FIP7912 XR 3,331,438

July 18, 1967 M. L. SLUSSER 3,331,438

METHOD FOR IN SITU RETORTING OF OIL SHALE EMPLOYING ARTIFICIAL BARRIERS

Filed Sept. 30, 1964

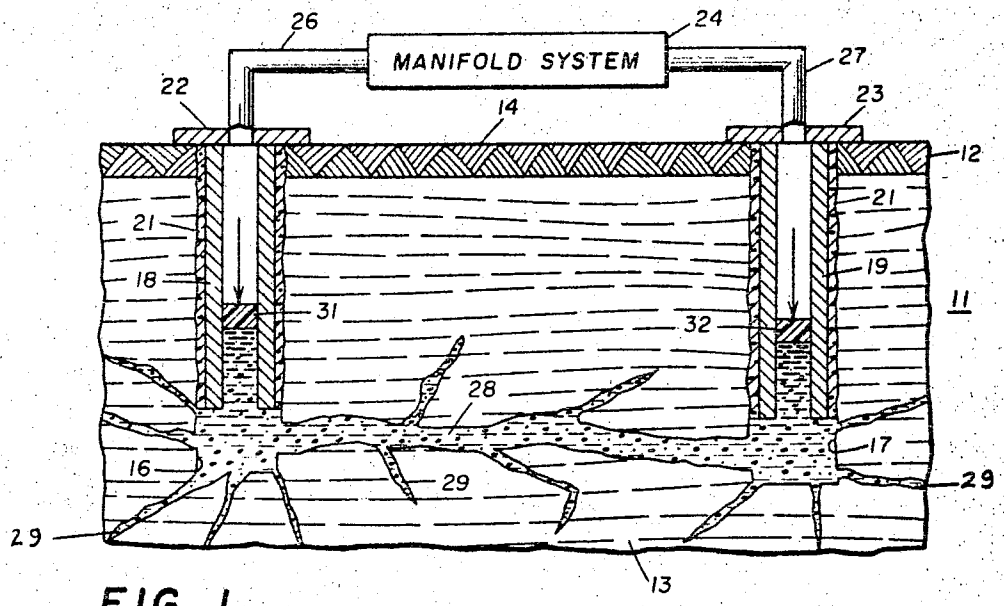


FIG. 1

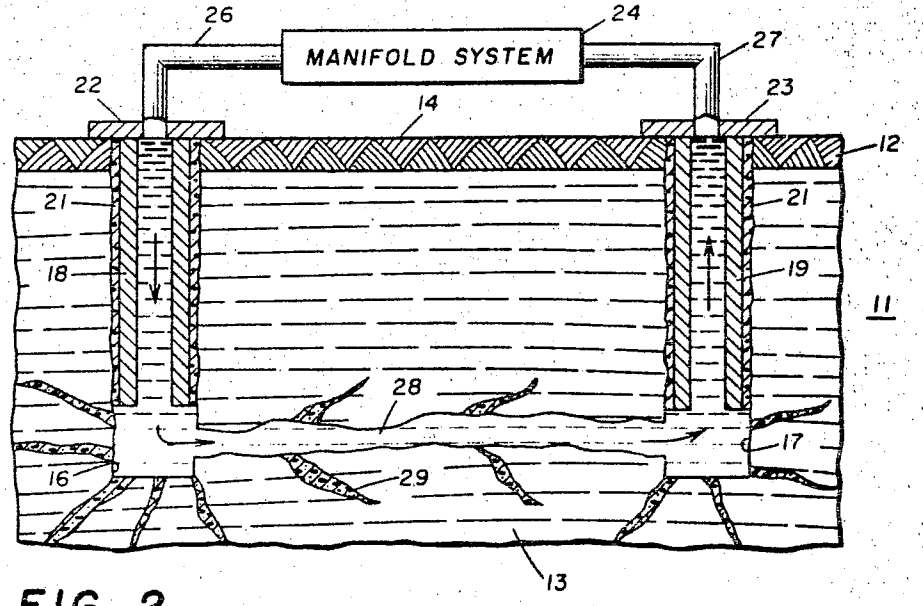


FIG. 2

MARION L. SLUSSER
INVENTOR.

