July 22, 1969 H. LANGE 3,456,730

PROCESS AND APPARATUS FOR THE PRODUCTION OF BITUMENS FROM UNDERGROUND DEPOSITS HAVING VERTICAL BURNING FRONT

Filed Aug. 22, 1967 2 Sheets-Sheet 1

FIG. 1

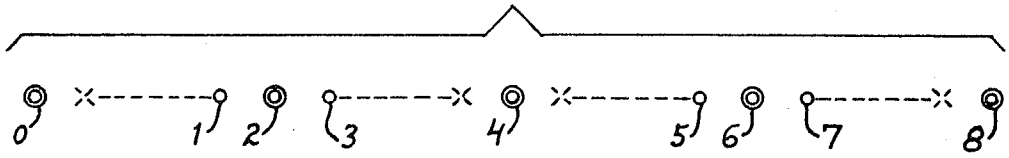


FIG. 2

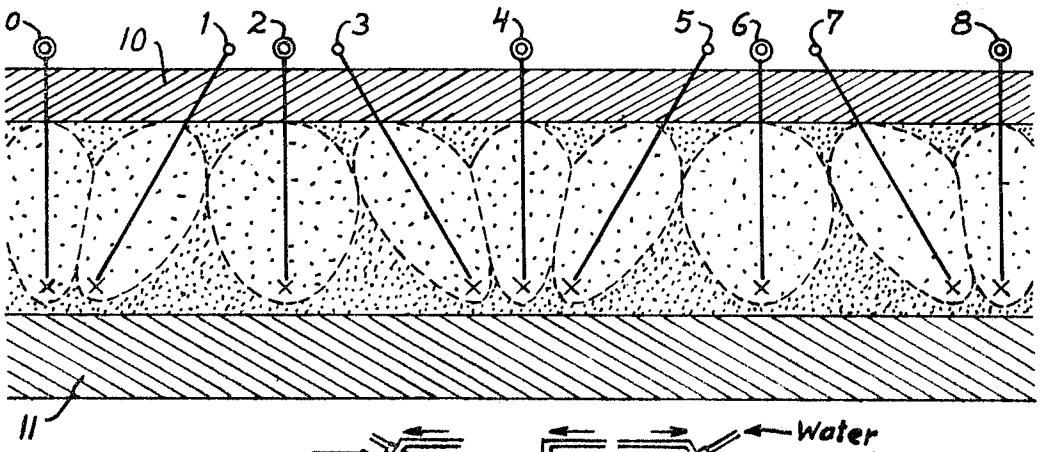
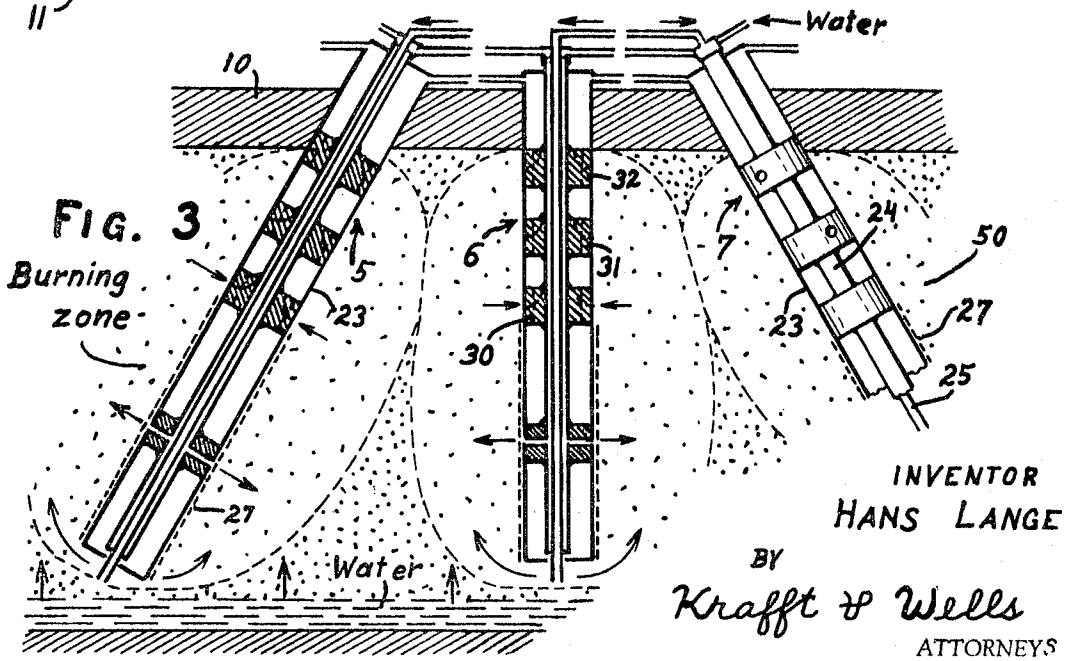


