May 10, 1966 F. G. CRIDER 3,250,327

RECOVERING NONFLOWING HYDROCARBONS

Filed April 2, 1963

FIG 1

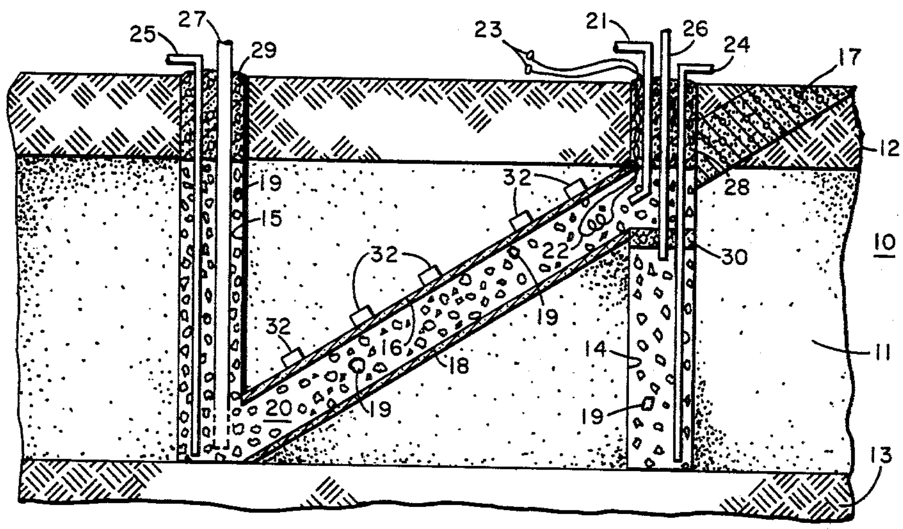


FIG 2

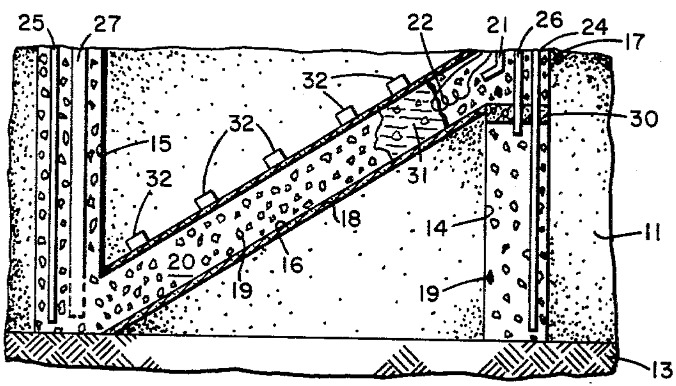
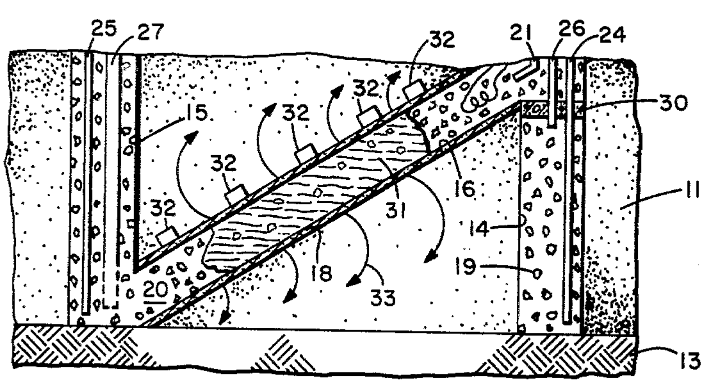


FIG 3



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RECOVERING NONFLOWING HYDROCARBONS

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This invention relates to the production of nonflowing hydrocarbons from subterranean formations. More particularly, it relates to a heating method for producing hydrocarbons from earth formations.

