United States Patent

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[73] Assignee **Phillips Petroleum Company**

[54] CRUSHING OIL SHALE WITH NUCLEAR EXPLOSIVES

5 Claims, 3 Drawing Figs.

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[51] Int. Cl. E21b 43/26
[50] Field of Search 166/36, 42, 11, 9, 247, 245, 308, 299, 259, 271, 303

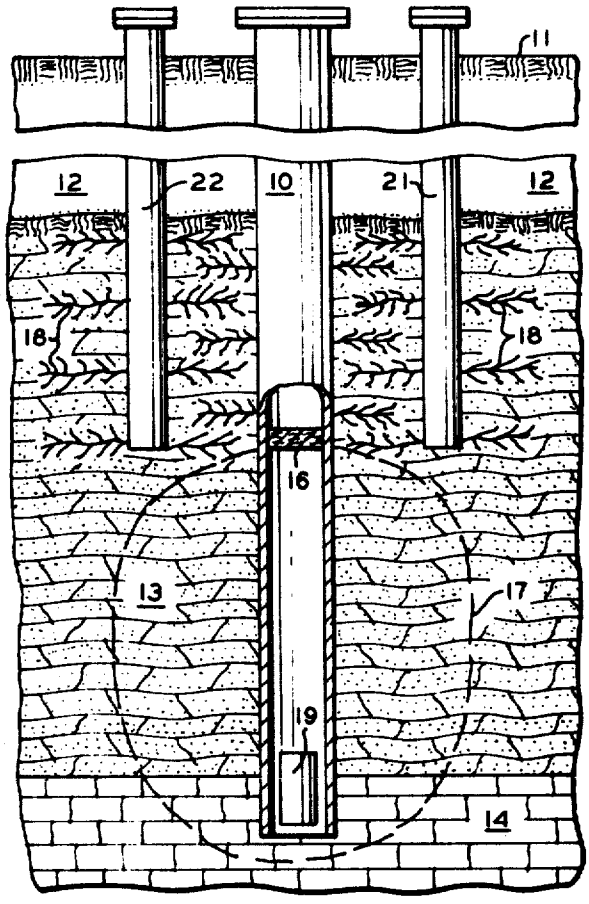
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ABSTRACT: The effectiveness of nuclear explosions in an oil shale stratum to create a mass of shale rubble, suitable for in situ retorting, is increased by hydraulically fracturing prior to the explosion a portion of the stratum above the level of the stratum which will be shattered by the explosion.