FIG. 3



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FIG. 4

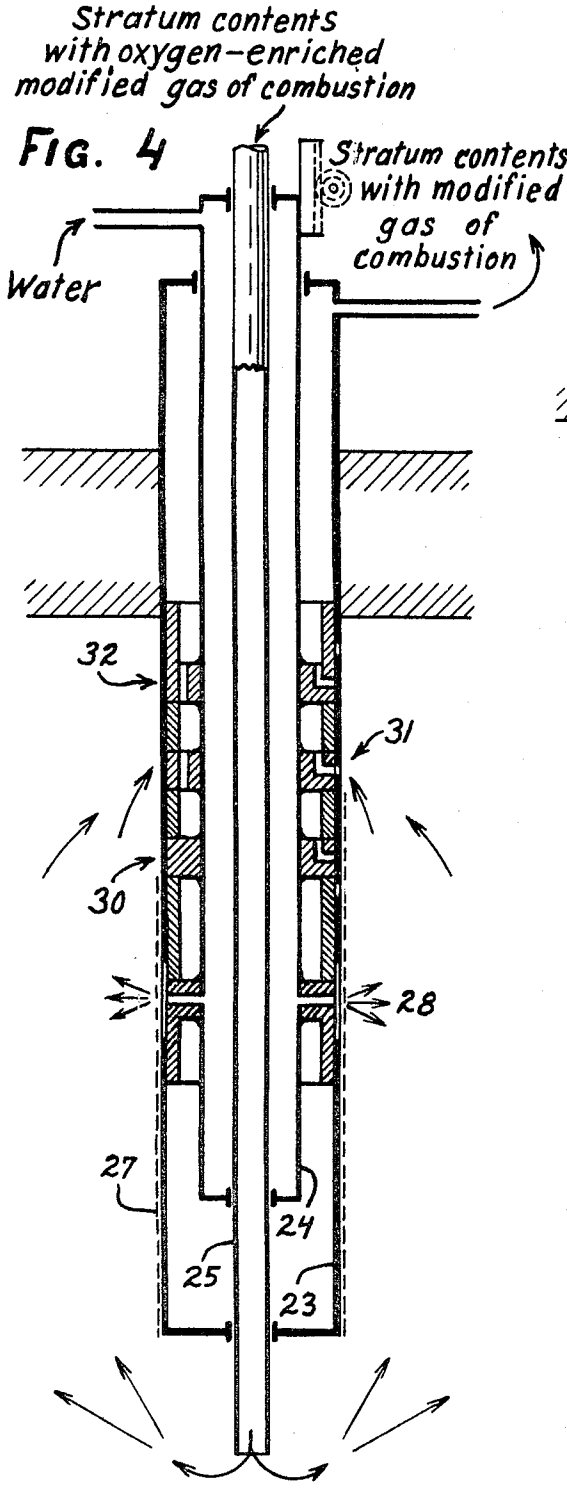
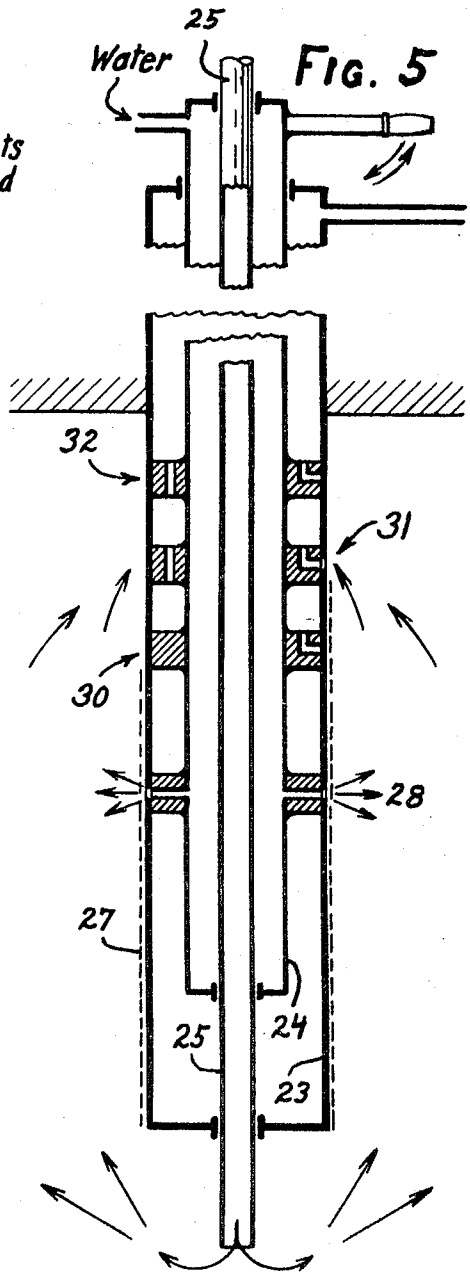