There are vast quantities of hydrocarbons contained in the earth that can be recovered only by heating the innate formations. One example is the great oil shale deposits in Colorado. The oil shale contains a solid resinous material known as kerogen. The kerogen will degrade upon heating to produce crude oil-like hydrocarbons. Another example is the vast Athabasca tar sands in Canada. The hydrocarbons in these tar sands are nonflowing under natural formation conditions. Heating the tar sands to moderate temperatures will fluidize the hydrocarbons sufficiently that conventional oil recovery methods can be used.

In situ combustion procedures in such formations are difficult to apply as the initial method of heating the formations. One reason for this is the original low permeability of the formations. The permeability may be as low as a few millidarcies which prevents sufficient fluid flow to sustain in situ combustion in the formation. Another problem may arise even where sufficient original permeability exists for in situ combustion. A liquid bank may be generated in the formation by the burning process. The liquid bank can prematurely terminate the in situ combustion process by interrupting fluid flow.

The initially low permeability prevents other in situ procedures, such as solvent extraction, from being used to recover the much desired hydrocarbons from these formations. Thus, it becomes necesary to remove at least part of the hydrocarbons from the formation to increase the permeability before attempting an in situ hydrocarbon recovery procedure.

Previous attempts to increase the permeability of the formations by means of an internal heating channel to remove some of the hydrocarbons have left much to be desired. For example, uniformly heating the formation to a given depth along extensive lengths of such channel is difficult. Some areas of the formation may be overheated and others may be underheated. Also, the heat transferred to the formation may be inefficient or inadequate to provide sufficient heat to release the nonflowing hydrocarbons from the formation. Further, the mechanisms for effecting heating are cumbersome and their use is difficult. Thus, the permeability of the formation cannot readily be uniformly increased by adequate hydrocarbon removal through heating. As a result, a subsequent in situ recovery procedure, for example, in situ combustion, will produce inefficient results.

It is therefore an object of the present invention to provide a method of producing hydrocarbons by heating the innate formations. Another object of this invention is to heat efficiently a hydrocarbon-containing formation by the transfer of heat primarily by convection. Another object of this invention is to heat controllably such formation along extensive lengths of an internal channel. Another object of this invention is to provide a controlled amount of heat to a formation at any particular location from an internal channel. Another object of this invention is to provide a safe and reliable heating means that can be positioned at any desired location in a channel without the cumbersome systems and structure heretofore known. Another object of this invention is to release hydrocarbons from subterranean formations by heating same. Another object of this invention is to provide a method for increasing the permeability of a subterranean formation by releasing its resident hydrocarbons.

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These and other objects will be apparent when considered in conjunction with the following description of certain preferred and illustrative embodiments of the present invention, the appended claims, and the attached drawings, wherein:

FIGURE 1 is a vertical section through an earth formation containing hydrocarbons and illustrating certain structures for practicing the method of this invention;

FIGURE 2 is a central partial view of FIGURE 1 illustrating the establishing of a burning zone in an internal channel in the formation; and

FIGURE 3 is the view of FIGURE 2 with the burning zone extending throughout the central portion of the internal channel.

In accordance with this invention there is provided a method of heating a formation containing a permeable refractory-filled channel through the control of the position and the heat-generating dimension of a stabilized burning zone in said channel.

The structures for practicing the method will be described prior to the steps of this invention.

Referring to FIGURE 1, the earth **10** is shown as comprising a formation **11** containing hydrocarbons which normally are not capable of flowing but which can be released from the formation by heat. For example, the formation **11** may be illustrative of the Athabasca tar sands. An overburden **12** and an underburden **13** may be present to confine the formation **11**.

An internal channel for fluid conveyance must be present through at least a part of the formation **11** to practice this invention. Such channel provides a passageway for containing a means for heating the adjacent formation **11**. A naturally occurring fissure, or rift, may provide the channel.