BY Emil J. Bednar

ATTORNEY

United States Patent Office 3,331,438 Patented July 18, 1967

3,331,438

METHOD FOR IN SITU RETORTING OF OIL SHALE EMPLOYING ARTIFICIAL BARRIERS

Marion L. Slusser, Arlington, Tex., assignor to Mobil Oil Corporation, a corporation of New York

Filed Sept. 30, 1964, Ser. No. 400,413
10 Claims. (Cl. 166—29)

ABSTRACT OF THE DISCLOSURE

This specification describes: A method for the in situ retorting of a subterranean deposit of oil shale to recover hydrocarbons, and in which method, a barrier to fluid flows is placed about that portion of the oil shale to be retorted. More particularly, via spaced wells, a fluid with a material to seal openings in the deposit is injected. The material may be hydraulic cement. Then, a fluid for temporarily sealing the openings is introduced into that portion of the deposit to be retorted, via the wells. This fluid may be a thixotropic clay in water, e.g., a drilling mud. Thereafter, the openings in that portion of the deposit to be retorted are filled, via the wells, with a fluid capable of excluding the priorly injected fluids. This last-injected fluid may be water or air. Lastly, in situ retorting is carried out in the mentioned portion of the deposit wherein fluid flows are contained by the established barrier, and hydrocarbons are recovered from these fluid flows.

This invention relates to a method for the situ retorting of oil shale to produce hydrocarbons which are commonly termed shale oil.

Distributed throughout the world are massive formations of oil shale providing a tremendous reserve of the organic material "kerogen." The magnitude of these formations is clearly displayed in some areas by oil shale outcrops hundreds of feet in vertical extent. The organic material kerogen is convertible to shale oil by retorting at temperatures usually in excess of 700° F. The produced shale oil includes liquid and gaseous hydrocarbonous fractions. It has been proposed to retort in situ portions of the oil shale formations as one means for producing shale oil. For this purpose, spaced apart wells penetrating the portion to be retorted are provided. Through such wells is the desired retorting result effected principally by the controlled flow of fluids through the oil shale.

In situ retorting may be obtained by injecting between the spaced wells fluids which apply to the oil shale by suitable mechanisms adequate heat for converting the kerogen into shale oil. The heat providing fluids may be combustible gases, combustion-supporting gases, and preheated gases, and mixtures thereof.

For the most part, these retorting methods, for effective operation, depend upon controllably flowing the heating fluids through the oil shale and moving the resulting shale oil to a point convenient for its recovery. It is this control of fluid movement in the in situ retorting of shale oil which provides severe problems to a successful employment of such methods. The problems reside in the oil shale formations being traversed by a network of fractures, both natural and artificial, which fractures are in fluid communication with one another at least to some degree. All fluid flows must take place through these fractures in the oil shale as it is retorted. Thus, it is apparent that the control of fluid flows through the fractures between spaced apart points in the oil shale being retorted is very difficult. Further, the loss of fluids via these fractures to areas of the oil shale outside that portion being retorted increases in magnitude with every pressure increase in the fluids moving between the points. For example, a pair of wells spaced apart about 15 feet were provided in a massive oil shale formation in communication with fractures, both natural and artificial. Approximately 9000 s.c.f.h. of air was injected into one well and 85 volume percent of the air was recovered at a 7 p.s.i.g. back pressure at the other well. Increasing the back pressure to 37 p.s.i.g. at the air-recovery well resulted in no air recovery as substantially all the injected air was lost to the surrounding oil shale formation through interconnecting fractures.

It is obvious from the foregoing that the majority of the fluids flowing through the oil shale between injection and production wells must be recoverable; otherwise, the shale oil produced by retorting cannot be recovered in acceptable quantities. This is especially important where the wells through which fluids in the oil shale are recovered are necessarily operated at increased pressures. In one aspect, operation of these wells at an increased pressure becomes necessary to maintain a desired fluid injectivity into the oil shale for proper retorting conditions. In another aspect, it becomes necessary to operate spaced apart injection and production wells at increased pressures so that the recovery or production well serves as a pressure sink to facilitate the recovery of the produced shale oil.

