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METHOD AND STRUCTURE FOR RETORTING OIL SHALE IN SITU BY CYCLING FLUID FLOWS

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FIG. 1

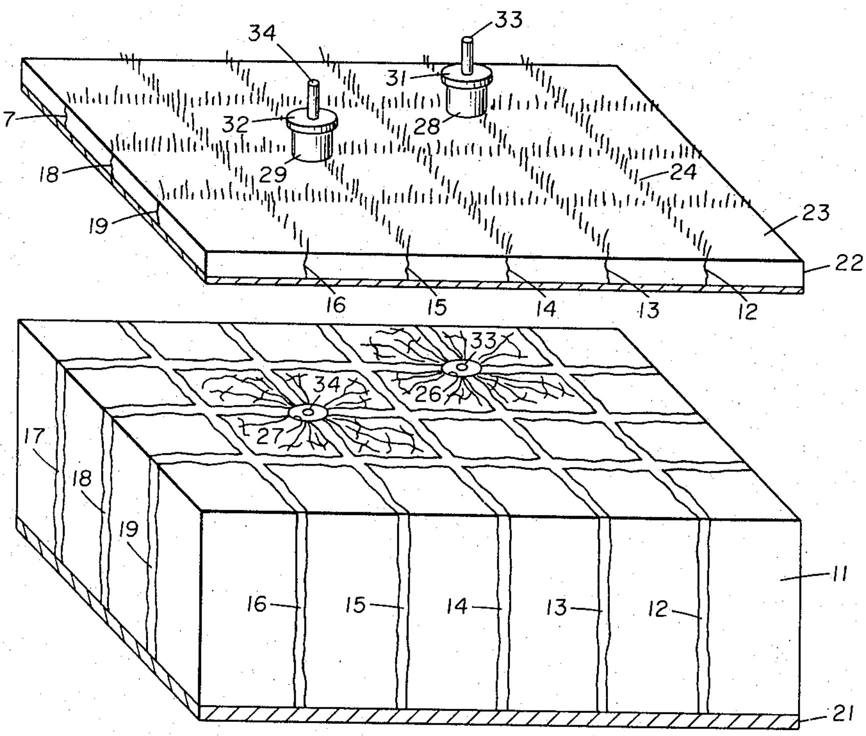
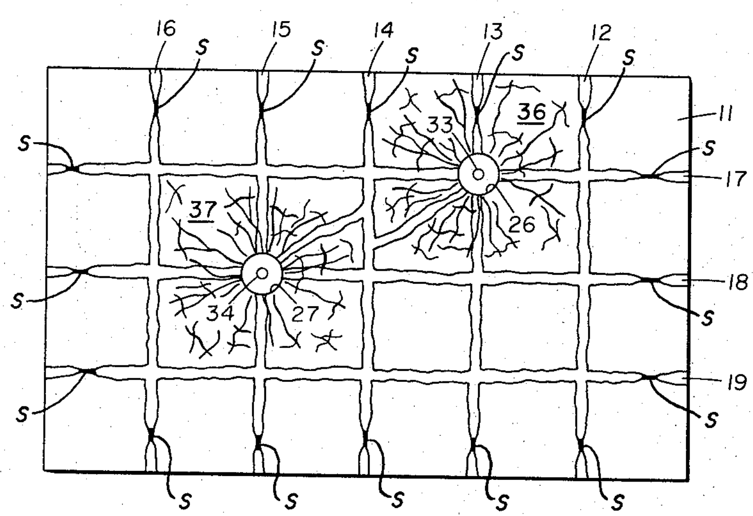


FIG. 2



MARION L. SLUSSER
INVENTOR

BY Emil J. Bednar
ATTORNEY

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METHOD AND STRUCTURE FOR RETORTING OIL SHALE IN SITU BY CYCLING FLUID FLOWS

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

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This invention relates to the recovering of hydrocarbons from an oil shale deposit by in situ retorting methods. More particularly, it relates to such retorting of oil shale in which natural fractures, and other physical properties, of the oil shale are utilized with the cycling of fluid flows for the in place production of shale oil.