FIG. 5



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PROCESS AND APPARATUS FOR THE PRODUCTION OF BITUMENS FROM UNDERGROUND DEPOSITS HAVING VERTICAL BURNING FRONT

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Continuation-in-part of application Ser. No. 349,589, Mar. 5, 1964. This application Aug. 22, 1967, Ser. No. 662,489

Claims priority, application Germany, Nov. 26, 1966, D 51,652

Int. Cl. E21b *43/24, 43/20, 33/12*

U.S. Cl. 166—256 11 Claims

ABSTRACT OF THE DISCLOSURE

In an underground deposit having highly viscous or solid bitumens therein and vertical and inclined borings extending into the deposit from the surface of the ground, with concentric tubing systems such as disclosed in U.S. Patent 3,242,989 installed in the borings, a process for obtaining bitumens from the deposits by conducting an in situ combustion in the deposits with an oxygen enriched gas of combustion such as disclosed in U.S. Patent application Ser. No. 440,852, filed Mar. 18, 1965, now U.S. Patent No. 3,344,856, the improvement comprising developing a burning zone with the oxygen enriched gas of combustion at the foot of each installed tubing system and upwardly along the axis thereof from the lower outlet of the innermost tube 25 to the successively open inlets of the outer tube 23, diverting and widening the burning front horizontally from the axis of the tubing system, sometimes with reversal of the burning and flow directions of the individual bores, and after sufficient heating with liquefaction of the stratum contents and vaporization thereof with steam from water injected to the intermediate tube 24 and, producing the stratum contents from all the borings.

CROSS-REFERENCES TO RELATED APPLICATIONS

Applicant claims priority under 35 U.S.C. 119 for the patent application Ser. No. D 51,652, filed Nov. 26, 1966, in the Patent Office of the Federal Republic of Germany.

Applicant refers to the U.S. patent application of Hans Lange, application Ser. No. 440,852, filed Mar. 18, 1965, now U.S. Patent No. 3,344,856, which in turn is a continuation-in-part of U.S. patent application Ser. No. 349,589, filed Mar. 5, 1964, now U.S. Patent No. 3,360,044. The application of Gunther Schlicht and Hans Lange, U.S. application Ser. No. 489,776, filed Aug. 9, 1965, now U.S. Patent No. 3,349,850, which in turn is a division of application Ser. No. 215,494, filed Aug. 6, 1962, now U.S. Patent 3,242,989, dated Mar. 29, 1966, is also referred to.

