer 214A (for example, the layer may be an angled layer and the opening is angled to be substantially horizontal in the layer). Opening 212 is an opening (for example, a relatively vertical opening) that extends from the surface into hydrocarbon layer 214A. Hydrocarbon layer 214A may be separated from hydrocarbon layer 214B by impermeable zone 216. In certain embodiments, hydrocarbon layer 214B is an upper layer or a layer at a lesser depth than hydrocarbon layer 214A. In other embodiments, hydrocarbon layer 214B is a lower layer or a layer at a greater depth than hydrocarbon layer 214A. In certain embodiments, impermeable zone 216 provides a substantially impermeable seal that inhibits fluid flow between hydrocarbon layer 214A and hydrocarbon layer 214B. In certain embodiments (for example, in an oil shale formation), hydrocarbon layer 214A has a higher richness than hydrocarbon layer 214B.

As shown in FIG. 4A, heating element 218A is located in opening 212A in hydrocarbon layer 214A. Overburden casing 220 is placed along the relatively vertical walls of opening 212 in hydrocarbon layer 214B. Overburden casing 220 inhibits heat transfer to hydrocarbon layer 214B while heat is provided to hydrocarbon layer 214A by heating element 218A. Heating element 218A is used to provide heat to hydrocarbon layer 214A. Formation fluids (such as mobilized hydrocarbons, pyrolyzed hydrocarbons, and/or water) may be produced from hydrocarbon layer 214A during and/or after heating of the layer by heating element 218A.

Heat may be provided to hydrocarbon layer 214A by heating element 218A for a selected amount of time. The selected amount of time may be based on a variety of factors including, but not limited to, formation characteristics or properties, present or future economic factors, or capital costs. For example, for an oil shale formation, hydrocarbon layer 214A may have a richness of about 0.12 L/kg (30.5 gals/ton) and the layer is heated for about 25 years. Production of formation fluids from hydrocarbon layer 214A may continue from the layer until production slows down to an uneconomical rate.

After hydrocarbon layer 214A is heated for the selected amount of time, heating element 218A is turned down and/or off. After heating element 218A is turned down and/or off, the heating element may be removed from opening 212A. In some embodiments, one or more portions of heating element 218A are left in opening 212A. For example, portions of hydrocarbon layer 214A may clamp or squeeze on heating element 218A so that the heating element cannot be completely removed from opening 212A. In such cases, heating element 218A may be broken at link 222 and the upper portion of heating element 218A is pulled out of the formation and the substantially horizontal portion of the heating element is left in opening 212A.

After heating element 218A is removed from opening 212, plug 224 may be placed into opening 212 at a selected location in hydrocarbon layer 214B, as depicted in FIG. 4B. In certain embodiments, plug 224 is placed into opening 212 at or near impermeable zone 216. Plug 224 may include isolation materials such as substantially impermeable materials or other materials that inhibit fluid flow between the hydrocarbon layers in the formation in openings 212 (for example, the plug may isolate hydrocarbon layer 214A). In some embodiments, packing 226 is placed into opening 212 above plug 224. In some embodiments, packing 226 is placed in opening 212 without a plug in the opening. Packing 226 may include substantially impermeable materials or other materials to inhibit fluid flow.

After plug 224 and/or packing 226 is set into place in opening 212, substantially horizontal opening 212B may be formed in hydrocarbon layer 214B. Opening 212B may extend horizontally from opening 212. In certain embodiments, opening 212B is a substantially horizontal opening in hydrocarbon layer 214B that terminates in the layer. In some embodiments, opening 212B is an inclined opening in hydrocarbon layer 214B (for example, the layer may be an angled layer and the opening is angled to be substantially horizontal in the layer). Opening 212B may be formed by punching (for example, drilling) through casing 220 on the wall of opening 212. Heating element 218B is then placed into opening 212B. Heating element 218B may be used to provide heat to hydrocarbon layer 214B. Formation fluids, such as pyrolyzed hydrocarbons and/or mobilized hydrocarbons, may be produced from hydrocarbon layer 214B during and/or after heating of the layer by heating element 218B.