This invention is directed, in an in situ method for retorting oil shale, toward the placing of a barrier to fluid flows about that portion of oil shale to be retorted. The placing of this barrier is obtained by procedural steps which are uncomplicated in nature and employ readily obtainable materials. Furthermore, these procedural steps are compatible with the procedures, materials, and operational structures employed with the known in situ methods for retorting oil shale.

It is therefore an object of the present invention to provide an insitu retorting method for recovering hydrocarbons from oil shale which overcomes the stated problems. Another object is to recover a major portion of the fluids flowing between an injection and a production well during the retorting of oil shale, especially at superatmospheric pressure levels. Yet another object is to prevent the undesired loss of fluids flowing between injection and producing wells, especially at superatmospheric pressure levels, exteriorly of the portion of the oil shale being retorted. A further object of the present invention is the limiting of fluid flows in accordance with the preceding objects by employing the injection and production wells and other means normally used in conventional in situ retorting procedures for producing shale oil. These and other objects will be apparent to those skilled in the art when read in conjunction with the accompanying detailed description, the appended claims, and the attached drawings.

In FIGURES 1 and 2 of the drawings, there is illustrated, in a vertical section taken through the earth, a portion of an oil shale formation provided with suitable structures by which the method of this invention may be practiced.

Referring particularly to FIGURES 1 and 2 of the drawings, a detailed description of a suitable structure in which to practice the invention will be first given. An oil shale formation, designated by the numeral **11**, may include a superimposed overburden **12** on a block of oil shale **13** to be retorted. Fluid-transferring means are provided for conveying fluids between the earth's surface **14** and the fractures or openings in the interior of the oil shale **13**. Such means may take the form of wells **16** and **17** spaced apart a suitable distance within the oil shale **13**, and each extending to a suitable depth into communication with openings in and beyond the portion of the oil shale **13** to be retorted. Extending downwardly from the earth's surface **14** to near the full depth of the wells **16** and **17** are conduits **18** and **19**, respectively. The conduits

18 and 19 are secured within the respective wells 16 and 17 by surrounding cement 21 or other suitable sealing material. Connected to the upper extremities of the conduits 18 and 19 are wellheads 22 and 23, respectively. A manifold system 24 may be disposed at the earth's surface to provide for the flow of fluids between the earth's surface 14 and the openings in the interior of the oil shale 13. The manifold system 24 may be of conventional design and its particular form is not important to the present invention. The wellheads 22 and 23 are interconnected by surface conduits 26 and 27, respectively, to the manifold system 24.

The oil shale 13 contains openings of varied nature throughout its extent, including that portion of the oil shale 13 residing between wells 16 and 17 which is desired to be retorted. These openings generally are a network of interconnecting fractures, natural or artificial, to provide the principal fluid-carrying channels in the oil shale 13. A channel 28, formed of some of these fractures, provides the most direct fluid communication between the wells 16 and 17. Also, the wells 16 and 17 and the channel 28 are in fluid communication with other openings extending outwardly into the surrounding oil shale formation 11. More particularly, such openings are those in which occurs the loss of the flowing fluids through the channel 28 in the oil shale 13 at increased pressure above atmospheric levels between the wells 16 and 17. For purposes of description, such openings are referred to and designated as thief openings 29, although the oil shale 13 is shown without a subtended stratum, it will be apparent that the oil shale 13 obviously rests upon some geological support which need not be shown or described.

Usually, a fluid can be circulated without any great loss from the manifold system 24 through the well 16 through the channel 28 to the well 17 when operated at low back pressures. However, increasing the back pressure in the well 17 obviously causes increased amounts of the injected fluid to be unrecoverably lost from the channel 28 and the wells 16 and 17 into the thief openings 29.

