Nov. 18, 1969 P. J. CLOSMANN 3,478,825

METHOD OF INCREASING THE VOLUME OF A PERMEABLE ZONE WITHIN AN OIL SHALE FORMATION

Filed Aug. 21, 1967 2 Sheets-Sheet 1

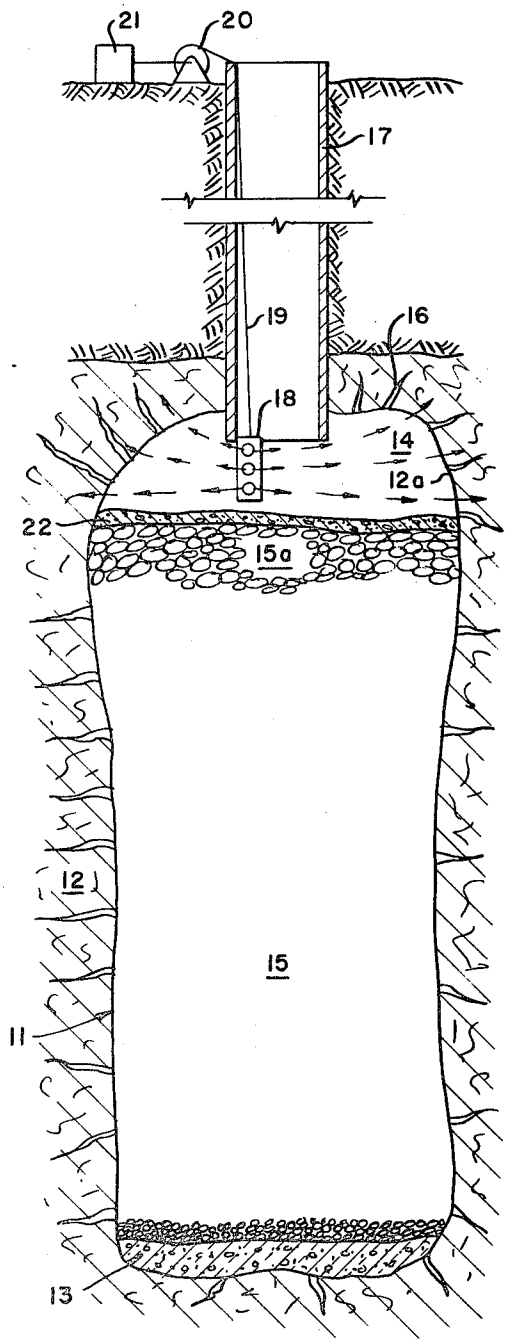


FIG. 1

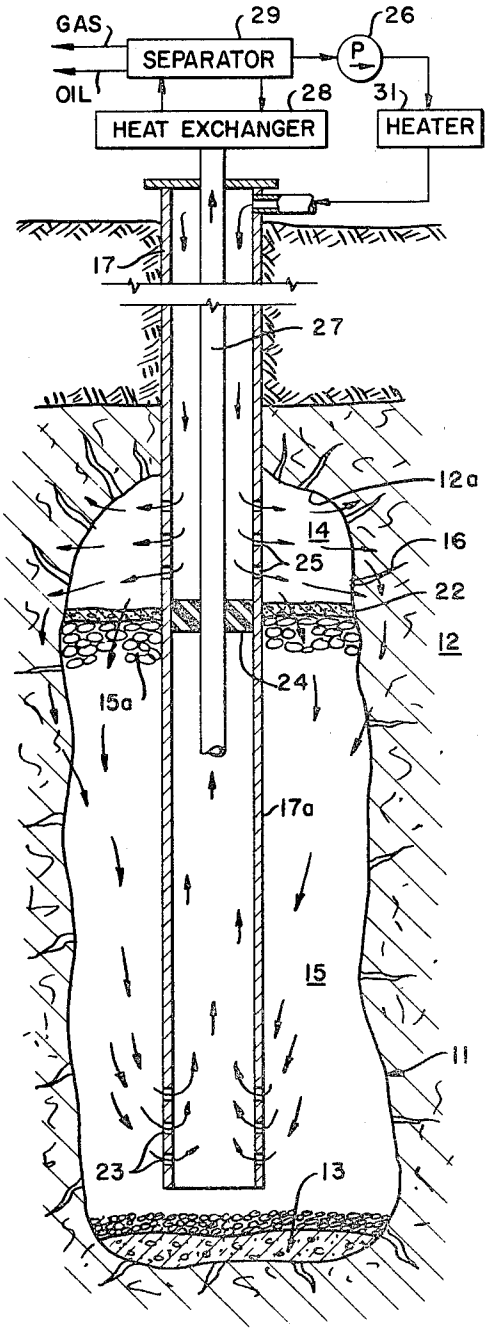


FIG. 2

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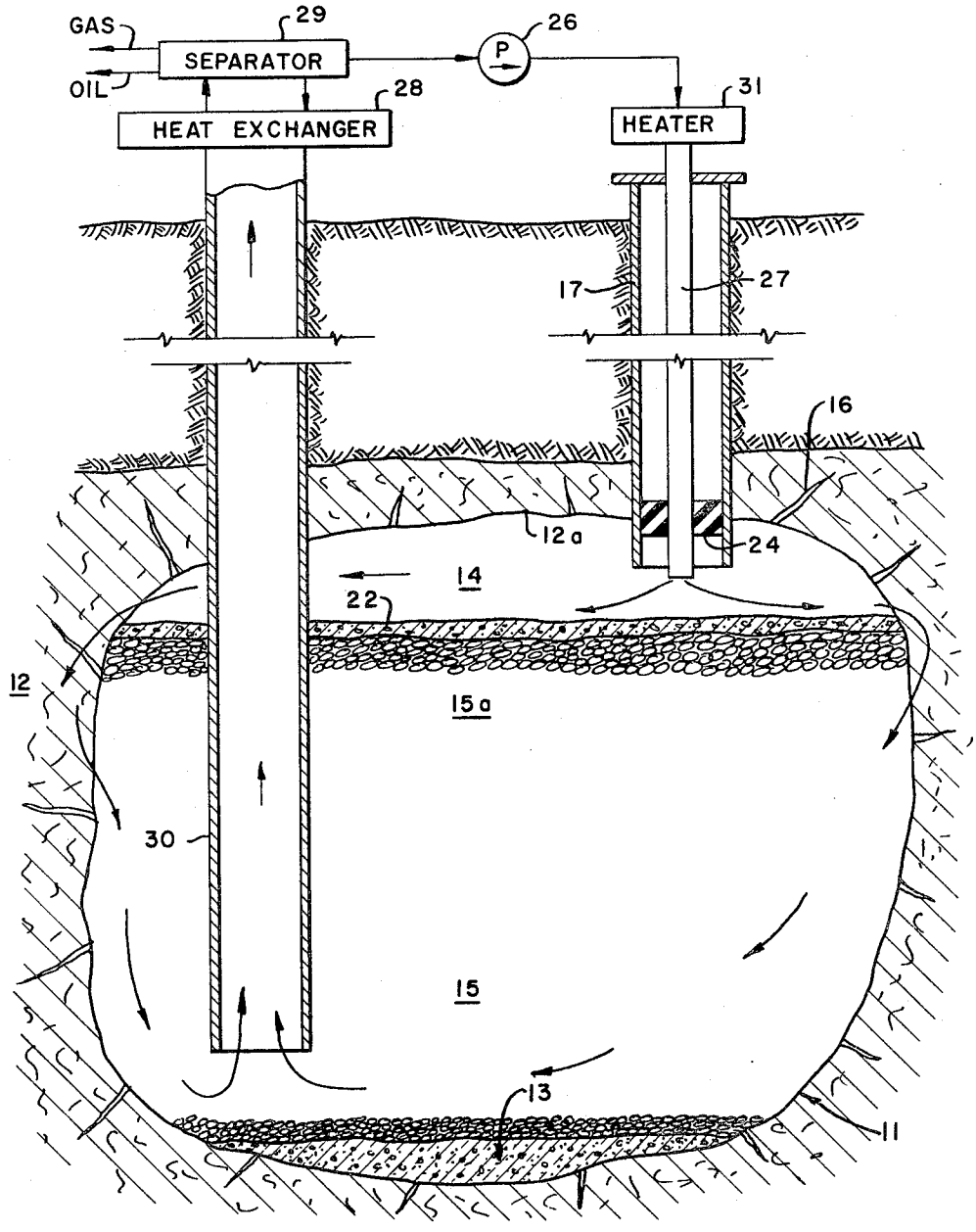


FIG. 3

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METHOD OF INCREASING THE VOLUME OF A PERMEABLE ZONE WITHIN AN OIL SHALE FORMATION

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Int. Cl. E21b 43/26
U.S. Cl. 166—299 10 Claims

ABSTRACT OF THE DISCLOSURE

An improved method of increasing the volume of the permeable zone created by detonation of a relatively high energy device within a subterranean oil shale formation by opening a borehole in the substantially void space created by the detonation of the device, opening perforations in the fractured zone surrounding the void space and circulating fluid between the void space and the rubble resulting from the detonation including flow through the perforations.