While the channel may occur naturally within the formation, the channel usually must be provided. The channel can be provided by a passageway leading from the earth's surface into the formation **11** and then returning to the earth's surface, or other discharge area. In FIGURE 1, an example of such a passageway is shown. Several substantially vertical boreholes **14** and **15** are provided, such as by drilling, to extend from the earth's surface into the formation **11**. The boreholes **14** and **15** may be provided with a perforated casing (not shown) for supporting the formation **11** about the boreholes **14** and **15** and permitting fluid communication with the formation **11**, if desired. A diagonal borehole **16** is provided by suitable means to extend through the intervening formation **11** between the boreholes **14** and **15**. The diagonal borehole **16** is placed in fluid communication with the boreholes **14** and **15**. The diagonal borehole **16** can be drilled by deviation methods from the borehole **14**. Preferably, the diagonal borehole **16** is drilled at an angle from the earth's surface through the formation **11** in a manner to intersect the borehole **14** at the upper extremity of the formation **11** and the borehole **15** at the lower extremity of the formation **11**. The diagonal borehole **16** usually will be straighter when drilled from the earth's surface than if directionally drilled from the borehole **14**. One apparatus that can be used to drill diagonally directed holes from the earth's surface is the Failing Model RB-25 Holemaster Drill. Any other drilling apparatus may be used, however, which can drill into the earth at an angle. Other means for providing an angularly disposed borehole can also be used, if desired. Lastly, the portion of the diagonal borehole **16** between the borehole 14 and the earth's surface may be filled with a concrete plug 17.

In formations, such as oil shale, which are not subject to collapse upon heating, the diagonal borehole 16 need not be cased. However, in loose or collapsing formations, such as tar sands, the diagonal borehole 16 is usually cased. The diagonal borehole 16 may be cased by inserting a liner 18 into it prior to placing the plug 17. The liner 18 may be metal or ceramic, and pervious or impervious. The liner 18 is preferably permeable, however, to expedite convection heating. One suitable permeable liner is a ceramic pipe manufactured with a given permeability which may be selected in the range from several millidarcies to several thousand darcies. The permeable ceramic pipe is available commercially in grades which will withstand a temperature of 3000° F.

The diagonal borehole 16, whether cased or uncased, is packed or filled, at least in part, with a permeable refractory material 19 in the formation 11 to be heated. Preferably, the entire borehole 16 is filled with the material 19. The boreholes 14 and 15 may also be filled with this material. Suitable permeable refractory materials are gravel, sand, pebbles, crushed brick, stone fragments, and mixtures thereof. Other materials having similar properties may also be used. Preferably, the material should have a melting point above the combustion temperature of the burning zone to be established in the diagonal borehole 16. However, the material 19 need not have a melting point above the combustion temperature since as long as fluid flow is continued while the material 19 is in a state of fusion it will remain permeable.

The material 19 should have a minimum particle size not less than the size providing a permeability in the filled diagonal borehole 16 only slightly greater than that permitting the fluid flow required to sustain combustion. The material 19 should have a maximum particle size somewhat less than the size at which the excessively large intervening spaces between particles permit combustion with unsupported flames to exist.

The permeable refractory material 19 may be placed into the boreholes 14, 15, and 16 by any suitable means. One means of placement is by wet packing. In wet packing, a slurry is formed of the material 19 and a liquid. The slurry is pumped into the boreholes 14, 15, and 16. The liquid is then removed, by any suitable means, from the slurry leaving the material 19 in place. Other placement means can be used if desired. The permeability of the material 19 may be heterogeneous or homogeneous in the boreholes 14, 15, and 16. Thus, by this invention, the boreholes 14, 15, and 16 are filled with a permeable refractory material 19 to provide a channel 20 extending from the earth's surface through the formation 11 and back to the earth's surface. As a result, the channel 20 is permeable to gas flow.