In the illustrative embodiment of the method of this invention now to be described, the thief openings 29 will be sealed to fluid flows to prevent the loss of fluids passing through the channel 28 in the oil shale 13 between the wells 16 and 17 while the channel 28 and the wells 16 and 17 will remain open to fluid flows. A first step of this method is the injecting, into openings of the oil shale 13, of a fluid capable of subsequently producing a material sealing such openings to fluid flow. Examples of such fluid are mixtures with water of hydraulic cement and of thixotropic clay, and mixtures thereof. Also, fluids convertible to plastics, and precipitatable metal salts can be used. Other fluids can be used as will be apparent to those skilled in the art. The amount of pressure differential to be sealed against and the in situ retorting conditions are substantially determinative of the active ingredient composition of the injecting fluid. A gel-type clay and neat cement mixture with water has been found to be of utility for most purposes since the amount of cement can be varied to produce seals of various strengths.

More particularly, the fluid is injected into the wells 16 and 17 via the manifold system 24 in suitable amounts filling the channel 28 and the thief openings 29 at least in part. Preferably, sufficient of the fluid for sealing the thief openings 29 is injected until the injection pressure is about that of the maximum operating pressure of the oil shale retorting procedure. As is obvious, injection of several batches of this fluid capable of providing a material sealing openings in the oil shale 13 may be necessary to fill the thief openings 29 to a desired extent. An interval is allowed before each subsequent injection to permit the priorly injected fluid to set. Also, in some cases it is found to be of particular advantage to use increasing concentrations of the active sealing ingredients during injection of the fluid.

Any means may be used for the injection of such fluid. Preferably, cementing plugs 31 and 32 are disposed in the wells 16 and 17, respectively. The plugs 31 and 32 are then driven downwardly with a pressurizing fluid applied from the manifold system 24 for displacing the first-mentioned fluid from the conduits 18 and 19 in the wells 16 and 17 in substantial quantities and pressures into the thief openings 29. A suitable driving fluid for driving the cementing plugs 31 and 32 is water. However, other fluids may be used. If desired, the cementing plugs 31 and 32 may be moved downwardly in the wells concurrently or separately while holding substantially the same pressure above each of such plugs. This insures that substantially the same injection pressure is maintained in each of the wells 16 and 17. After the fluid has been displaced into the thief openings 29 and has undergone a desired conversion to the sealing material, the cementing plugs 31 and 32 may be removed from the conduits 18 and 19, respectively, by any suitable means.

Another step is filling the channel 28 with a fluid capable of excluding the first injected fluid from such opening. Preferably, such fluid used for filling the channel 28 is one incapable of subsequently producing a material permanently sealing openings in the oil shale 13. For example, such fluid may be water, air, gel-type clays and water, and mixtures thereof. Preferably, this step of filling the channel 28 is delayed until the first injected fluid begins to form the material sealing the thief openings 29. Thereafter, the fluid capable of excluding the first injected fluid is moved through the wells 16 and 17 and the channel 28 from the manifold system 24. This step is clearly displayed in FIGURE 2. This excluding fluid may be circulated at any suitable pressure from the manifold system 24 through the surface conduit 26, the well 16, through the channel 28, into the well 17, and thence upwardly through the surface conduit 27 to return the first injected fluid to the manifold system 24. Preferably, the circulating pressure is not greater than the injection pressure at which the first injected fluid was introduced into the openings in the oil shale 13. Thus, sealing material is not displaced from the thief openings 29 by the excluding fluid which preferentially will flow through the channel 28 between the wells 16 and 17. However, where there is a tendency to displace the sealing material from the thief openings 29 it is preferred to use a mixture of water and a thixotropic clay to form a gel as the excluding fluid to maintain seals in the thief openings 29. The thief openings 29 in any event remain sealed with a sealing material, as can be seen in FIGURE 2.

Alternatively, the excluding fluid may be moved from the manifold system 24 simultaneously through the surface conduits 26 and 27 to displace the first injected fluid from the wells 16 and 17 and the channel 28 into the thief openings 29. Although this practice will fill the channel 28 with the fluid for excluding the first injected fluid, there is some danger of reopening the thief openings 29 to fluid loss. On such happening, it may be necessary to repeat the previous step if the loss of fluids into the thief openings 29 is too great. If desired, the excluding fluid here also may be a mixture of water and thixotropic clay to form a gel for reasons previously discussed.