BACKGROUND OF THE INVENTION

The field of the invention is broadly wells and processes for introducing heat and fluid thereto. Wells having below and above ground modification are also included in the field of the invention.

In order to obtain highly viscous, congealed solid bitumens from underground deposits, it has been suggested, among other procedures, to perform an in situ combustion of certain components of an underground deposit with a burning front established in the deposit so as to melt and/or vaporize the components ahead of the burning front, whereby the components are brought above ground in the liquid or gaseous state.

According to U.S. Patent 3,344,856, supra, an in situ

combustion for underground deposits is described in which a gas of combustion having a given composition is mixed with 80–90% oxygen to serve as a heat carrying medium and also as an oxidizing agent for supporting an in situ combustion of hydrocarbons in the underground deposit. An important characteristic of the gas of combustion which is introduced into the deposit from above ground, or is formed by in situ combustion underground, is that its components are completely soluble in the underground deposit. The components of the gas of combustion are carbon dioxide and steam and only small amounts of nitrogen. These components of the gas of combustion give their heat contents to the underground medium, such as to the liquefied and vaporized carbon contents, so as to provide a source of heat which, except for the added oxygen, is composed entirely of substances from the deposit.

The process for the recovery of liquid and solid bitumens from underground deposits disclosed in U.S. Patent 3,344,856 comprises the following steps:

(a) Locating at least one relatively deep flooding boring, at least one relatively shallow production boring, and at least one treatment boring, and at least one leading boring, said treatment and leading borings located between said flooding boring and said production boring in a spaced predetermined direction apart from one another in the stratum of an underground deposit of bitumens;

(b) Introducing into said treatment boring an activated gas of combustion comprising oxygen and hot modified gas of combustion comprising steam and carbon dioxide;

(c) Developing a hot reaction zone between at least one of said treatment borings and at least one of said leading borings having a given temperature range by the sensible heat of said gas of combustion and the reaction of a portion of said bitumens and hot oxygen and producing additional modified gases of combustion;

(d) Conducting further into said stratum ahead of said reaction zone said additional modified gases of combustion from (c), where they condense and dissolve to form a liquid phase with contents of the stratum; and

(e) Advancing said reaction zone and displacing ahead of it stratum contents of condensed and dissolved gas of combustion in the direction of the production boring by the introduction of water to said flood boring, and removing the advanced stratum contents through the production boring.

In U.S. Paatent 3,242,989, an apparatus is disclosed for heating underground deposits by the use of a heat source in the form of a nuclear reactor that is positioned in the borehole for heat carrying medium which is pumped in a vertical and horizontally expanding path between the deposit and the boring. The apparatus according to U.S. Patent 3,242,989 comprises: a center casing and a pair of inner and outer concentric tubular casings extending into an underground bituminous deposit with said inner casing being rotatable, means defining a plurality of passages vertically spaced in said outer casing and staggeredly positioned thereon, rotary valve means actuated by said inner casing for selectively opening and closing said passages, a permeable layer of solid material on the lower end of the outer surface of said outer casing and extending over about one-third of the height of the deposit, and a pump connected in fluid communication with said outer, inner and center casings for circulating a liquid therethrough.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to avoid the limitations of and to improve the efficiency of prior art processes.

Another object of the present invention is an improved

process for carrying out an in situ combustion in the stratum of a bituminous deposit.

Another object of the invention is an improved apparatus for carrying out the in situ process in the stratum of bituminous deposits.

A particular object of the present invention is to provide an in situ combustion process in the stratum of a bituminous deposit having a vertical burning front.

Upon further study of the specification, drawings and claims other objects and advantages of the present invention will become apparent.

According to the present invention, an in situ combustion of a heat carrying medium consisting of a stratum component which has been enriched with oxygen is used as a source of heat and energy according to the disclosure of U.S. Patent 3,344,856, supra, and a nuclear reactor is not necessary as a heat source.