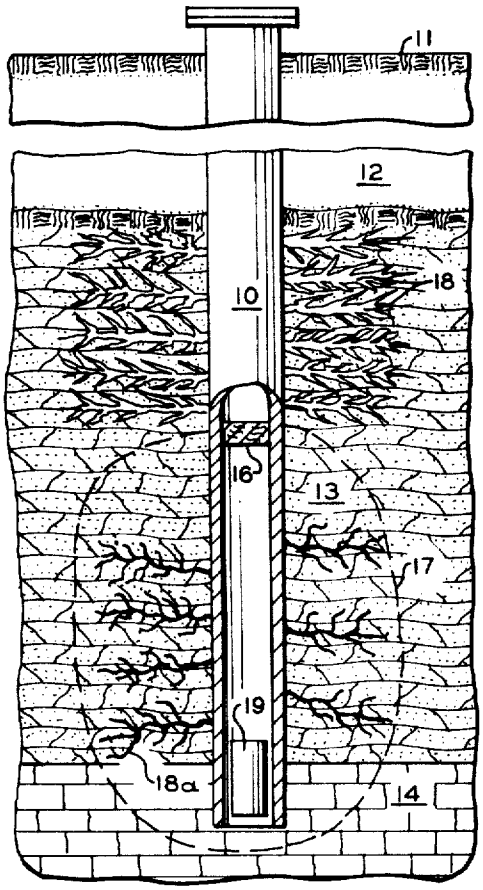


FIG. 1

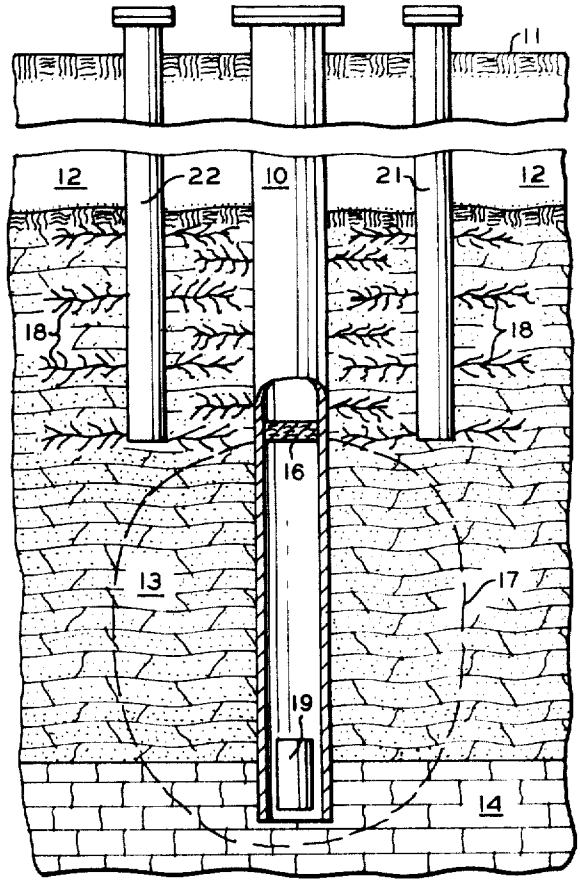


FIG. 2

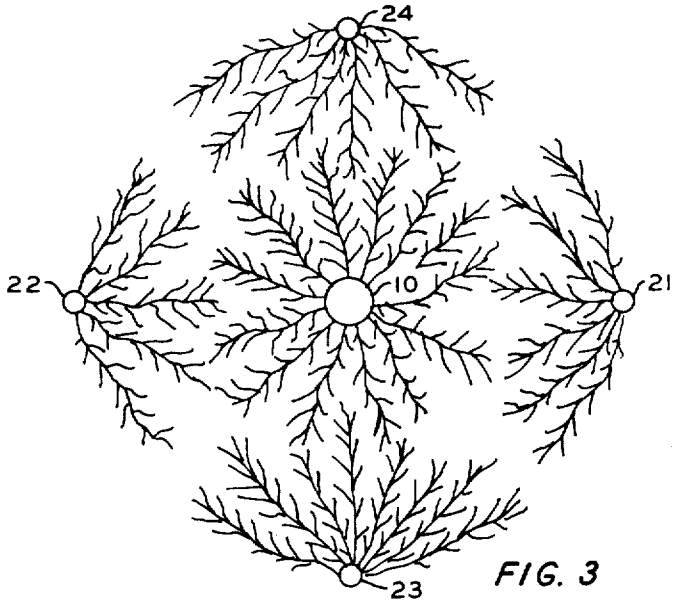


FIG. 3

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CRUSHING OIL SHALE WITH NUCLEAR EXPLOSIVES

This invention relates to crushing oil shale with nuclear explosives. In one aspect the invention relates to creating a mass of shale rubble from which oil can be recovered in situ. In another aspect the invention relates to a method for increasing the yield of crushed or shattered shale from the detonation of a nuclear device in an oil shale stratum.