Heating hydrocarbon layers 214A, 214B in the time-sequenced manners described above may be more economical than producing from only one layer or using vertical

heaters to provide heat to the layers simultaneously. Using relatively vertical openings 212 to access both hydrocarbon layers at different times may save on capital costs associated with forming openings in the formation and providing surface facilities to power the heating elements. Heating hydrocarbon layer 214A first before heating hydrocarbon layer 214B may improve the economics of treating the formation (for example, the net present value of a project to treat the formation). In addition, impermeable zone 216 and packing 226 may provide a seal for hydrocarbon layer 214A after heating and production from the layer. This seal may be useful for abandonment of the hydrocarbon layer after treating the hydrocarbon layer.

10 In some embodiments, heat may be scavenged from hydrocarbon layer 214A and used to provide heat to hydrocarbon layer 214B. For example, a heat transfer fluid may be circulated through opening 212A to recover heat from hydrocarbon layer 214A. The heat transfer fluid may later be used to provide heat directly or indirectly (for example, using a heat exchanger to transfer heat to another heating fluid) to hydrocarbon layer 214B. In some embodiments, heat recovered from hydrocarbon layer 214A is used to provide power (for example, electrical power) to other heaters (for example, heating element 218B used in hydrocarbon layer 214B).

15 In some embodiments, synthesis gas generation or other post-treatment processes may be performed in hydrocarbon layer 214A before heating in hydrocarbon layer 214B is started. For example, carbon dioxide or other materials may be sequestered in hydrocarbon layer 214A before plugging or sealing off the layer.

20 Further modifications and alternative embodiments of various aspects of the invention may be apparent to those skilled in the art in view of this description. Accordingly, this description is to be construed as illustrative only and is for the purpose of teaching those skilled in the art the general manner of carrying out the invention. It is to be understood that the forms of the invention shown and described herein are to be taken as the presently preferred embodiments. Elements and materials may be substituted for those illustrated and described herein, parts and processes may be reversed, and certain features of the invention may be utilized independently, all as would be apparent to one skilled in the art after having the benefit of this description of the invention. Changes may be made in the elements described herein. In addition, it is to be understood that features described herein independently may, in certain embodiments, be combined.

Claims:

1. A method for treating a hydrocarbon containing formation, comprising:

providing heat for a first amount of time to a first hydrocarbon layer in the formation from a first heater located in an opening in the formation, the opening and the first heater having a substantially horizontal or inclined portion located in the first hydrocarbon layer in the formation and at least one connecting portion extending between the substantially horizontal or inclined portion and the surface;

removing at least one connecting portion of the first heater from the opening;

placing an isolation material in the opening such that the isolation material at least partially isolates the layer in which the substantially horizontal or inclined portion of the first heater is located;

forming an additional substantially horizontal or inclined opening portion in a second hydrocarbon layer, the additional portion extending from at least one of the connecting portions of the opening;

placing a second heater in the additional substantially horizontal opening portion;
and

providing heat from the second heater to the second hydrocarbon layer.

2. The method of claim 1, further comprising producing fluids from the formation.

3. The method of any one of claims 1 or 2, wherein the first amount of time is sufficient time to produce a selected amount of hydrocarbons from the first hydrocarbon layer.

4. The method of any one of claims 1-3, wherein at least one of the connecting portions is coupled to an end portion of the substantially horizontal or inclined portion.

5. The method of any one of claims 1-4, wherein the second hydrocarbon layer is separated from the first hydrocarbon layer by an at least partially impermeable layer.
6. The method of any one of claims 1-5, wherein the isolation material at least partially isolates the opening above the first hydrocarbon layer or, alternatively, below the first hydrocarbon layer.
7. The method of any one of claims 1-6, further comprising uncoupling at least one connecting portion of the first heater from the substantially horizontal portion of the first heater.
8. The method of any one of claims 1-7, further comprising abandoning the first hydrocarbon layer after treating the formation by leaving the packing in place in the opening.
9. The method of any one of claims 1-8, wherein the connecting portion of the first heater is uncoupled from the substantially horizontal portion of the first heater by breaking one or more links on the first heater.
10. The method of claim 9, wherein the breaking is performed by pulling one or more of the connecting portions with a sufficient amount of force.
11. The method of any one of claims 1-10, wherein the formation comprises an oil shale formation.
12. The method of any one of claims 1-11, wherein the first hydrocarbon layer has a higher richness than the second hydrocarbon layer.
13. The method of any one of claims 1-12, wherein the first hydrocarbon layer is at a greater depth than the second hydrocarbon layer.

