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Parker

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[54] **RETORTING OF NUCLEAR CHIMNEYS**

[72] Inventor: **Harry W. Parker**, Bartlesville, Okla.

[73] Assignee: **Phillips Petroleum Company**

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[51] **Int. Cl.**.....**E21b 43/24,** E21b 43/26

[58] **Field of Search**.....166/247, 248, 256, 259, 271, 166/272, 303

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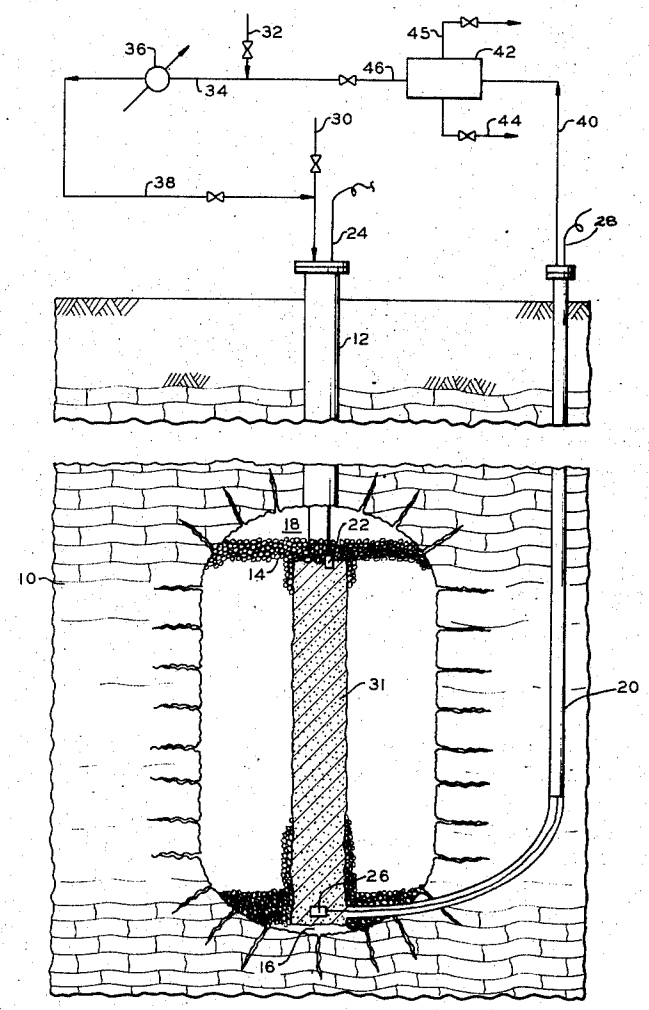
Primary Examiner—Stephen J. Novosad