The present invention combines a vertical circulation process with an in situ combustion and renders the reactor superfluous. By means of a source of heat energy that is produced directly in the stratum, from the stratum contents and oxygen, and is circulated throughout the stratum, the combination offers the possibility, even in a deposit of small yield, to render the stratum productive and to exploit the same.

The in situ combustion, which is used as a source of heat energy, is performed in the region of vertical and inclined borings where the upper and the lower ends of the borings are brought alternatively to within a given distance from each other.

At least one, and preferably a row of vertical and inclined borings are extracted from the surface of the ground into the stratum of the bituminous deposit. Into the borings are inserted an apparatus comprising three concentric casings. The innermost casing has connections for delivering modified gas of combustion enriched with oxygen from the surface to the stratum. The intermediate casing has means for delivering water or steam to the stratum. Mounted on the intermediate casing are rotary or longitudinally shiftable valves which cooperate with openings or inlets in the outermost casing.

The process is begun by injecting gas of combustion enriched with oxygen into the stratum through one or more of the inclined and vertical borings. The oxygen enriched gas of combustion is ignited and the stratum contents are heated to a fluid state. The inlet valves in the outermost casing are opened and the fluid stratum contents are brought to the surface for circulation and return through the innermost casing to the stratum. The burning front is advanced vertically along the axis of the outermost casing by subsequently opening the valve further up on the casing. As the burning fronts of adjacent borings expand vertically and horizontally, they connect with one another and it is then possible to carry out an in situ combustion between adjacent borings.

BRIEF DESCRIPTION OF THE DRAWINGS

The process and apparatus of the present invention may be further explained by reference to the attached drawings wherein:

FIGURE 1 is a plan view of alternately vertical and inclined borings inserted from the surface of the ground into the stratum of a bituminous deposit;

FIGURE 2 is a vertical section of the stratum in the plane of the borings of FIGURE 1;

FIGURE 3 is a more detailed showing of the apparatus used in FIGURE 2;

FIGURE 4 is a detailed showing of a vertical component of the apparatus of FIGURE 3 in which the valves are longitudinally adjustable; and

FIGURE 5 is a detailed showing of a vertical component of the apparatus of FIGURE 3 in which the valves are rotatably adjustable.

With particular reference to FIGURES 1 and 2, vertical borings **0**, **2**, **4**, **6** and **8** and inclined borings **1**, **3**, **5** and **7** are shown extending from the surface of the ground through upper cover rock **10** into the deposits having lower cover rock **11**. The symbol X designates the foot of the inclined and vertical borings.

FIGURE 3 illustrates the use of an apparatus generally similar to that disclosed in U.S. Patent 3,242,989, applied to the method of the present invention. The apparatus is inserted into inclined borings **5** and **7** having vertical borings **6** intermediate thereto. Each apparatus comprises three coaxial tubes **23**, **24** and **25**. The outermost tube **23** is surrounded by a permeable material **27** in the lower third of the productive portion of the deposit, down to the lower end of the tube. The outermost tube is also provided at successive higher levels with circumferentially staggered openings which are closed or opened successively in the upward or downward direction by rotary valves **30**, **31** and **32** on the middle tubing **24**. These openings can, however, also be opened or closed by movement of the middle tubing in the axial direction.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The process of this invention is characterized in that a burning zone **50**, as shown in FIGURE 3, is established by the oxygen enriched gas of combustion in the individual borings of a section of the stratum at the foot of the tubing system between the lowermost opening of the inner tube **25** and the successively opened outlets along the length of the outer tube **23**. By the introduction of water througr the middle tubing **24** and out of the lower opening at **28**, the burning zone is diverted and widened, sometimes with a reversal of the direction of burning in the stratum and of flow in the individual tubings, so that after sufficient heating of the deposits and liquefaction of their contents, the latter can with the help of flash-vaporization of the steam from the injected water, be brought through the various borings to the surface.