Means are provided for establishing a burning zone in the channel 20. By burning zone, for purposes of this invention, is meant an area of heat generation by oxidation of a fuel with or without light being produced. The means for establishing a burning zone include a conduit 21 extending from the earth's surface into the borehole 16 and fluid transferring means (not shown) connected thereto for injecting a combustible fluid mixture into the channel 20. Means for igniting the mixture in the channel 20 are provided. Such ignition means are preferably placed adjacent to the downstream extremity of the conduit 21. The ignition means may be an electric heating device 22 adapted to heat the mixture to ignition temperatures in the channel 20. A plurality of electrical conductors 23 may be provided for supply current to the heating device 22 from the earth's surface. Other igniting means can be also used, if desired.

Means are provided for recovering the hydrocarbons released from the formation 11 by heating. Such means include production conduits 24 and 25 positioned in the boreholes 14 and 15, respectively, for removing the released hydrocarbons from the formation 11. Means for moving the hydrocarbons through the production conduits 24 and 25 to the earth's surface may be provided by any suitable fluid transferring means.

A conduit 26 is provided the borehole 14 for introducing a fluid into the lower extremity of the borehole 14. Other means for pressuring the lower extremity of borehole 14 may also be used. A conduit 27 with a perforated portion or other exhaust means, is positioned in the borehole 15 for venting fluids from the channel 20 to the earth's surface, especially from the lower portions of the borehole 15.

Packer means 28 and 29 are positioned in the boreholes 14 and 15, respectively, to provide a fluid seal at the earth's surface about the various conduits extending from the formation 11. Packer means 30 are provided in the borehole 14 to isolate the portion of borehole 14 below the point of its intersection with diagonal borehole 16. Thus, the areas to either side of the packer means 28, 29, and 30 may be subjected to differential fluid pressures. Any suitable structure to provide these packer means 28, 29, and 30 may be used. Cement is well suited for this purpose. However, other packer structures may be used, if desired.

A suitable supply (not shown) of a combustible fluid mixture is fluidly connected to conduit 21. The combustible fluid mixture is usually comprised of a fuel and an oxidizing fluid. However, the combustible fluid mixture may be provided by any substances which, when chemically combined, generates heat with or without producing light. The fuel is a substance readily oxidized, such as hydrocarbons, alcohols, or hydrogen. This fuel preferably is a hydrocarbon which will be gaseous at the formation conditions in channel 20. However, the fuel may be any of the hydrocarbons such as natural gas, liquid hydrocarbons such as crude oil, kerosene, gasoline, furnace oil, and mixtures thereof. Some combustible material may also be included in the refractory packing material 19 in channel 20 as an auxiliary fuel. The oxidizing fluid may be air, oxygen, other oxygen-containing fluids, fluids capable of oxidizing the fuel such as fluorine and chlorine, and mixtures thereof. The oxidizing fluid is preferably gaseous at the formation conditions in channel 20.

Referring now to FIGURE 2, a detailed description of an illustrative embodiment of the steps of the method of this invention, will be given. The formation 11 having been provided with the channel 20, a burning zone 31 is established in the channel 20 as a first step of heating. For this purpose, a suitable combustible fluid mixture, such as natural gas and air, is injected into the channel 20 via the conduit 21. The electric heating device 22 is activated by supplying current to the conductors 23. Upon a sufficient increase in temperature in the channel 20 at the heating device 22, the combustible fluid mixture will ignite to produce the burning zone 31. The burning zone 31 is shown as a shaded area which represents an area of combustion in the channel 20 where sensible heat is generated at the heretofore defined temperatures. The residue fluids from the burning zone 31 pass out of the channel 20 via the conduit 27.

The burning zone 31 established in accordance with this invention may be sustained over a wide range of ratios of fuel to oxidizing fluid in the combustible fluid mixture. Also, the injection rate may be greatly varied without making the burning zone 31 unstable. The burning zone 31 ceases to exist when unstable. For example, the burning zone 31 can be sustained in the channel 20 with a mixture of natural gas and air which contains between about 60 and about 90 percent of air by volume. The burning zone 31 will be stable since it involves the continuous combustion of gas in an in-place stabilized oxidation. By stable, it is meant that the flame is stabilized on the hot surface of the material 19 in the channel 20. Further, no blow-off or back-flash of the combustion occurs as with unsupported flame-type combustion procedures for a similar change in burning conditions. The burning zone 31 is stable whether moving or stationary in the channel 20.