BACKGROUND OF THE INVENTION

Field of the invention

The invention relates to an improved method of increasing the volume of a permeable zone formed within an oil shale formation, and, more particularly, to a method of extending channels into the fractured zone surrounding the chimney of rubble created by detonation within the oil shale formation of a high energy device.

Description of the prior art

The use of contained nuclear explosions has been proposed in subterranean oil shale formations in an attempt to break up the oil shale formation so that shale oil can be recovered from the rubbled zone by known techniques, such as in situ retorting.

Experience has shown that when a relatively high energy device, such as a nuclear bomb, is exploded within a subterranean earth formation, an almost spherical cavity filled with hot gases is formed. This cavity expands until the pressure within the cavity equals that of the overburden. On cooling, the roof of the cavity collapses since, generally, it cannot support itself, and a so-called "chimney" develops. Chimney growth ceases when the rock pile substantially fills the cavity, or, a stable arch develops. In both cases, a substantially void space is formed below the overburden and above the rubble contained within the chimney. Surrounding the chimney is a fractured zone which results from the shock of the nuclear explosion.

One of the chief uncertainties with regard to the effects of nuclear explositions within a subterranean oil shale formation is the permeability distribution surrounding the cavity and subsequent chimney produced by a detonation. Evidence from prior explosions suggests that permeability of the fragmented zone may drop very rapidly with distance radially out from the primary rubble zone. A high and uniform permeability is important in order to provide maximum sweep efficiency in any underground hydrocarbon recovery process.

SUMMARY OF THE INVENTION

It is an object of this invention to establish suitable communication between fractures in the rocks around a chimney of rubble produced by the detonation of a relatively high energy explosive device and the interstices in the rubble contained within the chimney.

It is a further object to improve the sweep efficiency of underground hydrocarbon recovery processes used to extract shale oil from a fragmented oil shale formation by increasing the volume of the permeable zone which is created within the formation by the explosive device.

The concepts of this invention are carried out by improving the communication with fractures in the region around the chimney of rubble formed by the detonation of a relatively high energy device. A borehole opening is extended into the substantially void space at the top of the chimney and a perforating device is lowered through the borehole opening and directed against the wall of the fractured zone surrounding the chimney so as to open generally radial channels into the wall.

Fluid is then circulated by known means between the borehole opening and the rubble within the chimney so as to include the channels into the wall of the fractured zone thereby increasing the volume of the permeable zone that is swept by the circulating fluid.

If the permeability of the central rubble zone of the chimney is so high as to effectively divert all or most of the circulated fluid along a path confined within the rubble, material is preferably injected to form an impermeable layer near the top of the rubble contained within the chimney. Alternatively or additionally, a fluid having a relatively high frictional resistance to flow through the rubble contained in the chimney is used as the circulating fluid.

BRIEF DESCRIPTION OF THE DRAWING

FIGURE 1 is a vertical sectional view of an oil shale formation having a well extending into a permeable zone within the formation;

FIGURE 2 is a vertical sectional view of an oil recovery process applied to the oil shale formation of FIGURE 1; and

FIGURE 3 is a vertical sectional view of an alternate oil recovery process applied to the oil shale formation of FIGURE 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Turning to the drawing, FIGURE 1 shows a permeable fragmented zone **11** created within an oil shale formation **12**. Zone **11** is a nuclear chimney-type permeable zone created by detonating a relatively high energy explosive device, such as a nuclear bomb, within the formation **12**. Such detonation has been discovered to create a permeable chimney-shaped rubble-containing zone **11** having a solidified glassy rock portion **13** at its lower end and a substantially void space **14** at its upper end. The remainder of the chimney comprises a rubble **15** of relatively high permeability. Further information concerning the formation of a chimney by subterranean nuclear detonation can be obtained from the copending application to Prats, Ser. No. 613,600, filed Feb. 2, 1967.

As can be seen in FIGURE 1, the permeable zone **11** is surrounded by a series of fractures **16**. Many of these fractures extend along generally vertical planes and do not communicate with the rubble-filled zone **15**. In order to improve communication between the area of relatively high permeability adjacent the middle or center portion **15***a* of the rubble **15** and the radially outermost region adjacent fractures **16**, the rock around the edges of the permeable zone **11** adjacent the substantially void space **14** is perforated to open generally radial channels into the surrounding rocks. For example, a well **17** is extended into the substantially void space **14** and a perforating device **18**, such as a laser beam, explosive jet or bullet-type perforator or the like, is lowered into well **17** by means of a combined load carrying and electrical signal and/or current transmitting cable **19** coupled to a winch **20**. Of course, other means, mechanical or electrical or both,

can be used to selectively raise and lower the perforating device **18** within well **17**. For reasons of convenience, the remaining above ground components of well **17** have been omitted in FIGURE 1.