Oil is produced from oil shale by heating the shale to a temperature above about 500° F. At this temperature, kerogen, an organic substance present in the shale, decomposes or is converted to oil. In order to produce oil from oil shale in situ, it is necessary to fracture the shale to render the process commercially feasible. The in situ retorting of shattered or broken shale in nuclear chimneys produced by positioning and actuating a nuclear explosive device in a shale stratum is disclosed by M. A. Leakas and N. C. Carpenter in an article entitled "Fracturing Oil Shale with Nuclear Explosives for In Situ Retorting" presented in the Quarterly of the Colorado School of Mines, Vol. 60, No. 3, July 1965, Pages 7—30. The nuclear chimney in an oil shale is a highly permeable mass of broken and displaced shale ranging in size from blocks 2 to 3 feet across down to sand-sized grains. A250 kiloton device set off in a thick shale formation is estimated to create a collapse chimney 400 feet in diameter and 1,000 feet high.

The permeability of this mass of crushed and broken shale makes it feasible to produce oil from the mass by in situ retorting methods known in the art. Known methods include the injection of hot gases at temperatures of 500 to 1,000° F. and in situ combustion of a portion of the shale oil and driving out another portion with the resulting heat and gases.

The cost of a nuclear device is a substantial part of the cost of such a shale oil recovery program. Another cost factor in this method of recovering oil is the depth and diameter of the bore hole which must be drilled to place the nuclear device at the desired level in the stratum. The device will usually be placed deep in the stratum to avoid surface contamination by radio active products of the explosion. The diameter of a nuclear device increases with the energy yield of the device. High yield devices require a large diameter bore hole, in some cases up to 36 inches in diameter, and drilling such a bore hole involves a great deal of expense. By the practice of this invention, which involves an initial fracturing step, a nuclear device of a lesser energy yield can be utilized to create a mass of broken shale which is comparable in size to a mass produced by a greater energy yield device.

Accordingly, it is an object of this invention to reduce the cost of recovering oil from oil shale in situ.

Another object of the invention is to increase the yield of crushed shale resulting from the detonation of a nuclear device in a shale stratum.

Another object of the invention is to reduce the diameter of the bore hole utilized to implace nuclear devices in a shale stratum to crush a given amount of shale.

These and other objects will be apparent to one skilled in the art upon consideration of the specification, drawings, and appended claims.

FIG. 1 is a schematic cross-sectional view of one embodiment of the invention.

FIG. 2 is a schematic cross-sectional view of another embodiment of the invention.

FIG. 3 is a top plan view of the embodiment illustrated in FIG. 2.

According to the invention, there is provided a method whereby the effectiveness of a nuclear device detonated in an oil shale stratum to crush and shatter the shale is increased comprising fracturing the stratum prior to detonation of the device above the point at which the nuclear device is detonated. The entire zone from the level at which the nuclear device is emplaced to the upper limit of the oil shale strata can be fractured to form a larger mass of shale rubble than would result from the detonation of the nuclear device without such a fracturing.

In one embodiment of the invention, the bore hole which is drilled to provide access for positioning the nuclear device in a shale stratum is utilized to fracture the stratum at the desired level. Generally this bore hole will be cased; the casing can be perforated at the desired level and the hole plugged back. Conventional hydraulic fracturing methods can then be used to fracture the stratum radially and vertically to the desired extent.

In another embodiment of the invention a plurality of bore holes extending to the desired level in the stratum are provided about a central bore hole which is utilized to position the nuclear device. Fracturing of the desired zone of the stratum is carried out by employing the plurality of bore holes. The central bore hole can also be used in combination with the plurality of bore holes to fracture the stratum to the desired extent.

The extent to which the formation is fractured depends upon the size or energy yield of the nuclear device utilized to crush the shale, the level above the device at which the stratum is to be fractured and the degree of permeability which is desired in the final resulting mass of rubble. There are several suitable methods of fracturing a subsurface stratum known in the art. When hydraulic fracturing is used, propping agents, such as sand, walnut shells, aluminum pellets and the like can be included in the fracturing fluid to retain the fractures open. The fracturing fluid and propping agents, having a different density than the shale, provides for refraction of shock waves from a nuclear explosion and the refraction results in a greater shattering of the shale.