Oil shale must be heated, i.e., retorted, to obtain hydrocarbonaceous shale oil. Many methods have been proposed for recovering shale oil from oil shale residing in massive subterranean formations. Usually, a suitably pressurized heating gas is injected into the massive shale formations to effect in situ combustion for thermally converting the organic matter, kerogen, in the oil shale into a fluid state. The heating gas also acts as a driving media for the production and recovery of the hydrocarbonous shale oil from the oil shale. Vast quantities of heat are required for the in situ conversion of oil shale into the desired hydrocarbon product, shale oil. Consideration of the inefficiencies of the application of heat underground and for losses in the production and collection of the shale oil readily points out the great difficulty in providing an economically satisfactory method of in situ retorting for the recovery of shale oil.

One proposal for carrying out an in situ retorting procedure is through the injecting of a heating gas into the oil shale and producing the retorted shale oil therefrom through the same well. For example, reference may be taken to United States Patent 3,139,928 for such a procedure. The injection of the heating gas and the production of retorted shale oil into, and out of, respectively, a given portion of the oil shale from a single well is a substitute for the flowing of heating gas and retorted shale oil between injection and production wells through fractures in the oil shale. However, the retorting method using cyclic fluid flows from the same well is strictly usable only in an oil shale which is very strong, unfractured, and otherwise impermeable. Particularly, a common well, for injection and production purposes, appears usable only at considerable depths within the solid oil shale formations able to withstand considerable fluid pressure without appreciable leakage of the pressurized fluids to the surrounding areas beyond their recovery from the well. It will be obvious that great inefficiencies arise in this type of method from the losses in both the injected heating gas and the produced shale oil where any appreciable leakage of these fluids occurs from a cavern, well, or the like, throughout the oil shale formation.

There are deposits of oil shale pervaded with many interconnecting fractures, including vugs, and other type openings, through which fluids can readily leak. Generally, these interconnected fractures are aligned into a fracture system. It has been found that these fractures are oriented predominantly vertically, and there is an apparent fluid permeability in such system, in at least one direction, by which fluids can flow through the oil shale deposit sufficiently that in situ retorting is feasible between spaced injection and production wells. However, the cycling of fluid between injection and production flows from the same well for the in situ retorting of oil shale in deposits with these interconnection fractures causes losses of the heating gas and the retorted shale oil

in amounts so great that continued cyclic operation becomes an economical and operational impossibility. It is therefore an object of the present invention to provide method and structure for the cycling of injection of the heating gas and production of the retorted shale oil through the same well to be carried out in oil shale deposits which are infused with a plurality of fluidly interconnected fractures while avoiding any appreciable leakage and substantial loss of pressurized fluids as would occur with prior flow cycling procedures.

According to the present invention, through well means in fluid communication with the interconnecting fractures in this character of oil shale deposit, steps are carried out wherein a peripheral pressure seal is provided in the oil shale in spaced relationship about the well means. Particularly, the pressure seal is established in the interconnected fractures about the well means and so arranged that heating gas can be introduced to obtain in situ combustion under elevated pressures through the well means into the interconnected fractures in fluid communication therewith, without appreciable leakage of this, or any other, fluid to parts of the oil shale deposit from which recovery cannot later be obtained. Further, this pressure seal can be arranged to withstand any magnitude of pressure of the injected heating gas, even approaching the pressure at which induced fracturing of the oil shale occurs. This pressure seal is formed without reliance entirely upon the placement of artificial seals, such as by grouting, cementing, or sealing with drilling muds or the like. After the pressure seal is formed, then cooperating steps for the injection of the heating gas and the production and recovery of the retorted shale oil are carried out from the well means. If desired, after a substantial part of the oil shale about the well means which receives the heating gas is retorted, disruption of the established peripheral seal is obtained. Thereafter, by certain steps, a new peripheral pressure seal can be formed at an increased radial spacing from the well means beyond the initial pressure seal and the steps of cycling of fluid flows may again be carried out between injection and production with the concomitant recovery of the retorted shale oil through the well means. Variations of steps in the present method may be employed to achieve yet more enhanced recovery of the retorted shale oil. It will be apparent from the following description of preferred embodiments of the present invention that oil shale deposits containing interconnecting fractures arranged in a fracture system may be retorted in situ employing the described cycling of fluid flows with a high level of utilization of the heating gas for combustion and a high level of shale oil recovery for each volume of the injected gas and retorted oil shale.