14. The method of any one of claims 1-13, wherein the isolation material provides an impermeable layer between the first hydrocarbon layer and the second hydrocarbon layer.
15. The method of any one of claims 1-14, wherein the opening has a first end portion at a first location on the surface of the formation and a second end portion at a second location on the surface of the formation.
16. The method of any one of claims 1-15, wherein the opening comprises a u-shaped opening.
17. The method of any one of claims 1-16, wherein the connecting portions of the opening comprise relatively vertical portions.
18. The method of any one of claims 1-17, wherein the substantially horizontal portion of the opening extends between at least two relatively vertical connecting portions of the opening in the first hydrocarbon layer.
19. The method of any one of claims 1-18, wherein the additional substantially horizontal portion of the opening extends between at least two relatively vertical connecting portions of the opening in the second hydrocarbon layer.
20. The method of any of claims 1-19, wherein the substantially horizontal portion of the first heater is left in the substantially horizontal portion of the opening after removing the connecting portions of the first heater from the opening.

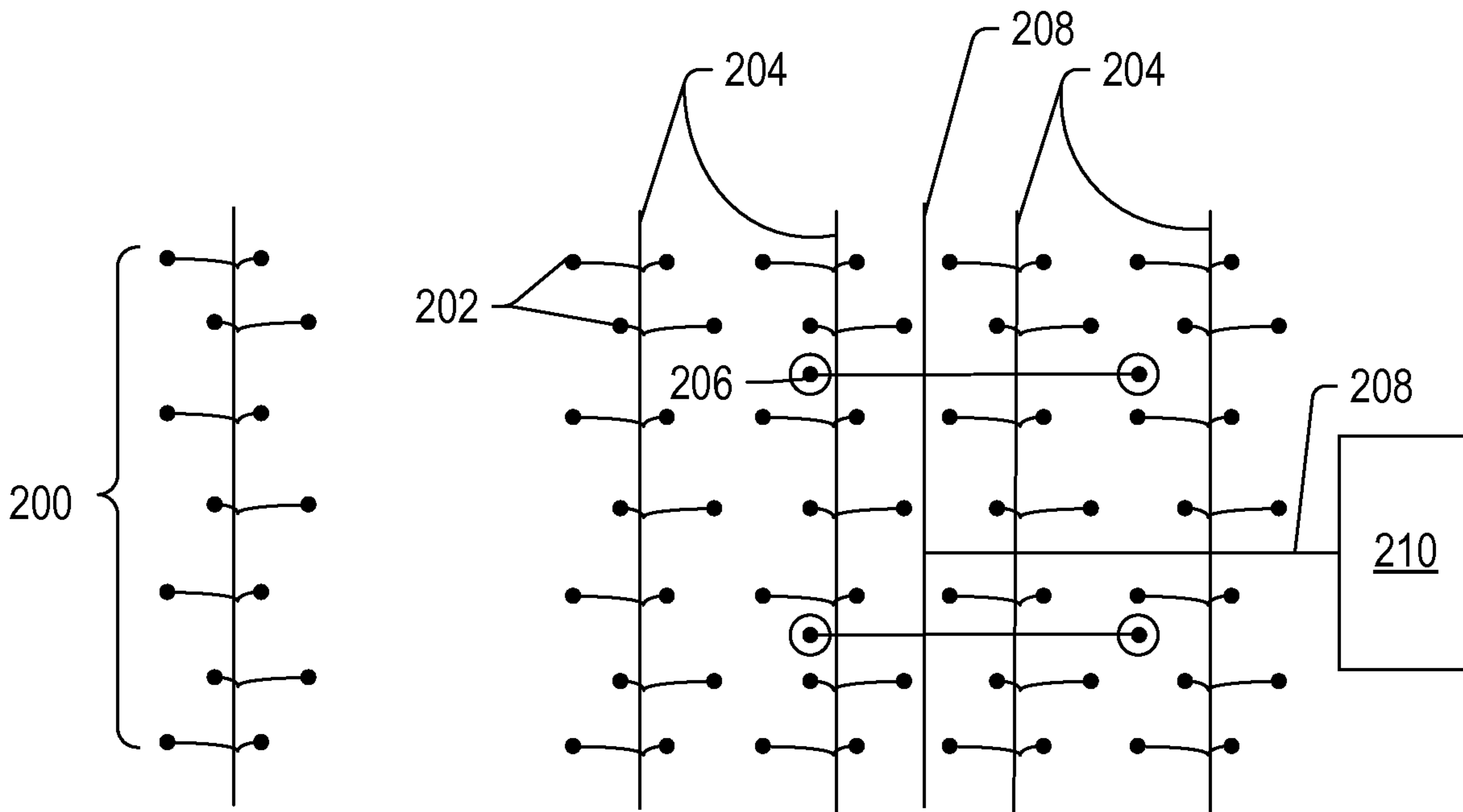
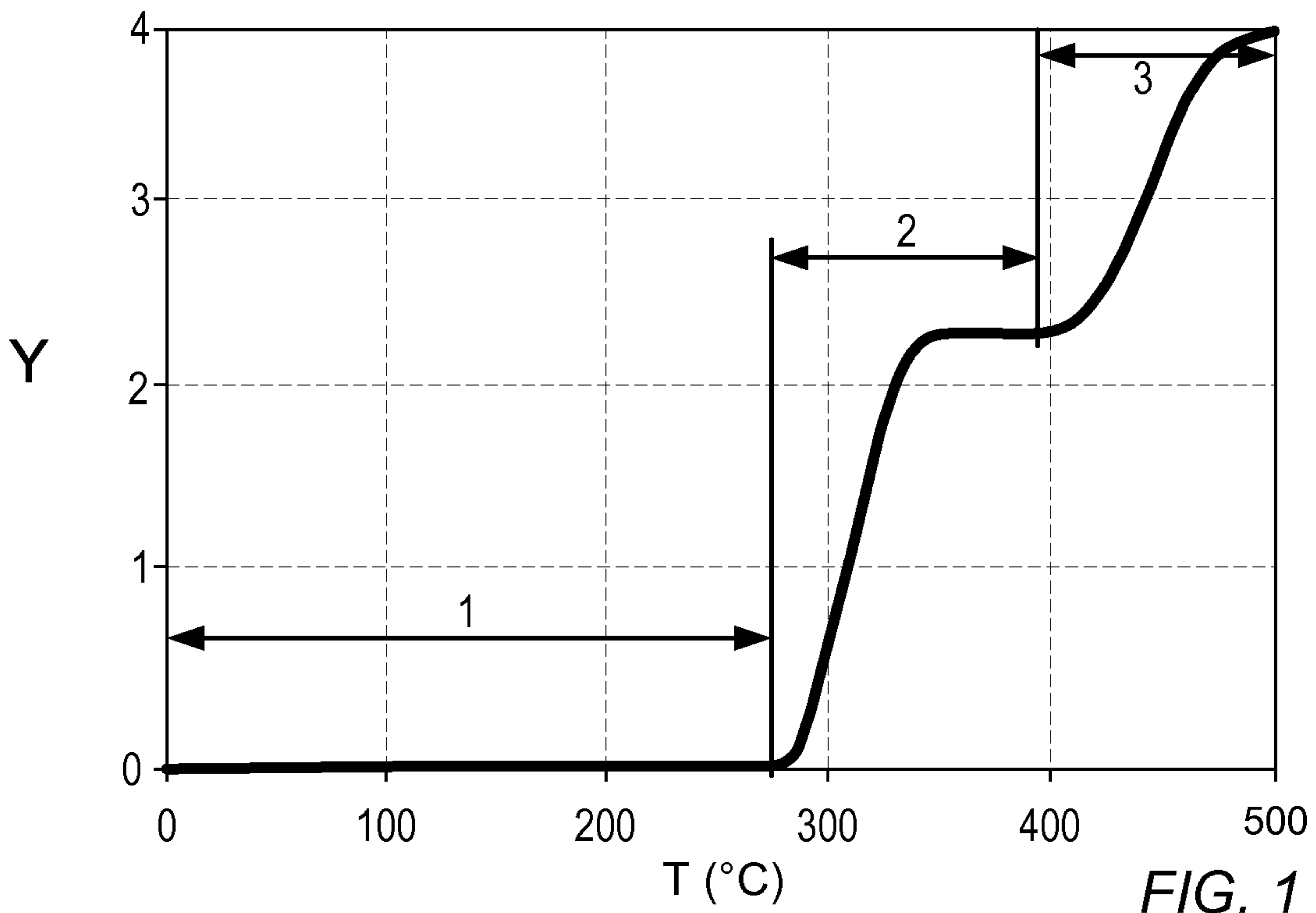