In operation, the perforating device **18** is lowered through well **17** into the substantially void space **14** and moved into position so as to form channels that contact the fractures **16** surrounding space **14**. Conventional operating or prime mover means **21**, coupled to winch **20** and perforating device **18**, are preferably used to remotely control the operation of the perforating device **18**. Thus, cable **19** is of sufficient strength to raise and lower perforating device **18** and contains therein the necessary electrical leads (not shown) for actuating the perforating device **18**.

Since it has been recently discovered that hard rock can be crumbled with a laser beam, this method is readily adapted to carrying out the concepts of my invention. The substantially void space **14** can be anticipated from the detonation of a nuclear device; however, if necessary, sufficient space for the perforating device **18** can be provided by some suitable form of under-reaming at the top of the permeable zone **11**.

In some cases, the permeability of the central portion **15***a* of the rubble **15** will be so high as to effectively divert all or most of the fluids to be injected as will be discussed later. In such cases, an impermeable layer **22** is formed near the top of the central portion **15***a* of rubble **15**. This is preferably accomplished by injecting some very viscose material such as a non-porous cement or resin formulation or other suitably selected agents which will solidify in situ within the rubble **15**. The layer **22** tends to divert most of the injected fluids to the sides of the chimney, through the channels opened into the wall of the chimney (shown in dotted lines in FIGURE 1) and into the fractures **16** thus tending to improve the sweep efficiency in subsequent hydrocarbon recovery processes. Alternatively, the tendency for fluid injected near the top of the rubble **15** to flow preferentially through the central portion **15***a* is also reduced by injecting a fluid having a relatively high frictional resistance to flow, such as an emulsion or a foam. The use of foam injection to advance a combustion front down through a chimney is described in detail in copending application Ser. No. 689,181, filed Dec. 8, 1967. Instead of or in addition to depositing a layer of impermeable material on or near the top of the central portion **15***a* of rubble **15**, the central portion **15***a* of rubble **15** may be filled with a material having a relatively uniform permeability that is low compared with the average permeability of the fragmented oil shale. Such a material can comprise a bed of relatively fine sand, a layer of porous cement, or a porous mixture of resin and sand or the like.

Various means of inducing perforations or openings in the wall **12***a* of the oil shale formation **12** surrounding the void space **14** may include explosives, jet or bullet perforators or systems for jetting a stream of abrasive fluid against the wall **12***a* of the shale oil formation **12**.

As can be seen from the above discussion, the perforations into wall **12***a* are preferably opened along generally radial directions from the central portion **15***a* of the rubble **15**. This provides a radial extension of the substantially solid-free void space **14** near the top of the permeable zone **11** and permits communication with the system of fractures **16** surrounding the zone **11**. Thus, as discussed below concerning FIGURES 2 and 3, when fluid is circulated through the permeable zone **11** from the top to bottom, full injection pressure is applied across the solid-free area thereby establishing better fluid communication with the outermost portions of the fractured zone which includes the chimney-type permeable zone **11** and the fractured area surrounding zone **11**. If the permeability within the fractured oil shale is sufficiently uniform, a so-injected fluid will travel downward while tending to maintain a level horizontal front.

Various types of processes can be used to increase the volume of the permeable zone **11** created within the oil shale formation **12** utilizing the perforations in wall **12***a* of oil shale formation **12**. FIGURES 2 and 3 illustrate alternate processes wherein like numerals refer to like parts of FIGURE 1.

In FIGURE 2, after the perforations have been made in the wall **12***a* of oil shale formation **12**, well **17** is extended as at well portion **17***a* to the bottom of the rubble area **15** where communication is established with the rubble **15** by means of openings **23** formed in well portion **17***a*. Well **17** is preferably drilled into the bottom of rubble area **15** while the zone **11** is hot, or at least warm, from the explosion. Well **17** is equipped for injecting fluid through the borehole opening above packer **24** and through openings **25** formed in well **17** and into the upper portion of the permeable fragmented zone **11**. The fluid circulates in a generally vertical downward flow path that includes flow through the perforations in the wall **12***a* of oil shale formation **12** surrounding permeable zone **11**. The permeable channel providing unobstructed fluid communication between openings **25** in well **17** and openings **23** in well portion **17***a* is formed by known techniques. One preferred technique is the acidizing of a tuffaceous streak as described in application Ser. No. 619,259, filed Feb. 28, 1967. As is well known in the art, the fluid is heated prior to circulation by means of a heating device **31**. In other words, the fluid is pumped by means of pump **26** through heating device **31**, through the unobstructed permeable path as indicated by the arrows in FIGURE 2, and up tubing string **27** where the oil and gas entrained in the heated circulating fluid passes through a heat exchanger **28** and into separator **29**. At this point, the oil and gas components are separated as is well known in the art. The fluid is recirculated from separator **29** through pump **26** as again is well known in the art. Further discussions concerning the circulation of a fluid until the oil shale derived fluidizable materials are entrained in the fluid can be found in copending Ser. No. 632,006, filed Apr. 19, 1967 to Prats.