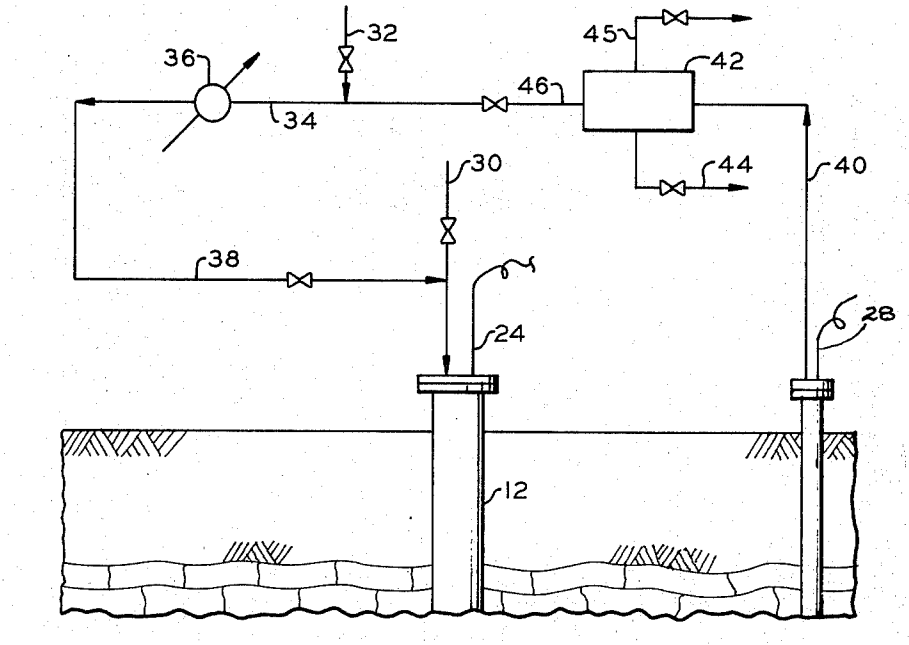
Attorney—Young and Quigg

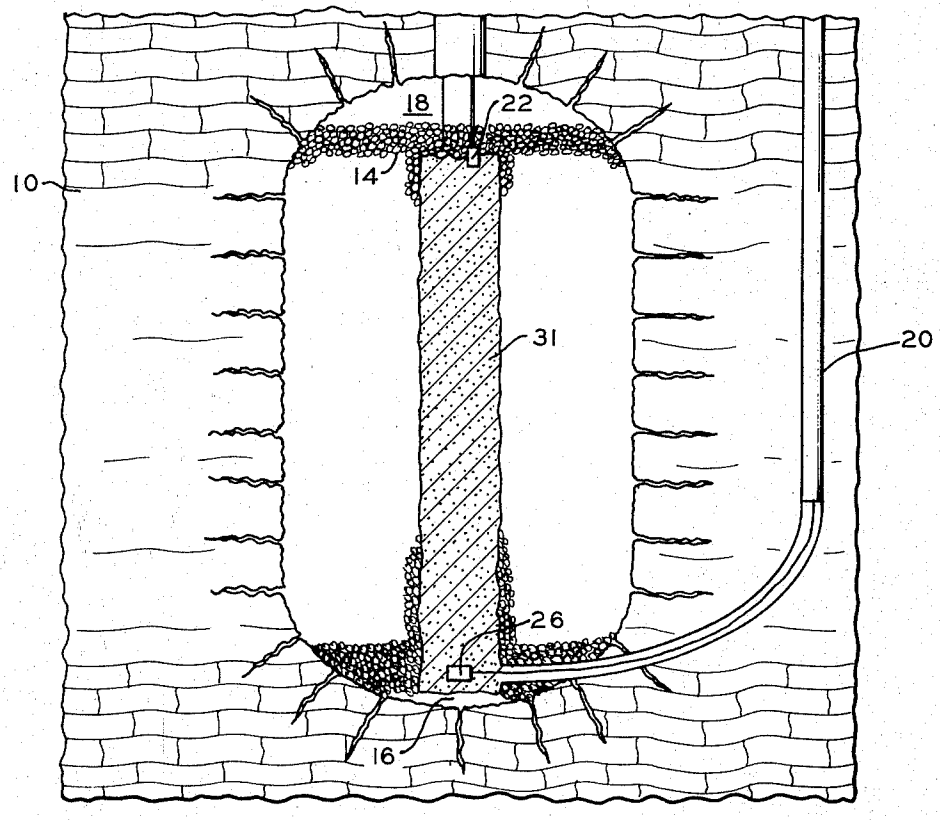
[57] **ABSTRACT**

Oil-yielding rubble in a nuclear chimney is preconditioned for retorting by forming a generally vertical column of coke-like rubble therein. The mass of rubble in the chimney is then retorted by introducing a hot heating medium. Hydrocarbons educed from the rubble can be recovered in any suitable manner.

9 Claims, 1 Drawing Figure







INVENTOR.
H.W. PARKER

BY

Young and Quigg

ATTORNEYS

RETORTING OF NUCLEAR CHIMNEYS

This invention relates to retorting of nuclear chimneys formed in oil-yielding strata.

The in situ retorting of oil-yielding strata, such as oil shale, coal deposits, etc., has been proposed. For example, oil can be 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. Various methods of fracturing, such as the use of explosives or hydraulic fracturing, are known in the art. The use of nuclear devices to fracture shale is disclosed by M. A. Lekas 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*, Volume 60, No. 3, July 1965, pages 7–+. The nuclear chimney thus formed in an oil shale stratum is a highly permeable mass of broken and displaced shale ranging in size from fine grains to blocks 2 to 3 feet across.

A serious problem in the in situ retorting of fractured oil-yielding strata is compaction of the strata during retorting. In oil shale, as the kerogen is decomposed or is converted to oil, there is obtained a material which tends to settle during retorting and fill the voids in the bed of rubble. This causes a loss in permeability, causing at least a reduction in gas flow, and can cause complete stoppage of the retorting process. During the retorting of kerogen-rich, commercially attractive shales, the shale itself can become plastic-like and flow into the void spaces in the rubble bed under the weight of the rubble bed itself. Similar decomposition and compaction can occur in coal.

The present invention solves the above problem by preconditioning the bed of rubble in the nuclear chimney to avoid loss of permeability during the retorting.