The stated object, and other related objects, will become more apparent when considered in conjunction with the following detailed description, the appended claims, and the attached drawings, wherein:

FIGURE 1 shows in isometric perspective a subterranean formation of oil shale having a fracture system in reference to which an illustrative embodiment of the method of this invention will be described; the oil shale is shown in exploded relationship as the lower block with a superimposed covering of overburden; and

FIGURE 2 is a plan view of the oil shale block of FIGURE 1 showing a plurality of interconnected fractures in fluid communication with well means in the oil shale.

Referring now to FIGURE 1 of the drawings, a detailed description of an illustrative embodiment of the method of this invention will be given immediately after first describing the oil shale deposits in which its use is so advantageous. Massive oil shale **11** illustrates a structure of certain deposits having networks of interconnected fractures, which fractures are arranged into a fracture system. The fractures 12 through 16 are aligned along one horizontal direction, and the fractures 17 through 19 are aligned in another horizontal direction; and the fractures are all fluidly interconnected in such a manner that unless some means of control are provided fluids can readily escape throughout the fracture system. One example of the oil shale 11 is the Parachute Creek member of the Green River Formation in Colorado. The fractures in their natural state in this formation produce appreciable leakage of a pressurizing fluid injected into any one of them and prevent satisfactory recovery of the injected fluid using only a single well. The term "fracture" as used herein is intended to include all types of conductors with high permeability to fluids whether open or filled with debris.

Interposed along the horizontal in such oil shale deposit usually are one or more strata 22, which may be tuffaceous structures providing natural barriers to vertical fluid flows. A surface overburden 23 is generally present and may have a thickness up to 1000′ or more. The oil shale 11 usually rests upon a supporting substrata 21.

The fracture system of the oil shale 11 is reflected by surface phenomena in many cases. For example, vegetative growth 24 usually will be in alignment with most of the larger fractures extending below the surface of the earth. This growth in an area which is quite arid is believed prompted by the accumulation of moisture in these fractures. However, a geological survey, or other means, can be employed to determine the location of the fractures in the system, if desired. In the oil shale 11, all apparent permeability to fluids resides in the fractures 12 through 19 for practical purposes. The solid oil shale intervening between these fractures has effectively zero permeability to fluids and an exceedingly small porosity and low thermal conductivity. However, the permeability to fluids is very greatly increased after the oil shale 11 is retorted; then the permeability to fluids resides in both the fractures and those portions of the oil shale previously retorted.