Thus, it can be seen that the perforations in the wall **12***a* improve the flow of fluid from the central portion **15***a* to the outlying portions of the permeable zone **11**. This improves the efficiency of either an injection of fluid near the top and a production of fluid near the bottom, or the reverse. An upward circulation can advantageously be used in a gas heating process as for example, a process of the type described in Patents Nos. 2,813,583; 3,233,668; 3,241,411 or the like. In these processes, the fluids circulating through the oil shale at the temperatures in the oil shale are mainly gases which are circulated relatively rapidly in order to transport heat throughout the oil shale. A downflowing circulation can advantageously be used to advance a combustion front down through the oil shale or to permeate the oil shale with an oil solvent vapor or liquid which is initially or tends to become, liquid due to either condensation or dissolving of shale oil components within the chimney. A suitable extraction process of this type is described in copending application Ser. No. 656,815, filed July 28, 1967.

FIGURE 3 shows an alternate process for increasing the volume of the permeable zone **12** created within oil shale formation **12**. Like numerals refer to like elements of FIGURE 2. In place of the same well being opened into both the void space **14** and the lower end of the rubble area **15**, a well **30**, independent of well **17**, is opened into the lower end of the rubble **15**. Thus, the circulating fluid exits from tubing string **27**, is circulated through the perforations in the wall **12***a* of oil shale formation **12** and thus through fractures **16**, and enters the well **30** at its lower end adjacent to the bottom of rubble **15**. Again, conventional equipment and techniques, such as heating device **31**, pump **26**, separator **29** and heat exchanger **28**, can be used for pressurizing, heating, injecting, producing

and separating components of the fluid that is circulated through the permeable zone **11**.

I claim as my invention:

1. In a method of increasing the volume of the permeable zone created within a subterranean oil shale formation by detonating at least one relatively high energy explosive device within the formation to form a chimney of rubble surrounded by a fractured zone and having a substantially void space near its top, the improvement comprising the steps of:

opening a borehole into the substantially void space near the top of the chimney;

opening perforations into the wall of the fractured zone surrounding the upper end of the chimney of rubble adjacent the substantially void space along generally radial directions from the central portion of the rubble contained in the chimney;

establishing unobstructed fluid communication between the substantially void space and the lower end of the chimney of rubble; and

circulating fluid along the lines of unobstructed fluid communication established between the substantially void space and the lower end of the chimney along a generally vertical path that includes flow through at least some of the perforations into the fractured zone surrounding the upper end of the chimney.

2. The method of claim **1** including the step of depositing a layer of permeability reducing material along the upper portion of the rubble adjacent the center of the chimney containing the more permeable fragmented oil shale.

3. The method of claim **2** including the step of impregnating the rubble adjacent the center of the chimney containing the fragmented oil shale with material having a relatively uniform permeability that is low compared with the average permeability of the rubble.

4. The method of claim **1** wherein the step of circulating fluid includes injecting a fluid having a relatively high frictional resistance to flow through the rubble contained in the chimney.

5. The method of claim **1** wherein the step of establishing unobstructed fluid communication between the substantially void space and the lower end of the chimney of rubble includes opening a borehole into the rubble contained in the lower end of the chimney.

6. The method of claim **1** wherein the step of establishing unobstructed fluid communication between the substantially void space and the lower end of the chimney of rubble includes opening the same borehole into both the substantially void space and the lower end of the chimney.

7. The method of claim **1** wherein the step of opening perforations includes jetting a stream of abrasive fluid against the wall of the fractured zone until openings are formed therein.

8. The method of claim **1** wherein the step of opening perforations includes the steps of:

lowering a perforating device through the borehole opening; and

moving the perforating device into operative position within the substantially void space of the chimney.

9. The method of claim **1** including the step of extracting shale oil from the circulating fluid.

10. The method of claim **1** including the step of impregnating the rubble adjacent the center of the chimney containing the fragmented oil shale with material having a realtively uniform permeability that is low compared with the average permeability of the rubble.

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U.S. Cl. X.R.

166—247, 297, 303