FIG. 2

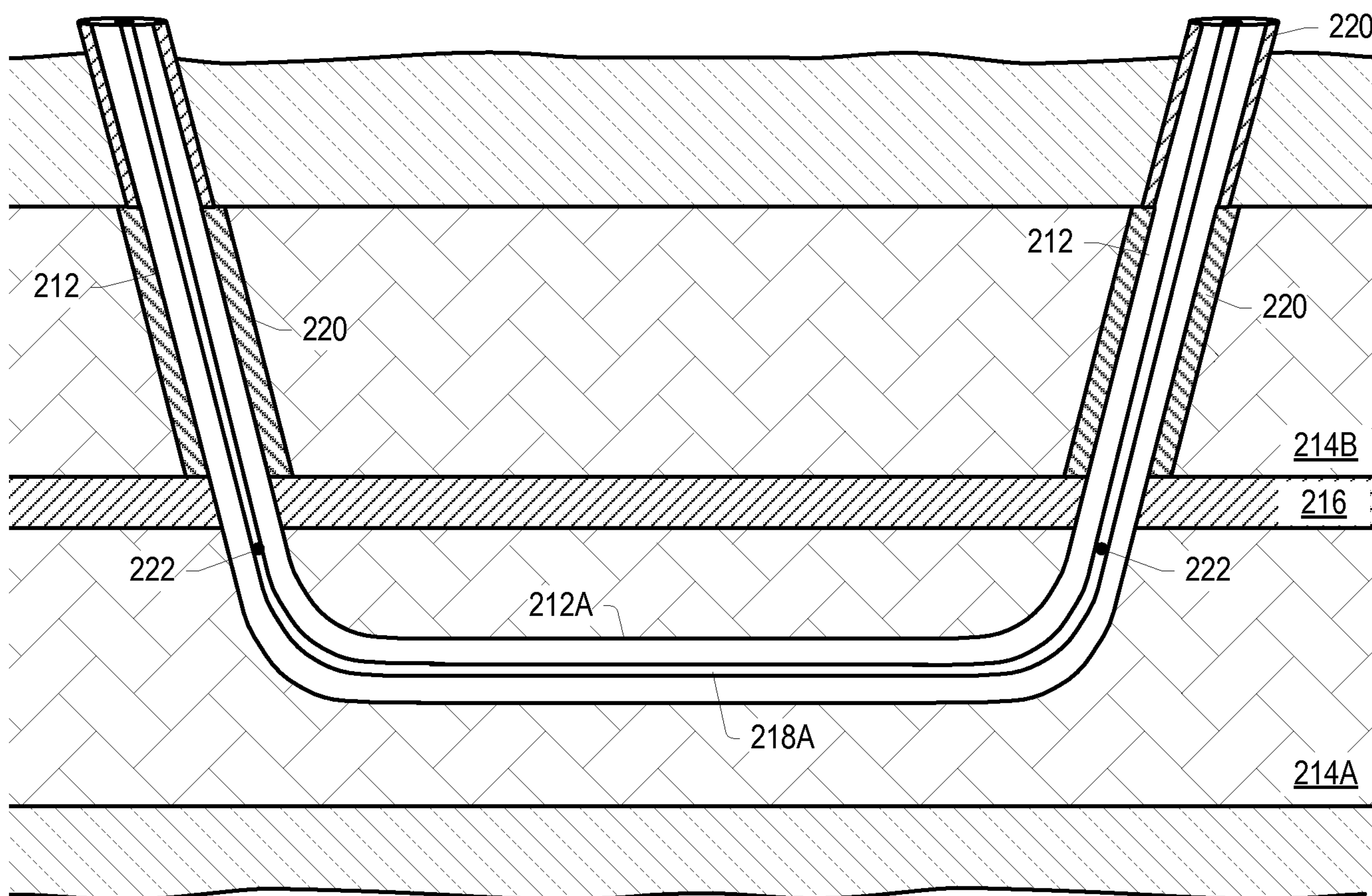