The control of movement of the burning zone 31 is dependent upon the balance of heat generated and dissipated in the combustion of the combustible fluid mixture. The burning zone 31 will be stationary when the amount of heat generated therein is substantially equal to the heat dissipated by transferal of heat from the burning zone 31 to the formation 11 and upstream to the combustible fluid mixture. At this condition, the upstream combustible fluid mixture becomes preheated and its burning velocity will increase until it equals the burning velocity in the burning zone 31. When the heat transferred upstream to the incoming combustible fluid mixture is greater than this amount, the burning zone 31 moves upstream. When the heat transferred upstream to the incoming combustible fluid mixture is less than this amount, the burning zone 31 moves downstream.

More particularly, the balance of heats generated and dissipated is a function only of the volumetric rate of flow of the combustible fluid mixture injected into the channel 20 and the ratio of fuel to oxidizing fluid. This is possible since the other conditions affecting combustion are relatively constant in formation 11. Thus, the movement of the burning zone 31 is readily controlled by regulating the rate of introducing the combustible fluid mixture into the channel 20, the ratio of fuel to oxidizing fluid in the combustible fluid mixture, or both. In this manner, the burning zone 31 in the channel 20 can be moved from any position therein upstream or downstream relative to the flow of the combustible fluid mixture. Also, by this means, the burning zone 31 can be made stationary in the channel 20.

In summary, any unbalance in combustion conditions effecting the balance of heat about the burning zone 31 short of extinguishing combustion will result only in moving the burning zone 31 in the channel 20. Usable flameless combustion in the burning zone 31 continues under these conditions.

I have found that there is a unique value of the ratio of fuel to oxidizing fluid for any combustible fluid mixture independent of the injection rate that will make the burning zone 31 stationary in the channel 20. This unique value for such mixture exists for any given set of physical conditions defining the combustion environment present in the channel 20. Further, the heat-generating dimension of the burning zone 31 can be controlled by regulating the rate of introducing the combustible fluid mixture having the unique ratio of fuel to oxidizing fluid into the channel 20. By heat-generating dimension, in this invention, is meant the amount of heat generated by the burning zone and the longitudinal dimension of the burning zone 31 in the channel 20 in which sensible heat is produced. The term "sensible heat," as used herein, is the heat transferred from the burning zone 31 to the formation 11 adjacent channel 20 to produce a temperature sufficient to initiate the release of some of the resident hydrocarbons. Thus, the amount of heat per unit distance supplied by the burning zone 31 in the formation 11 along channel 20 is controllable by the calorific power of the fuel. Also, the linear distance along the channel 20 where this amount of heat per unit distance is supplied is controllable by the injection rate of the mixture. In certain cases, the burning zone 31 may be extended the entire length of the channel 20. In other cases, the burning zone 31 may be provided an axial dimension less than that of the channel 20, and moved to successive positions along the length of channel 20. Alternatively, the burning zone 31 may be incrementally expanded the entire length of the channel 20. Obviously, a number of possible combinations of these steps of supplying heat by the burning zone 31 in the channel 20 are possible.