As stated above, the burning zone which is formed around the tubing system of a boring can be diverted and widened in the horizontal direction. This is effected by the introduction of water through the permanently open passageways at **28** in the horizontal direction between the inlet and outlet openings of the tubings. The water forces the burning zone away from the borehole axis into the neighboring parts of the stratum while the resulting hot steam, besides its direct heating effect, also causes flash vaporization of voltaile components of the deposit which escapes to the surface through inlet openings of the tubing system. A permeable layer around the tubular system in the lower portion of the deposit is established by making the boring in this region of larger diameter and filling the resulting intermediate space between the wall of the boring and the casing with porous sand.

It has been found advantageous to enclose a section of the deposit by rows of borings in which the individual boreholes are alternately vertical, as at **0**, **2**, **4**, **6** and **8**, and inclined, as at **1**, **3**, **5** and **7**. As is shown in the drawings, the tubings in adjacent borings are in close proximity to each other alternatively at the rock formation above, or at the formation below the deposit. The minimum distance between adjacent borings is determined by the kind of rock, and can be from 10 to 100 meters. In homogeneous rock formations, minimum spacings of 30 to 50 meters have been found advantageous. After the formation of a burning zone around each boring and gradual warming of the stratum in the regions between adjacent borings, production is obtained through all the borings.

The heating of the intermediate regions by heat conduction laterally from the heat carrier into the deposit results from the great temperature difference between the relatively hot heat carrier flowing upwardly from the burning zone to the head of the boring, and the relatively cool intermediate regions. In this manner large amounts of heat are conducted across these short paths into the inter-

mediate regions without any movement of the stratum contents.

After the temperature of the products in the deposit has been raised to the boiling point of water under the existing pressure conditions, the inclined borings are used as injection borings for the oxygen-enriched gas of combustion. The gas is delivered at the foot of the inclined boring from the innermost tube **25** into the deposit. The removal of the liquefied and vaporized stratum contents is accomplished in a controlled manner by the vertical borings where the fluidized material enters successively through the uppermost openings of the outermost tubes **23**. To reach all portions of the deposit and to prevent the formation of particular flow channels, the direction of flow through certain borings may be reversed.

Under particular operating conditions, when the temperature of the product reaches the temperature of boiling water, all the borings of that portion of the deposit are operated as injection borings and only a single vertical boring near the center of the deposit is operated as a production boring. The gas of combustion after its enrichment with an oxygen carrier is introduced in graduated amounts through the innermost tube **25**, namely through the lowest opening. Here also the medium on occasions is introduced alternately through this lowermost opening or through an upper opening of the outer tube **23**.

After sufficient warming of the section of the deposit that is enclosed by the borings and after diminished production, water is introduced as flooding water through the lower openings of the tubing systems of all borings and becomes successively warmed through the liberated hot oil. The water is introduced into the deposit to displace the stratum contents toward the upper portion of the deposit for delivery through the openings in the upper portion of the tubing system **23** to the surface, first through the lowermost openings and then through openings at higher levels **30–32** as the level of the water rises.

With only slight differences, the tubing system used here corresponds to the tubing system of U.S. Patent 3,242,989 for bitumen production. Without the use of an atomic reactor as a stationary source of heat, and with the production of the required heat by in situ combustion to produce a movable source of heat externally of the apparatus, the oxygen enriched gas of combustion is introduced through the innermost tube **25** into the deposit where it is returned through the various openings in the outermost tube **23** to above ground. A portion of this product in the form of an inert gas of combustion, is then again enriched with oxygen and returned through the innermost tube **25** for recirculation through the deposit.

After a burning front has been formed in the immediate neighborhood of the boring, water is continually introduced through the middle tube **24** and the communicating openings at **28** in the outer tube **23** for injection into the burning front to drive it out and widen it horizontally. The steam which is formed in the hot burning front causes some flash vaporization of the stratum contents. The intermediate tubing **24** which is rotatable or movable vertically is closed at its lower end. It receives the water from a separate conduit. Its coordination with the outlet openings of the surrounding outer tube **23** is such that there is uninterrupted injection of water into the stratum.

From the foregoing description, one skilled in the art can easily ascertain the essential characteristics of this invention, and without departing from the spirit and scope thereof, can make various changes and modifications of the invention to adapt it to various usages and conditions. Consequently, such change and modifications are properly, equitably, and intended to be, within the full range of equivalence of the following claims.