In the present method, well means are provided for conveying fluids between the earth's surface and the oil shale 11 with these means penetrating into fluid communication with the fractures 12 through 19 in their interconnection by the fracture system. Such well means may be provided by boreholes 26 and 27 which extend into the oil shale 11 from the earth's surface or other accessible locations. However, the present invention may be practiced employing one, both, or more than two, boreholes and their related assemblies. Any means may be employed for producing these boreholes 26 and 27. They are completed with suitable apparatus for conveying the fluids required for retorting oil shale 11 by in situ combustion. Preferably, the boreholes 26 and 27 are uncased through their extent in the oil shale 11 but contain casings 28 and 29, respectively, extending from the earth's surface throughout the overburden 23. The casings 28 and 29 may be cemented, or otherwise fluidly sealed, within the surrounding boreholes 26 and 27. Carried on the casings 28 and 29 are wellhead assemblies 31 and 32. The wellheads 31 and 32 are arranged with conduits 33 and 34, respectively, whereby pressurized fluids, namely heating gas, and the shale oil produced by retorting, are transferred between the earth's surface and the oil shale 11 through the boreholes 26 and 27. The boreholes 26 and 27 are spaced in the oil shale 11 sufficiently remote from the nearest atmospheric vent that no appreciable leakage of substantially all of the pressurized fluids thereabout occurs to regions where return to the well means by reduced pressure flow is impossible. For example, the well means in the oil shale 11 are placed from the nearest atmospheric vent in the oil shale 11, such as an exposed cliff face, canyon, or another borehole vented to the atmosphere, at such distance that no substantial quantities of the pressurized fluids would escape unrecoverably from the oil shale 11. Obviously, such atmospheric vents must be avoided or the loss of nearly all of the pressurized fluids in the oil shale 11 will necessarily result.

It is found very desirable in many instances to fracture the oil shale 11 about the boreholes 26 and 27, and this result may be obtained through any means. Fracturing increases the surfaces of the oil shale 11 exposed to a heating gas. With momentary reference to FIGURE 2, the fracturing of the oil shale 11 should preferably produce volumes of rubble 36 and 37, surrounding the boreholes 26 and 27, respectively. The volumes of rubble 36 and 37 desirably have an apparent permeability to fluids greater than 1 darcy whereby sufficient flow channels exist that fluid communication therethrough is maintained while being subsequently subject to in situ combustion. Fracturing of the oil shale may be by explosives, hydraulic fracturing, or other means, effected about the well means.

As another step of the present method, a heating gas is supplied from a suitable source (not shown) at elevated pressure, through the well means via conduits 33 and 34 into the interconnected fractures 12 to 19. The heating gas is an oxygen-containing gas, so that in situ combustion can be effected in the oil shale 11. Combustible and noncombustible gases, in various proportions and combinations, may be admixed in the heating gas to vary its combustion-supporting properties as found desirable. The heating gas upon injection, especially if preheated, can produce sufficient heating in the oil shale 11 to initiate combustion by an auto-oxidation mechanism. In situ combustion can be effected by supplying heating gas into the boreholes 26 and 27 of the well means in conjunction with the auxiliary heating of the adjacent surfaces in the oil shale 11 to elevated temperatures until combustion is initiated by spontaneous ignition. Under these conditions, the heating gas, supplied at a rate sufficient for maintaining combustion of the oil shale, is continued to be introduced from the well means into the fractures 12 through 19 at a first pressure of a magnitude greater than atmospheric but less than about the pressure which induces fracturing in the oil shale 11. After combustion of the oil shale 11 is obtained, the temperature and velocity of the resulting combustion front can be regulated by adjusting the composition, temperature, and volumetric rates of the heating gas. Usually, the oil shale 11 is preferably heated to temperatures above 500° F., and more preferably, between 500° F. and 1000° F. The combustion of hydrocarbon materials in the oil shale 11 produces the heat to decompose the kerogen into fluid shale oil and residual coke as the resulting hydrocarbonous products.

It has been found in the oil shale 11, continuing to supply the heating gas into the fractures 12 to 19 at the first pressure for a sufficient period of time produces a peripheral pressure seal at some radial distance about the well means in the oil shale 11 by the effects of the heating. The seal is denoted by the letter S. The mechanisms of how this seal is formed are not completely understood. It is believed that the seal is formed through action of the fractures being filled with carbon particles, and gums, and the thermal expansion of the oil shale 11, to close each of the fractures at their narrowest openings which usually reside some distance from the well means. Since the pressure seal is in narrow fractures which restricts fluid flows conveying heat, a combustion front must retort the adjacent oil shale masses before it reaches the seal sufficiently to disrupt it. The seal cannot be obtained without a greatly increased loss of hydrocarbons where there is a cycling, or reversal in flow, of the fluids in the oil shale 11 before the seal is completely formed. The amount of fluids lost before the peripheral pressure seal is completed is not significant when compared to the large volume of oil shale 11 enclosed within the seal, and the great volumes of shale oil which can be obtained from such oil shale volume. Thus, a peripheral pressure seal is produced in the oil shale **11** by steps of this invention to contain the presurized fluids within an area about the well means. Therefore, the loss of the retorted shale oil to the surrounding formation is restricted and the shale oil is recoverable without appreciable leakage radially outwardly through existing fractures for the remaining steps of this method.