If desired, the fluid for filling the channel 28 and excluding the first injected fluid may be a slug of water followed by air or the combustion-supporting gas to be used in the in situ combustion procedure. Alternatively, the combustion-supporting gas may be passed through the channel 28 to clear it of the first injected fluid or to establish fluid communication therethrough between the wells 16 and 17. This latter step is also one of the initial steps in known procedures for carrying out in situ retorting. Thereafter, the remaining steps for carrying out the desired in situ retorting procedure may be practiced. Such steps may include igniting the combustibles in the oil shale 13, in situ combustion of the oil shale adjacent the channel 28, and recovering the resulting shale oil.

Returning now to FIGURE 1, a second embodiment of the method of the present invention will be described. The structural arrangement previously described with respect to the drawings may be utilized. In this embodiment a fluid capable of subsequently producing a material sealing openings in the oil shale to fluid flows is injected into the thief openings **29**. Also injected is a fluid capable of subsequently producing a material temporarily sealing openings in the oil shale **13** to fluid flows during the time the first-mentioned fluid produces said sealing material. This fluid is injected through the channel **28** in that portion of the oil shale **13** residing between the wells **16** and **17** which portion is to be retorted. Thereafter, the channel **28** is filled with a fluid capable of excluding therefrom the fluid for producing a sealing material in the thief openings **29**, and lastly, follows the carrying out of the in situ retorting procedure in that portion of the oil shale **13** between the wells **16** and **17**.

As one step of this embodiment, a fluid capable of subsequently producing a material temporarily sealing openings in the oil shale **13** to fluid flows is injected from the earth's surface through the channel **28**. Any fluid capable of producing this desired result may be used. For example, a fluid containing a mixture of water with a thixotropic hydrated clay has been found to be of utility. Drilling muds formed of bentonite and water are especially suitable for use. Preferably, this fluid is injected through the channel **28** in the same manner as the first injected fluid, such as hydraulic cement, was introduced into the oil shale **13** in the first-described embodiment. Preferably, this fluid is introduced under pressure conditions similar to those used for carrying out the in situ retorting of the oil shale.

As another step, a fluid capable of subsequently producing a material sealing openings in the oil shale **13** to fluid flows is injected into the thief openings **29** communicating with the wells **16** and **17**. This fluid may be the same as that described for the first injected fluid of the first embodiment. A fluid found to be of utility consists of a mixture with water of substances selected from the group consisting of thixotropic hydrated clay, hydraulic cement, and mixtures thereof. Preferably, such fluid is introduced under the same conditions as that fluid filling the channel **28**. This arrangement reduces the amount of the last injected fluid that enters the channel **28**. This fluid can be injected through the wells **16** and **17** into the interconnected thief openings **29** by any suitable means, such as was described for the first injected fluid in the first embodiment. Preferably, the wells **16** and **17** are filled with such fluid and the fluid displaced from these wells by cementing plugs **31** and **32** driven downwardly by a pressured fluid applied from the manifold system **24**.

Another step is the filling of the channel **28** with a fluid capable of excluding fluids producing a sealing material which includes both the first and second injected fluids. Any suitable fluid may be used. For example, water is of utility. For this purpose, the cementing plugs **31** and **32** are removed from the conduits **18** and **19**, respectively, by any suitable means. Thereafter, such excluding fluid is passed through the wells **16** and **17** from the manifold system **24** to displace the resident fluids from the wells **16** and **17** and channel **28**. Preferably, this fluid is circulated in the same manner as was described in the second step of the first embodiment. Preferably, the fluid is introduced to fill the channel **28** at somewhat less pressure than the injection pressures of either of the other injected fluids. Thus, the thief openings **29** in communication with the channel **28** and the wells **16** and **17** remain filled with a sealing material of one nature or the other. However, the channel **28** is open to fluid flow between the wells **16** and **17**. If desired, the last injected fluid may be water, air, and combustion-supporting gas, and mixtures thereof.