Accordingly, an object of the invention is to provide an improved process for retorting oil-yielding rubble in a nuclear chimney. Another object of the invention is to provide a process for the in situ retorting of oil-yielding rubble in nuclear chimneys without substantial loss of permeability during said retorting. Another object of the invention is to precondition the rubble in a nuclear chimney by forming therein a relatively narrow, generally vertical column of permeable, at least partially retorted, coke-like rubble prior to initiating the principal retorting operation. Other aspects, objects, and advantages of the invention will be apparent to those skilled in the art in view of this disclosure.

Thus, in accordance with the invention, there is provided a method for producing hydrocarbons from an oil-yielding stratum in situ, said stratum having formed therein a nuclear chimney containing a mass of rubble, which method comprises: forming in said mass of rubble a generally vertical column of permeable, at least partially retorted, coke-like rubble; thereafter, retorting said mass of rubble by passing a heating medium therethrough in an amount and for a period of time sufficient to heat said mass of rubble and educe hydrocarbons therefrom; and recovering said educed hydrocarbons from said chimney.

In one method of practicing the invention, a liquid electrolyte, such as a brine, is flowed down through the rubble in a nuclear chimney to form a relatively narrow, generally vertical path of increased electrical conductivity. Next, a high electrical potential is applied between a pair of electrodes positioned in the upper and lower end portions of the path of brine flow. Electric current is supplied for a period of time sufficient to evaporate the brine, heat the rubble to release hydrocarbons therefrom, and form a generally vertical column of permeable, at least partially retorted, coke-like material. The chimney is then retorted by introducing a hot gas or vapor into the upper part of the chimney to educe oil and other hydrocarbons from the rubble contained therein. The educed liquid and vaporous hydrocarbons flow downwardly through the rubble and are produced from a well bore communicating with the bottom of the chimney.

Any suitable electrolyte can be used in the practice of the invention. Suitable electrolytes include aqueous solutions of salts, such as salts of the alkali metals, or mixture of such salts. Representative examples of these salts include sodium chloride, sodium sulfate, sodium carbonate, calcium chloride, potassium chloride, and others. It will be understood by those skilled in the art that the addition of various electrolytes to water is a variable which can be controlled. The amount of such a salt which can be dissolved in the water is a function of the temperature of the solution, and the water can be heated prior to preparing the electrolyte in order to as nearly as possible saturate the water with the particular salt being used. The invention is not limited to the use of any particular electrolyte, but sodium chloride is generally preferred for preparing the electrolyte since it is readily available. Said electrolytes are used to increase the conductivity of the rubble and to insure that the current follows a relatively narrow path and thus forms a relatively narrow column of increased conductivity.

The application of an electric potential to earth strata is known in the art as electrolinking and electrocarbonization. The concept is disclosed in U.S. Pat. No. 2,795,279, issued June 11, 1957, in the name of E. Sarapuu. Electrolinking is a short duration electrical treatment utilizing the conductivity of a carbonaceous fuel bed, and comprising passing an electric current through a hydrocarbon-containing formation with sufficient current density to create a low resistance path through the formation. Electrocarbonization is an extended form of electrolinking and can be accomplished only after the electrolinking has formed a carbon or carbon-like linkage from which carbonization can proceed. It is necessary that the electric current passing through the fuel strata be of sufficient voltage and amperage to overcome whatever resistance there may be and raise the temperature of the stratum to the point of decomposition of the hydrocarbons therein to form a coke or coke-like carbon channel or zone. This requires the application of predetermined amounts of electrical power in order that whenever the electrical power is applied, heating will start the decomposition of hydrocarbons in the fuel stratum. As the column of permeable, at least partially retorted coke-like rubble is formed and grows, the voltage will drop due to the lessened resistance and the current density will increase. The amount of electric power required in the practice of the invention will depend upon the nature of the formation, the spacing of the electrodes, and other fac-

tors. Thus, the invention is not limited to using any particular voltage and/or current amperage. All that is required is that sufficient power be used to overcome the resistance of the rubble and raise the temperature thereof in the path between the electrodes sufficient to form a column of the permeable, at least partially retorted rubble. While it is not intended to so limit the invention, the amount of electric power used will, generally speaking, usually be within the range of from 200 to 2,000 volts and about 100 to about 2,000 amperes.