The following experimental data are illustrative of the heating method of this invention. A stable burning zone was obtained in a stainless steel tube having an outside diameter of one inch. The tube was packed with 35–40 mesh sand. A natural gas-air mixture was introduced into the tube at a pressure of 100 pounds per square inch gauge. The injection rate was varied between 0.340 and 0.760 standard cubic foot per minute. The caloric power of the natural gas was about 950 British thermal units per standard cubic foot of gas. The tube was exteriorly heated by a flame to a temperature sufficient to ignite the mixture. The burning zone produced was comprised of microareas of combustion stabilized and supported by the sand. The burning zone appeared to be of the nature of flameless combustion. No unsupported flames were present. The concentration of fuel and oxidizing fluid in the natural gas-air mixture was varied over the range of from 66 to 90 percent of air by volume. It was found that the burning zone was stationary, independent of the injection rate, with a natural gas-air mixture containing 84.8 percent of air by volume and with the other burning conditions constant. The length of the burning zone in the tube and the total heat generated was proportional to the injection rate of the natural gas-air mixture. The burning zone was moved through the tube at a mixture composition other than containing 84.8 percent air by varying the ratio of gas to air in the mixture, the composition of the gas, the composition of the mixture, and by changes in pressure, injection rate, or a combination of these conditions. The direction of movement was determined by the balance betwen the heat generated and dissipated at the burning zone. As a result, controlled rates of movement were obtained between 0.08 and 0.97 inch per minute.

From the foregoing, it is apparent that the ratio of the fuel to oxidizing fluid may be such as to make the burning zone 31 stationary. Where the burning zone 31 is not in a given position in the channel 20 for the heating of the formation 11, the burning zone 31 is moved to such position as seen in FIGURE 3 by varying the combustion conditions effecting the balance of heat. Generally, a change in the injection rate, or the composition of fuel and oxidizing fluid of the combustible fluid mixture, or both, will provide the desired movement. Once the burning zone 31 is at the given position, the ratio of fuel to oxidizing fluid in the combustible fluid mixture injected into the channel 20 is adjusted, with other conditions remaining constant, until the burning zone 31 remains substantially stationary. By substantially stationary, it is meant that the burning zone 31 does not move along the channel 20; or if it moves, the distance of movement is very small compared to the length of the burning zone 31 in the channel 20. Thus, for practical purposes, the burning zone 31 can be made both stable and stationary at a given position in the channel 20. Any changes in pressure or other condition affecting combustion other than mixture composition, particularly the ratio of fuel to oxidizing fluid, will only vary the total heat generated and the linear extent of the burning zone 31 in the channel 20 when the burning zone 31 is stationary.

As another step, the rate of introducing the mixture into the channel 20 is regulated to produce a given heat-generationg dimension of the burning zone 31. A plurality of temperature sensing means 32 disposed along the channel 20 can be used to determine when the burning zone 31 is stationary in the channel 20 and its extent. For example, the burning zone 31, when stationary in the channel 20 intermediate the boreholes 14 and 15, may be extended substantially the entire length of the portion of the channel 20 provided by the diagonal borehole 16 by increasing the rate at which the mixture is injected via the conduit 21. Preferably, as is shown in FIGURE 3, the rate of introducing the mixture into the channel 20 is regulated so that initially only the central portion of the formation 11 spaced apart from the boreholes 14 and

15 is heated to a temperature sufficient to release the contained hydrocarbons. This mode of releasing hydrocarbons by heating the formation 11 provides for several advantages. First, a portion of the formation 11 adjacent the boreholes 14 and 15 remains unheated. These unheated portions of the formation 11 then serve as fluid barriers to confine the heat-released hydrocarbons in the central portion of the formation 11. Second, the transfer of heat from about the burning zone 31 in the channel 20 is principally by convection. The released hydrocarbons confined to the central portion of the formation 11 circulate about the channel 20 to be repeatedly heated and then diffuse through the formation 11, as illustrated by arrows 33. Thus, large areas of the formation 11 can be heated from the channel 20 principally by convection. Heated gases from the burning zone 31 will supplement the convection heating by released hydrocarbons in the formation 11 provided the casing 18 is permeable. These heated gases from the burning zone 31 generally prevent any released hydrocarbons from entering the channel 20 from the formation 11. If desired, all the heated gases from the burning zone 31 may be passed by suitable means, such as the channel 20, into the formation 11 to extract maximum heating benefits from them.