In either of the described embodiments of this invention it will be apparent that the fluid producing the relatively permanent sealing material may be displaced into an ultimate position by a fluid producing a temporary sealing material or one incapable of producing a sealing material, or a combination of both. In another aspect, a material producing a temporary sealing material may be used to fill the channel **28** in that portion of the oil shale to be retorted so as to block entry of the fluid producing the relatively permanent seal which is introduced into the openings in that portion of the oil shale not to be retorted.

Although the present invention has been described relative to only two spaced wells, it will be obvious to those skilled in the art that it may be applied to various patterns of wells to provide circumferential seals about distinct portions of the oil shale **13** to be retorted. Thus, by this means, seals capable of preventing losses of the operational fluids at the pressures required for in situ retorting of the oil shale are formed by application of the described steps.

Of particular advantage in this invention is the use of fluids forming sealing materials in which water of hydration is essential in the forming of the sealing material. In such instances, as the in situ retorting produces elevated temperatures at such seals, the water of hydration is removed and the seals will fail. Inasmuch as such sealing material as hydraulic cement has a heat conductive coefficient much like oil shale, a uniform advance of the retorting temperatures through the oil shale will produce uniform extensions of the retorting procedure from one portion of the oil shale to another by rupturing the surrounding seals or barriers. Thus, by application of the described steps to adjacent portions of the oil shale, successive portions of the oil shale may be retorted with continuous control of the fluid flows by the limitations imposed through seals placed in the oil shale beyond each portion being retorted.

Although the present method has been described specifically applied to oil shale formations for illustrative purposes, it can be used in other types of earthen deposits containing hydrocarbon materials through which fluids must flow in openings such as fractures and the like during in situ retorting procedures. One example is the Athabasca tar sands.

From the foregoing it will be apparent that there has been provided a method well suited for satisfying all of the stated objects of this invention. Various changes and alterations may be made in the steps described for this method by those skilled in the art without departing from the spirit of the invention. It is intended that such changes and alterations under these conditions are to be included within the scope of the following appended claims.

I claim:

1. In an in situ retorting method for recovering hydrocarbons from the subterranean deposit through well means in fluid communication at spaced locations with openings in and beyond that portion of the deposit to be retorted, the improvement comprising the steps of:

(a) injecting from the earth's surface via the well means into openings in the deposit a fluid containing hydraulic cement and water in amounts sufficient to subsequently produce a material sealing openings containing the fluid to fluid flows,

(b) injecting water from the earth's surface via the well means into the openings in that portion of the deposit to be retorted to exclude the first-mentioned fluid therefrom, and

(c) carrying out in situ retorting with fluid flows limited to the portion of the deposit to be retorted and recovering the resulting hydrocarbons from these fluid flows.

2. In the method of claim **1**, the improvement in step (b) of injecting air from the earth's surface via the well

means immediately following the injection of water and into the same openings in the deposit.

3. In the method of claim 2, the improvement of varying the amounts of hydraulic cement and water contained in the injected fluid during the carrying out of step (a).

4. In an in situ retorting method for recovering hydrocarbons from a subterranean deposit through well means in fluid communication at spaced locations with openings in and beyond that portion of the deposit to be retorted, the improvement comprising the steps of:

(a) injecting from the earth's surface via the well means a fluid capable of subsequently producing a material sealing openings containing the fluid to fluid flows into openings in the deposit other than in that portion to be retorted and a fluid capable of subsequently producing a material temporarily sealing openings containing said fluid to fluid flows during the time the first-mentioned fluid produces said material into openings in that portion of the deposit to be retorted,

(b) filling via the well means the openings in that portion of the deposit to be retorted with a fluid capable of excluding the priorly injected fluids from such openings, and

(c) carrying out in situ retorting with fluid flows limited to the portion of the deposit to be retorted and recovering the resulting hydrocarbons from these fluid flows.