As the next step, the supply of the heating gas into the well means, namely the boreholes **26** and **27**, is terminated when the inflow of such gas is substantially reduced in rate at the mentioned first pressure at which it flows into the oil shale **11**. This indicates that the peripheral pressure seal has formed in the fractures **12** through **19** interconnected in fluid communication with the well means. It will be apparent that an equilibrium condition has been obtained at this time wherein the amount of pressurized fluid introduced into the well means is about equal to that which is escaping the pressure seal, if any escapes at all. Generally, this leakage of fluid will be small in amount, as for example about 100 to 200 s.c.f.h. When this restricted leakage of fluid condition is obtained, the next step of the present invention is practiced.

In this step, the pressurized fluids contained within the peripheral pressure seal in the oil shale **11** are vented through the well means into a suitable hydrocarbon recovery system (not shown). The hydrocarbons are recovered from such vented fluids in the system. The system can be conventional in design and its particular form is not critical in the present invention. The system is considered to be connected operatively to receive the vented fluids through the conduits **33** and **34** at the wellheads **31** and **32**. The pressurized fluids are vented from the well means until the outflow of these fluids is substantially reduced in rate at a second pressure less than the first pressure. Usually, these fluids need not be vented down to a nearly zero flow rate at atmospheric pressure for satisfactory results. There will be in most cases some pressure above atmospheric, but less than the first injection pressure, at which the outflow of fluids is so reduced in rate that further amounts of shale oil recovered from these vented fluids do not warrant continued operation under this step.

The heating gas, after completing the step of venting the pressurized fluids, is again injected to promote in situ combustion through the well means into the oil shale **11** at a third pressure greater than the second pressure at which the fluids were vented but not greater than about the first pressure under which the peripheral pressure seal was formed in the oil shale **11** so as to induce fracturing. Preferably, the heating gas is injected at the third pressure about equal to the first pressure at which the heating gas was supplied through the well means in the earlier step whereby the peripheral seal is protected against being ruptured. The injection of the heating gas again is continued until the rate of flow into the well means substantially ceases at this injection pressure as in the earlier injection step.

Thereafter, the step of venting the pressurized fluid from the well means with recovering of the shale oil may again be practiced.

The steps of injecting the heating gas into the well means and venting the pressurized fluids through the well means can be practiced one or more times for repeatedly cycling fluid flows during the in situ retorting of the oil shale **11** about the well means and within the peripheral pressure seal until a substantial part of the oil shale **11** about the well means, which part receives the heating gas contained within the peripheral seal, is retorted. At this time, depending upon the circumstances, the retorting method may be considered to be complete after substantial quantities of oil shale are recovered.

The pressure seal is, to great advantage, self-adjusting to the approaching combustion front propagated from the well means by repeating the preceding steps. As the combustion front begins to disrupt the seal at any location, some leakage of the fluids occurs and, as a result, the pressure seal is relocated downstream of its former location. This is an advantage not found with seals produced by muds, grouts, cements, and the like. Additionally, this nature of the pressure seal in the present method permits in situ retorting of all the oil shale intervening between it and the well means. As a result, no special precautions need to be taken to protect the seal during the practice of the described steps other than not unintentionally fluidly fracturing it.