As another step, the burning zone 31 is maintained in the channel 20 for a sufficient length of time to heat the formation 11 adjacent the boreholes 14 and 15 sufficiently to release the contained hydrocarbons. At such time when the pressure differential between the released hydrocarbons and the channel 20 is sufficient, the hydrocarbons will flow into the boreholes 14 and 15.

If it is desired to accelerate the production of the released hydrocarbons, an additional step may be taken wherein the injection rate of the combustible fluid mixture is increased sufficiently to expand the burning zone 31 so as to heat directly portions of the formation 11 adjacent either or both of the boreholes 14 and 15 sufficiently to release the contained hydrocarbons. Then, all the released hydrocarbons can flow toward either or both of the boreholes 14 and 15.

Alternatively, as another step, the burning zone 31 may be moved to a position to heat the portion of the formation 11 adjacent either borehole 14 or 15 to release the contained hydrocarbons.

It may also be desirable as another step to move the burning zone 31 from a first position intermediate the boreholes 14 and 15 to a succession of positions along the channel 20 until all the desired hydrocarbons are released from the formation 11. This mode of heating is of especial utility in greatly extended lengths of the channel 20 that cannot be covered by the greatest possible extension of the burning zone 31.

The hydrocarbons released by heating the formation 11 are recovered from the boreholes 14 and 15 by means of the production conduits 24 and 25, respectively, as the final step in the method of this invention.

Auxiliary steps to assist in confining the released hydrocarbons in the formation 11 to preserve convection heating may be taken, if desired. For example, natural gas or other fluids can be pressured via conduit 26 to a sufficient degree into the portion of the borehole 14 below the packer means 30 so that the released hydrocarbons from the adjacent portions of the formation 11 cannot flow into the borehole 14. Other steps can also be used to prevent the released hydrocarbons from flowing into the boreholes 14 and 15, if desired.

Although the temperatures required to release hydrocarbons may be considered to be relatively high since they can range from about 200° F. to about 1000° F. or higher, the required heating of the formation 11 can be effectively obtained because the present method of heating principally transfers heat by convection from a burning zone easily capable of supplying great quantities of heat. The heating can also be controlled as to the application of the desired temperatures with the result that a desired amount of hydrocarbons are released from the formation 11.

After a portion of hydrocarbons are released from the formation 11 to the given distance from the channel 20, the permeability of the formation 11 will have become increased. Further, a residual amount of carbonaceous material remains in the formation 11. If desired, an in situ combustion procedure may be practiced on the formation 11 from the boreholes 14, 15, and 16 to recover further amounts of hydrocarbons. However, any subsequent in situ hydrocarbon recovery procedure may be practiced on the formation 11, which procedure is dependent upon a certain increase in permeability being obtained in the formation 11.

Thus, by this invention there is provided a method of heating in a permeable refractory-filled channel that can provide a desired amount of heat energy along a certain distance of the channel and at a given location in a formation.

From the foregoing it will be apparent that a method is disclosed which accomplishes all of the stated objects of this invention. Various modifications of the disclosed method may be made by one skilled in the art without departing from the spirit of this invention. For this and other reasons the present description is intended to be illustrative of this invention, and only the appended claims are to be considered as limitative of the invention.

What is claimed is:

1. A method for releasing hydrocarbons from an earth formation by in situ heating comprising the steps of:
- (a) providing a plurality of spaced vertical boreholes in the earth, each of said boreholes in fluid communication with a formation containing heat-releasable hydrocarbons,
- (b) providing a channel containing a permeable refractory material and extending at least in part in the formation containing heat-releasable hydrocarbons, said channel fluidly interconnecting at least two of the boreholes,
- (c) introducing a combustible fluid mixture into the channel,
- (d) igniting the combustible fluid mixture to provide a burning zone in the channel,
- (e) adjusting the ratio of fuel to oxidizing fluid in the combustible fluid mixture until the burning zone remains substantially stationary in the channel,
- (f) regulating the rate of introducing the combustible fluid mixture into the channel to produce a given heat-generating dimension of the burning zone in the channel,
- (g) continuing to introduce the combustible fluid mixture into the channel until the hydrocarbons within a given distance from the burning zone are released from the formation, and
- (h) recovering the released hydrocarbons.