Any suitable heating medium, such as hot hydrocarbons, hot combustion gases, superheated steam, or other essentially oxygen-free, nonoxidizing gas, can be used in the retorting step of the invention which is carried out after the electrolinking and electrocarbonization step. High heat capacity vaporous hydrocarbons containing from two to six carbon atoms per molecule and having a heat capacity of at least about 20 Btu's per pound mol are one presently preferred heating medium. However, it is within the scope of the invention to use hydrocarbons containing more or less carbon atoms. For example, the shale gases released from the shale during the retorting are a presently preferred heating medium. These gases can be recovered and recycled as described hereinafter. Said heating medium is introduced into the preconditioned nuclear chimney at a temperature, in an amount, and for a period of time sufficient to heat and educe hydrocarbons from the rubble contained therein. It is usually desired to heat the rubble in the chimney to a temperature within the range of about 500° to about 1,200° F. When retorting oil shale, it is preferred not to exceed a temperature of about 1,500° F. so as to avoid possibly reducing the compressive strength of the retorted shale and thus increase the tendency of same to compact.

The drawing is a diagrammatic illustration of a nuclear chimney, partly in cross section, and illustrating various embodiments of the invention.

Referring now to the drawing, the top of a nuclear chimney, resulting from the detonation of a nuclear device in a shale formation **10**, is penetrated by a bore hole **12**. The shale rubble **14** extends from a solidified melt zone **16** at the bottom of the mass, substantially to the top of the rubble mass, leaving a void space **18** which is formed by settling of the rubble. A bore hole **20** extends through the shale formation adjacent the nuclear chimney and into communication with the lower portion of rubble mass **14**. A first electrode **22** is disposed in the upper portion of said rubble mass, preferably near the center thereof, and is connected to a source of power (not shown) at the surface by means of insulated conductor **24** which extends up through said first bore hole **12**. A second electrode **26** is positioned in the lower portion of said rubble mass **14**, preferably in the central portion thereof and generally below said first electrode **22**, and is connected to said source of power by means of insulated conductor **28** which extends up through said second bore hole.

The surface equipment includes a conduit **30** for introducing a brine solution through first bore hole **12** into the mass of rubble **14**. Conduit **32** is connected to a source of gaseous heating medium, not shown. Heating medium from conduit **32** can be passed via conduit **34**, through heater **36**, and then through conduit **38** for introduction into the mass of rubble via conduit **30** and bore hole **12** as described further hereinafter. Educed liquid and vaporous hydrocarbons can be recovered from the nuclear chimney through second bore hole **20** by means of a pump, not shown, and conduit **40**.

In the practice of one method of the invention, an electrolyte, such as a saturated sodium chloride solution, is introduced via conduit **30** which extends down through first bore hole **12** to the top of the rubble mass **14** in the nuclear chimney. Said electrolyte drains down through the rubble mass in a relatively narrow, generally vertical column. When the electrolyte reaches the bottom of the chimney, a high electrical potential is applied between electrodes **22** and **26**. Electrolyte flow is usually terminated prior to application of the electric potential. As the brine evaporates due to the heat generated by the electric current, electrolinking occurs and a conducting path of permeable, at least partially retorted, coke-like rubble is formed by electrocarbonization. Continued application of the high electric potential heats the rubble further and enlarges said conducting path. The heat produced causes hydrocarbons to be released from the shale, leaving said generally vertical column of permeable, at least partially retorted, coke-like rubble. Said column does not compact because the adjacent unheated shale will support same due to bridging. The electric potential is preferably applied in an amount and for a period of time sufficient to establish a column **31** having a diameter or cross section of about 5 to 15 feet, as shown in the drawing. However, columns having a diameter outside said range, e.g., up to about one-fourth the diameter or cross section of the chimney can be used in the practice of the invention.

After said column **31** has been established, a heating medium, such as high heat capacity hydrocarbon gases, is passed from conduit **32**, through conduit **34**, heater **36**, conduit **38**, and into conduit **30** for introduction into rubble mass **14**, preferably at the top of said column **31**. The major portion of said hot gases will flow downwardly through the mass of rubble **14** around said central column **31** because, at least initially, the permeability of said mass **14** is at least as great as, or greater, than the permeability of column **31**. However, some of said gases will flow down through said column **31** and flow outwardly therefrom into said rubble mass **14**. When permeability of the rubble mass **14** is decreased during the retorting, more of the hot gases introduced via conduit **30** will flow down through column **31** and flow outwardly therefrom into said rubble mass **14**, thus maintaining a flow of hot gases into and through the nuclear chimney at all times during the retorting process.

The temperature of the introduced heating gases is high enough to produce the desired kerogen decomposition but low enough to minimize endothermal decomposition and fusion of the carbonate minerals, etc., in the shale. Generally speaking, gas temperatures within the range of about 500° to about 1,200° F., preferably from 750° to 950° F., will produce the desired kerogen decomposition and good oil yield. The rate and pressure at which the hot gases are injected into the mass of rubble **14** will be dependent upon the composition of the oil shale, the composition of the hot gases, and the particle size distribution of the mass of

rubble. Generally speaking, the pressure of the introduced gases will be above 15 psig.