FIG. 3A

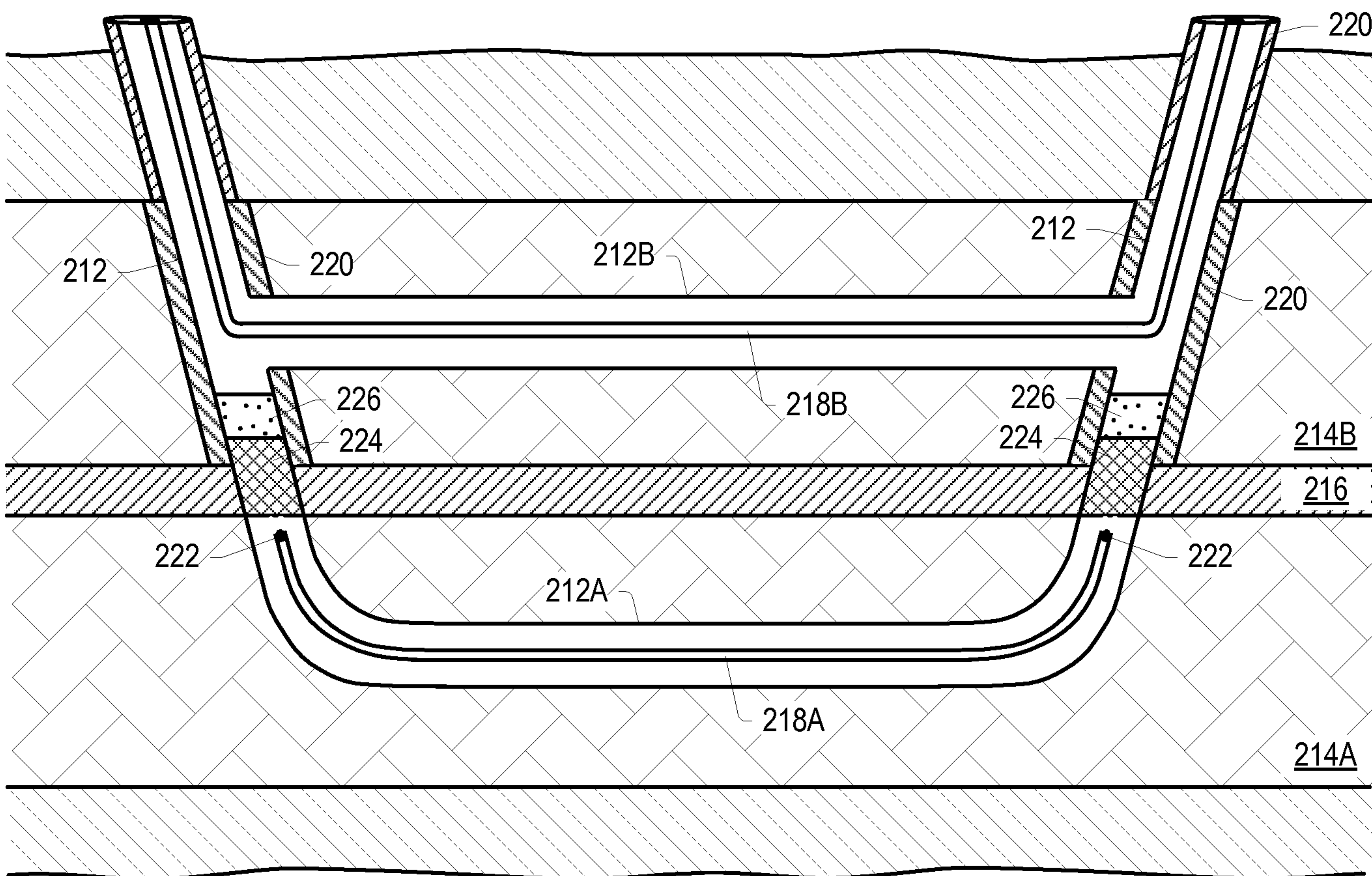


FIG. 3B