2. A method for releasing hydrocarbons from an earth formation by in situ heating comprising the steps of:
- (a) providing a plurality of spaced vertical boreholes in the earth, each of said boreholes in fluid communication with a formation containing heat-releasable hydrocarbons,
- (b) providing a channel containing a permeable refractory material and extending at least in part in the formation, said channel fluidly interconnecting at least two of the boreholes,
- (c) introducing a combustible fluid mixture into the channel,
- (d) igniting the mixture to provide a burning zone in the channel,
- (e) moving the burning zone to a given position in the channel,
- (f) adjusting the ratio of fuel to oxidizing fluid in said mixture until the burning zone remains substantially stationary in the channel at said position,
- (g) regulating the rate of introducing the mixture in-

to the channel to provide a given generation of heat by the burning zone in the channel,

(h) continuing to introduce the mixture into the channel until the hydrocarbons within a given distance from the burning zone are released from the formation, and

(i) recovering the released hydrocarbons.

3. The method of claim **2** wherein fluid pressure is maintained in at least one borehole in excess of formation pressure to prevent the released hydrocarbons from flowing into each said pressured borehole.

4. The method of claim **2** wherein the burning zone is initially positioned in the channel intermediate the boreholes fluidly connected to such channel and the heat generated, at a time subsequent to the release of a given amount of hydrocarbons, is increased sufficiently that the formation adjacent at least one borehole is heated sufficiently to release the contained hydrocarbons.

5. The method of claim **2** wherein the rate of introducing the mixture into the channel is increased at a time subsequent to the release of a given amount of hydrocarbons sufficiently to expand the burning zone along a direction parallel to the direction of flow of the mixture until the burning zone extends substantially the length of the channel.

6. A method for releasing hydrocarbons from an earth formation by in situ heating comprising the steps of:

(a) providing a plurality of spaced vertical boreholes in the earth, each of said boreholes in fluid communication with a formation containing heat-releasable hydrocarbons,

(b) providing a channel containing a permeable refractory material in the hydrocarbon-containing formation, which channel fluidly interconnects at least two of said boreholes,

(c) establishing a substantially stationary burning zone in the channel,

(d) regulating the heat-generating dimension of the burning zone to maintain a supply of heat to the formation surrounding the channel,

(e) maintaining the burning zone in the channel until the hydrocarbons within a given distance from the burning zone are released from the formation, and

(f) recovering the released hydrocarbons.

7. A method for releasing hydrocarbons from an earth formation by in situ heating comprising the steps of:

(a) providing a plurality of spaced vertical boreholes in the earth, each of said boreholes in fluid communication with a formation containing heat-releasable hydrocarbons,

(b) providing a channel containing a permeable refractory material in the formation, which channel fluidly interconnects at least two of said boreholes,

(c) establishing a substantially stationary burning zone in the channel intermediate the boreholes,

(d) regulating the heat generated by the burning zone to heat the formation surrounding the burning zone in the channel,

(e) maintaining the burning zone in the channel until the hydrocarbons within a given distance from the burning zone are released from the formation, whereby the formation between the boreholes will be heated by convection to a maximum distance from the burning zone before the formation adjacent each borehole will be heated sufficiently to permit the released hydrocarbons to flow into the borehole, and

(f) recovering the released hydrocarbons.

8. The method of claim **7** wherein fluid pressure is maintained in at least one of the boreholes in excess of formation pressure to prevent the released hydrocarbons from flowing into each said pressured borehole.

9. The method of claim **57** wherein the heat generated by the burning zone, at a time subsequent to the release of a given amount of hydrocarbons about the burning zone, is increased sufficiently that the formation adjacent at least one borehole is heated sufficiently to release the contained hydrocarbons.

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