As the kerogen is decomposed, educed hydrocarbons (liquid and vaporous) flow by gravity drainage down through rubble mass **14**, collect in the bottom of the mass above solid melt zone **16**, and are recovered through second bore hole **20** by means of a pump (not shown) which is connected to conduit **40**.

The product hydrocarbons are passed from conduit **40** into separation means **42** which can comprise any suitable means for effecting the desired separation, e.g., between liquid and gaseous hydrocarbons, or between water and hydrocarbons as when steam is used as the heating medium. Shale oil is recovered from separating means **42** via conduit **44**. When the hot gases being used in the practice of the invention are hot hydrocarbons and it is desired to recycle same, the gases from separating means **42** are passed via conduit **46** into conduit **34** for introduction into the nuclear chimney as previously described. When the hot gases being used for retorting are hot combustion gases or some other nonhydrocarbon gas, they can be vented from separating means **42** via conduit **45**, if recycle thereof is not desired.

As mentioned above, high heat capacity hydrocarbon gases, and particularly shale gases produced from the shale, are the preferred retorting gases for use in the practice of the invention. Not only do said high heat capacity gases reduce the volume of gas necessary to heat a given volume of oil shale, but they also act as solvents as they travel downwardly through the mass of shale rubble and facilitate oil production by this action. Additionally, olefins in the hydrocarbon gases, such as ethylene and propylene, will react with the kerogen decomposition products and enhance the quality of the oil recovered.

While the invention has been described and illustrated as employing one bore hole **12** communicating centrally with the upper portion of the nuclear chimney, and establishing one vertical column **31** comprising a permeable, at least partially retorted, coke-like material, it is within the scope of the invention to provide more than one bore hole communicating with the top of the nuclear chimney. It is also within the scope of the invention to establish more than one generally vertical column of said coke-like material in the nuclear chimney, and thus further aid the maintenance of permeability in the rubble mass and/or the flow of the hot gases into and through said mass of rubble during the retorting process.

While certain embodiments of the invention have been described for illustrative purposes, the invention is not limited thereto. Various other modifications of the invention will be apparent to those skilled in the art in view of this disclosure. Such modifications are within the spirit and scope of the disclosure.

I claim:

1. A method for producing hydrocarbons from an oil-yielding stratum in situ, said stratum having formed therein a nuclear chimney containing a mass of rubble, which method comprises: forming in said mass of rubble a generally vertical column of permeable, at least partially retorted, coke-like rubble by flowing a liquid electrolyte downwardly through said mass of rubble in a relatively narrow, generally vertical path; applying an electric potential across said path in an amount and for a period of time sufficient to form said column; thereafter, retorting said mass of rubble by passing a heating medium therethrough in an amount and for a period of time sufficient to heat said mass of rubble and educe hydrocarbons therefrom; and recovering said educed hydrocarbons from said chimney.

2. A method according to claim **1** wherein said stratum is an oil shale formation.

3. A method according to claim **2** wherein said heating medium comprises a hot hydrocarbon.

4. A method according to claim **2** wherein said heating medium is steam.

5. A method according to claim **1**, said method comprising, in combination, the steps of:

a. providing a first bore hole communicating with the upper portion of said chimney;
b. providing a second bore hole communicating with the lower portion of said chimney;
c. providing a first electrode disposed in the upper portion of said rubble;
d. providing a second electrode disposed in the lower portion of said rubble;
e. flowing a liquid electrolyte downwardly through said rubble in a relatively narrow, generally vertical path;
f. thereafter, passing an electric current between said electrodes and through the rubble therebetween so as to vaporize said electrolyte, heat said rubble and release hydrocarbons therefrom, and form a relatively narrow, generally vertical column of permeable, at least partially retorted, coke-like rubble between said electrodes;
g. terminating the flow of electric current between said electrodes;
h. thereafter, retorting said mass of rubble by passing a heating medium therethrough in an amount and for a period of time sufficient to heat said mass of rubble and educe hydrocarbons from said mass of rubble; and
i. recovering said educed and released hydrocarbons from said chimney.

6. A method according to claim **5** wherein said stratum is an oil shale formation.

7. A method according to claim **6** wherein said heating medium comprises hot shale gases recovered from the retorting of said mass of rubble.

8. A method according to claim **6** wherein said heating medium comprises superheated steam.

9. A method according to claim **6** wherein said heating medium comprises a hot hydrocarbon.

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