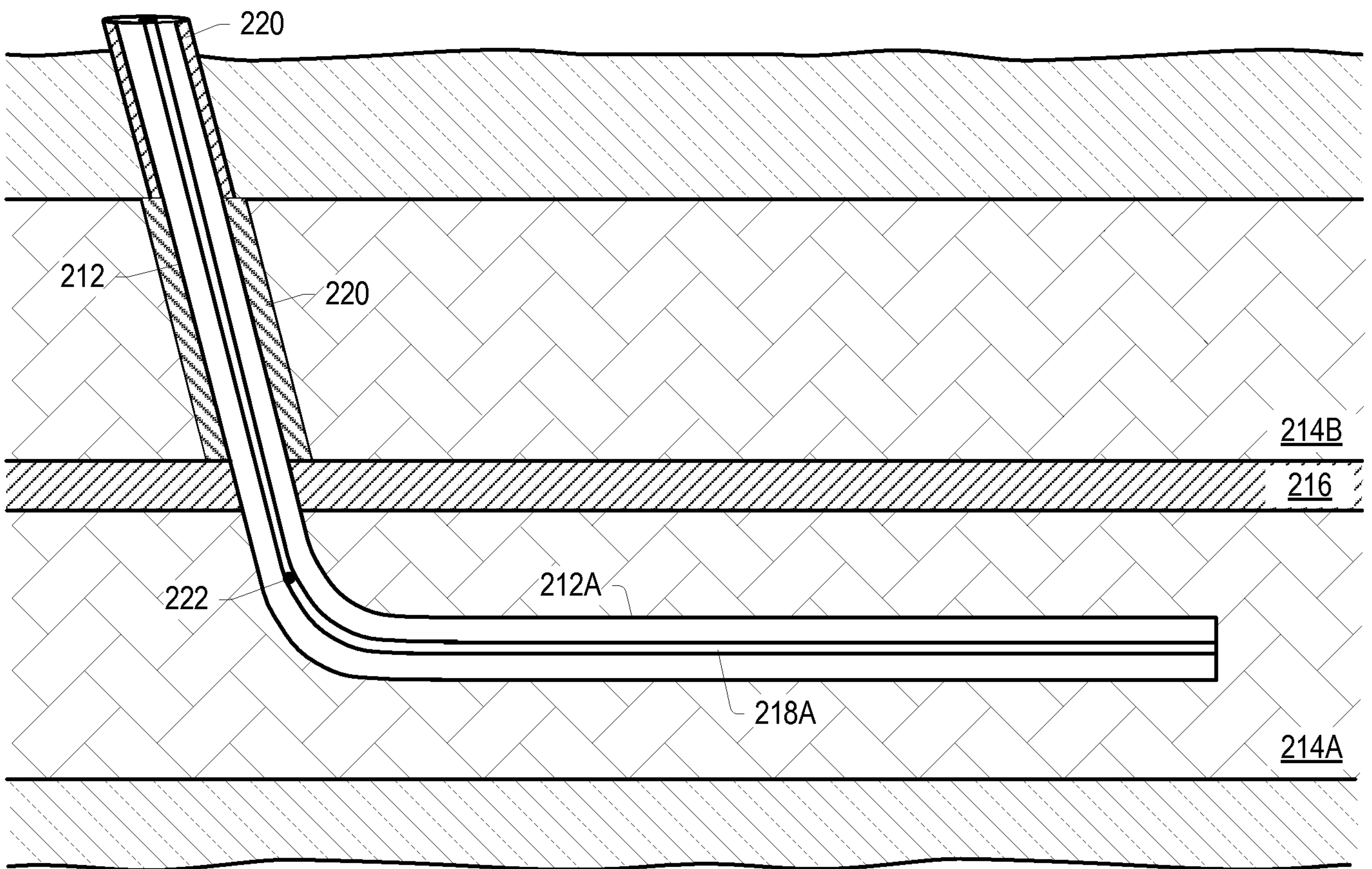


FIG. 4A