5. In an in situ retorting method for recovering hydrocarbons from a subterranean deposit through well means in fluid communication at spaced locations with openings in and beyond that portion of the deposit to be retorted, the improvement comprising the steps of:

(a) injecting from the earth's surface via the well means a fluid capable of subsequently producing a material temporarily sealing openings containing the fluid to fluid flows into openings in that portion of the deposit to be retorted,

(b) injecting from the earth's surface via the well means a fluid capable of subsequently producing a material sealing openings containing said fluid to fluid flows into openings in the deposit other than in that portion to be retorted,

(c) filling via the well means the openings in that portion of the deposit to be retorted with a fluid capable of excluding the priorly injected fluids from such openings, and

(d) carrying out in situ retorting with fluid flows limited to the portion of the deposit to be retorted and recovering the resulting hydrocarbons from these fluid flows.

6. In the method of claim 5, the improvement in step (a) wherein the fluid contains water and a thixotropic hydrated clay and in step (b) wherein the fluid contains water with a substance selected from the group consisting of thixotropic hydrated clay and hydraulic cement, and mixtures thereof.

7. In an in situ retorting method for recovering hydrocarbons from a subterranean deposit through well means in fluid communication at spaced locations with openings in and beyond that portion of the deposit to be retorted, the improvement comprising the steps of:

(a) injecting from the earth's surface via the well means a thixotropic hydrated clay and water mixture into openings in that portion of the deposit to be retorted,

(b) injecting from the earth's surface via the well means a mixture containing water with a substance selected from the group consisting of thixotropic hydrated clay and hydraulic cement, and mixtures thereof, into openings in the deposit other than in that portion to be retorted,

(c) filling via the well means the openings in that portion of the deposit to be retorted with water to exclude said mixtures producing sealing materials therefrom, and

(d) carrying out in situ retorting with fluid flows limited to the portion of the deposit to be retorted and recovering the resulting hydrocarbons from these fluid flows.

8. In an in situ retorting method for recovering hydrocarbons from a subterranean deposit through well means in fluid communication at spaced locations with openings in and beyond that portion of the deposit to be retorted, the improvement comprising the steps of:

(a) injecting at a first pressure, which pressure is about the greatest in magnitude to be employed during retorting, from the earth's surface via the well means a fluid capable of subsequently producing a material temporarily sealing openings containing the fluid to fluid flows into openings in that portion of the oil shale to be retorted,

(b) injecting at a second pressure not greater than the first pressure from the earth's surface via the well means a fluid capable of subsequently producing a material sealing openings containing said fluid to fluid flows into openings in the deposit other than in that portion to be retorted,

(c) filling via the well means at a pressure less than the second pressure the openings in that portion of the deposit to be retorted with a fluid capable of flowing to exclude the fluids producing a sealing material from such openings, and

(d) carrying out in situ retorting with fluid flows limited to the portion of the deposit to be retorted and recovering the resulting hydrocarbons from these fluid flows.

9. In the method of claim 8, the improvement in step (a) wherein the fluid contains water and a thixotropic clay and in step (b) wherein the fluid contains water with a substance selected from the group consisting of thixotropic clay and hydraulic cement, and mixtures thereof.

10. In the method of claim 8, the improvement in step (b) wherein the fluid contains water with a substance selected from the group consisting of thixotropic clay and hydraulic cement, and mixtures thereof, and the amounts of each such substance in the fluid is varied during injection into the openings in the deposit.

References Cited

UNITED STATES PATENTS

1,870,869	8/1932	Ranney et al.	299—2
2,365,039	12/1944	Andresen	166—29
2,973,813	3/1961	Parker	166—11
3,010,512	11/1961	Hurley et al.	166—11
3,055,423	9/1962	Parker	166—11
3,070,159	12/1962	Marx	166—25 X
3,190,355	6/1965	Clement	166—25 X
3,198,249	8/1965	Willman	166—25 X

CHARLES E. O'CONNELL, *Primary Examiner.*

ERNEST R. PURSER, STEPHEN J. NOVOSAD, *Examiners.*