I claim:

1. In an underground deposit having highly viscous or solid bitumens therein and borings having vertical and inclined axes extending into the deposit from the surface of the ground, tubing systems installed in said borings comprising first, second and third concentric tubes wherein said first tube is the outer tube and has openings in the surface thereof, said second tube is the intermediate tube and has rotating valves affixed thereto cooperating with said openings and said third tube is the innermost tube with an outlet at the bottom thereof, a process for obtaining bitumens from the deposits by conducting an in situ combustion in the deposits with an oxygen enriched gas of combustion, the improvement comprising;

(a) developing a burning zone with the oxygen enriched gas of combustion at the foot of each installed tubing system and upwardly along the axis thereof from the lower outlet of the innermost tube;

(b) diverting and widening the burning front horizontally from the axes of the tubing systems in the borings;

(c) after heating of the stratum contents, introduction of water into the middle tubing whose lower end is closed and expulsion of said water through the continually open lowermost valve, liquefaction and flash vaporization ahead of the burning zone by the steam that is formed by vaporization of the expelled water, and removal of the liquefied and further heated bitumens through upper openings of all the borings, beginning with the lowermost opening of the three superimposed rotary valves; and

(d) widening and expanding the horizontal reaches of the flowing hot stratum contents and of the burning front by closure of the lower opening and by opening the middle rotary valve, and after further expansion of the horizontal warming front by closing the middle rotary valve and instead opening the upper rotary valve.

2. The process of claim **1**, wherein the burning and flow directions of the individual borings are reversed.

3. The process of claim **1**, characterized in that upon reaching the boiling point of the water under the existing pressure conditions in the deposit the stratum contents are flashed, the inclined borings are then used only as injection borings for the oxygen enriched combustion gas and the vertical borings only as production borings for the liquefied and flash steam treated stratum contents, whereby the oxygen enriched combustion gas is introduced at the feet of the inclined borings and the stratum contents delivered through the successively opened upper openings to above ground.

4. The process of claim **3**, wherein the direction of flow is reversed.

5. The process of claim **1**, characterized in that progressively with the increased warming of the stratum, the stratum contents are delivered in the specified manner only by a single vertical boring at the center of the deposit that is being exploited, and oxygen enriched gas of combustion is injected in measured amounts into the stratum at the feet of all the remaining vertical and inclined borings.

6. The process of claim **5**, wherein said oxygen enriched gas of combustion is injected alternately through the lower and upper openings in the tubing systems of the remaining borings.

7. The process of claim **1**, characterized in that in a last phase of the process the injection of enriched oxygen into the borings is stopped, and that by floating with water that has become heated after its injection from the feet of all borings, the liquefied stratum contents are displaced for delivery through the successively opened inlet openings in the upper portions of all borings to above ground.

8. The process of claim **7**, wherein said stratum contents are progressively removed through openings at higher levels in said tubing systems as the water level rises.

9. An apparatus for obtaining bitumens from an underground deposit having highly viscous or solid bitumens, said apparatus comprising a first tube (**23**) in the form of an outer casing with selectively controlled longitudinally spaced openings at different levels and a per-

manently open water outlet passageway (28) at a lower level, a second tube (24) carrying longitudinally spaced valves (30), (31) and (32) and movable relative to the first tube to selectively control the longitudinally spaced openings and also providing a permanently open passageway for water from the interior of the second tube and through the permanently open passageway (28) to the stratum, a third tube (25) coaxial with the first and second tubes and forming a fluid-tight fit with the lower end of the second tube, a permeable covering over the water outlet passageway (28) extending around the outside of the first tube, and means for conducting an oxygen-containing gas from above ground to the upper end of the third tube.

10. The apparatus of claim 9, in which the movement of the second tube relative to the first tube to selectively control the longitudinally spaced openings is a rotary movement.

11. The apparatus of claim 9 in which the movement of the second tube relative to the first tube to selectively control the longitudinally spaced openings is a longitudinal movement.

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U.S. Cl. X.R.

166—52, 226, 272, 303