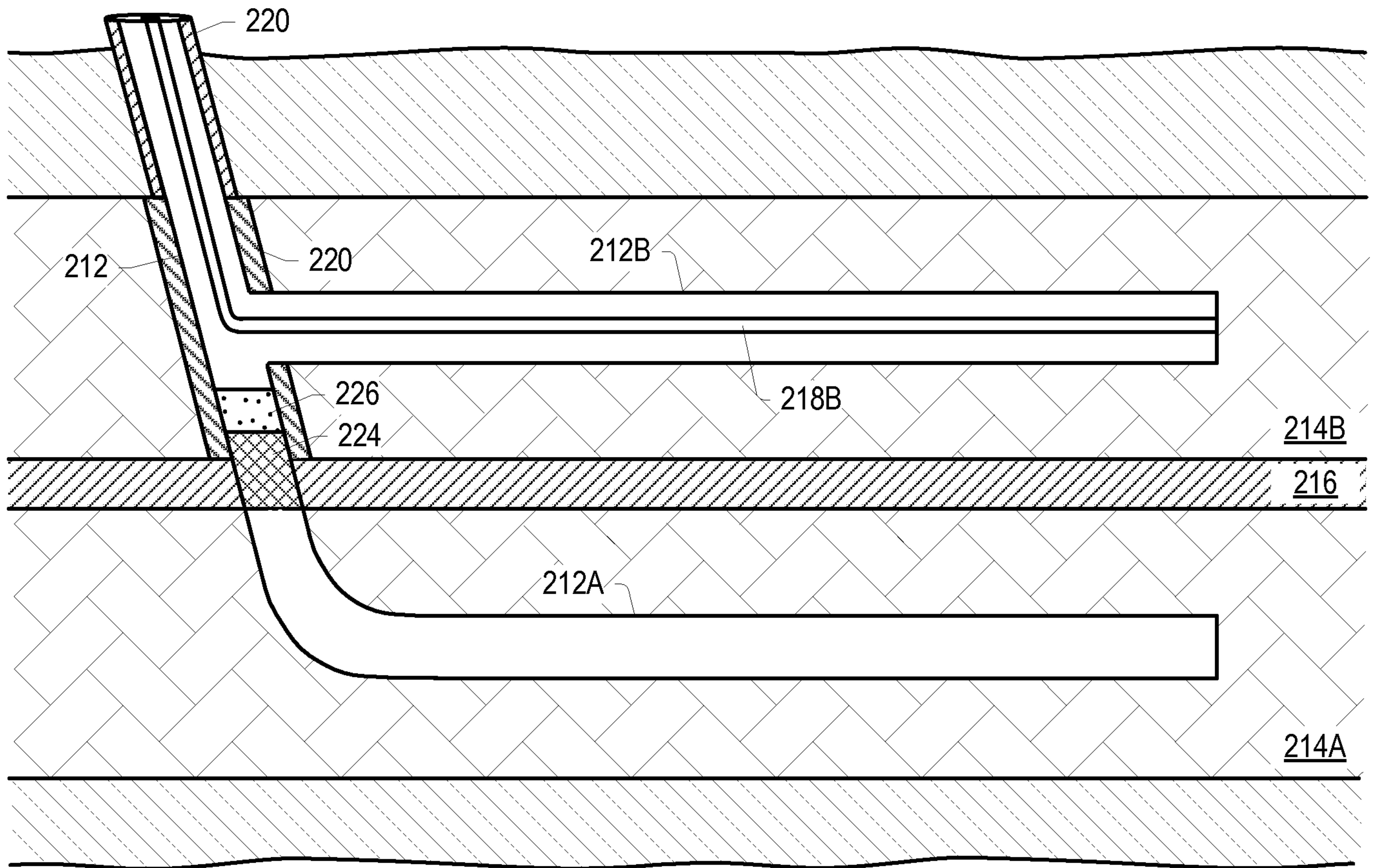


FIG. 4B