Referring now to the drawings wherein like reference numerals denote like elements, the invention will be described in detail. In FIG. 1, a bore hole 10 extends from the surface 11, through an overburden formation 12, which does not contain oil, through a stratum of oil shale 13 and into an underlying stratum 14 which does not contain oil. In the practice of the method of the invention, the bore hole 10 is plugged back as is shown at 16 above the level of an anticipated initial collapse chimney (shown by a broken line 17) which would result from the detonation of a nuclear device without the fracturing step. If the bore hole is cased, perforations are made in the casing. The zone between the level of plugged portion 16 and the upper limit of shale stratus 13 is fractured The fracture system so produced is denoted generally by reference numeral 18. Fracturing in the anticipated initial collapse chimney, shown as 18a, enhances the effect of the nuclear device in crushing the shale. Because of ease of operation and well developed techniques, hydraulic fracturing is presently preferred. A nuclear device 19 is positioned in the bottom of bore hole 10 before or after the fracturing step. Upon detonation of the device there is created a cylindrical mass of shale rubble which extends to the upper limits of shale stratum 13.

In an alternative method the drilling of bore hole 10 can be interrupted at the desired level in the stratum, allowing fracturing without the necessity of plugging the hole back. This method is particularly advantageous when conventional molecular explosives are used to fracture the formation. The bore hole can then be extended to the desired depth an oil shale 13 or stratus 14 and the nuclear device positioned and actuated.

FIGS. 2 and 3 illustrate an embodiment of the invention wherein the zone is fractured through a plurality of bore holes in the stratum rather then relying upon a single central bore hole.

IN FIG. 2, a central bore hole 10 extends to the bottom of oil shale stratum 13 and bore holes 21 and 22 extend to a level immediately above the top of the anticipated initial collapse chimney 17. Bore holes 21 and 22 are representative of a plurality of bore holes which can be positioned about central bore hole 10. The stratum between the top of collapse chimney 17 and the upper limits of stratum 13 is extensively fractured employing fluid pumped under high pressure through the plurality of bore holes including bore hole 10. Bore holes 21 and 22 are of a relatively small diameter compared to bore hole 10 since they are required to transport fracturing fluid only. The

detonation of nuclear device **19** in bore hole **10** results in a mass of shale rubble or a chimney which extends substantially through the thickness of the stratum, whereas, if the stratum had not been fractured prior to the detonation, the chimney would be defined as shown by line **17**. The prefracturing step allows the use of a smaller yield energy device and permits the drilling of a smaller diameter bore hole (**10**) to implace the device in the stratum.

FIG. **3**, a plan surface view shows wells **21**, **22**, **23**, and **24** positioned in a ring pattern about well **10**. Additionally there is depicted a fracture system **18** which is formed in the stratum.

Reasonable modification and variation, such as positioning the plurality of wells shown in FIGS. **2** and **3** in other than a ring pattern, are within the scope of the invention which defines a novel method of crushing oil shale.

That which I claim is:

1. In a method of increasing the effectiveness of a nuclear device detonated in a central bore hole in an oil shale stratum in forming a mass of shale rubble comprising fracturing said stratum prior to the detonation of said nuclear device in a

zone vertically above the top of an anticipated normal initial collapse chimney of said nuclear device, the improvement which comprises fracturing said stratus through a plurality of additional bore holes extending into said zone to a level in the vicinity of said top of an anticipated normal collapse chimney and positioned around said central bore hole, and then detonating said nuclear device to form a collapse chimney of greater vertical extent than would be obtained in the absence of the resulting fractures.

2. The method of claim **1** wherein said plurality of bore holes and said central bore hole are used in combination to fracture said stratum.

3. The method of claim **1** wherein said stratum is hydraulically fractured.

4. The method of claim **1** wherein said hydraulic fractures are propped.

5. The method of claim **1** also including the step of fracturing said stratum within the limits of said anticipated normal initial collapse chimney.