As is apparent, there has been provided a novel structure within the oil shale **11** by which cyclic flow of fluids during injection and production steps can be effected from a common well means without appreciable leakage and substantial loss of the pressurized fluids. The peripheral pressure seal disposed within the fractures, in combination with the well means and geological characteristics of the oil shale, has essentially produced a new type retort by which in situ retorting can be obtained. Thus, all the advantages of fluid-tight surface retorts are obtained below ground.

If desired to retort greater areas of the oil shale **11** after completing the above steps, the heating gas can be supplied during injection into the oil shale **11** with increased pressure sufficient to induce fracturing of the oil shale **11** and disruption of the peripheral pressure seal. Once fracturing is accomplished, fluid communication between the well means and the fractures **12** through **19** exteriorly of the peripheral seal will be obtained. Thereafter, the steps of supplying the heating gas through the well means to produce another peripheral pressure seal at about the first pressure and terminating the supply of the heating gas when the new pressure seal is effected can be undertaken. Then practicing the earlier described steps of venting the pressurized fluids through the well means and recovering the hydocarbons from them, again injecting the heating gas to promote in situ combustion to the well means and thereafter venting the pressurized fluids, will result in retorting more of the oil shale **11**, which steps may be repeated as desired.

Where two boreholes **26** and **27** are employed at spaced horizontal locations in the oil shale **11** and each is in fluid communication with at least one fracture interconnected with other of the fractures **12** through **19** of the fracture system, then the steps of the present invention may be practiced through either or both of these well means. The steps may be practiced concomitantly or alternately through these well means and in any order. For example, the steps of injecting the heating gas into the oil shale **11** may be all practiced through the borehole **26**, whereas the borehole **27** may be employed for venting the pressurized fluid from the oil shale **11**. Also, the well means can be shifted between their use for injection and for production purposes on alternate pressure cycles. However, if it is desired, borehole **26** may be used exclusively for injecting the heating gas into the oil shale **11** and the borehole **27** may be used exclusively for venting from the oil shale **11** the pressurized fluids carrying the produced shale oil.

From the foregoing it will be apparent that the described method and structure provide for the placement of well means in the oil shale **11** to utilize the fracture system and the apparent permeability to fluids in such a manner that in situ retorting of shale oil may be effected through cycling of fluid flows through the same well means. This is all accomplished without resort to providing artificial seals entirely by use of cements, grouts, or the like, and without any appreciable leakage of the pressurized fluids introduced and established within the oil shale structure.

It will be readily appreciated from the foregoing description that herein is disclosed a novel method and structure adapted for obtaining the recovery of shale oil from underground formations of massive oil shale containing fracture systems. Further, these hydrocarbons can be obtained without practicing extensive auxiliary steps so that the retorting of the oil shale may be carried out without appreciable leakage of pressurized fluids into areas of the formation from whence they cannot be recovered using common well means.

Various changes and modifications of the method of this invention may be made without departing from the scope thereof. These departures are contemplated in presenting this invention and they are intended to be within the scope of the appended claims. As many embodiments as possible may be made of the invention without departing from its scope. It is to be understood that with regard to the scope of the present description all matter herein set forth is to be interpreted as illustrative and not limitative.

What is claimed is:

1. A retorting method employing in situ combustion of a subterranean deposit of oil shale having interconnected fractures, which fractures are oriented predominantly vertically and aligned with interconnection into a fracture system having permeability to fluids in at least one direction by which fluids can flow through such oil shale, comprising the steps of:

(a) providing well means for conveying fluids between the earth's surface and the oil shale with said means penetrating the oil shale into fluid communication with interconnected fractures in the fracture system and remote from any atmospheric vent through which fracture-contained pressurized fluids suffer appreciable leakage and substantial loss,

(b) supplying a heating gas through the well means into the interconnected fractures in fluid communication therewith and initiating combustion in the oil shale adjacent the well means with the heating gas in maintaining combustion in the oil shale introduced at a first pressure in the fractures greater than atmospheric pressure and less than the pressure at which induced fracturing of the oil shale occurs,

(c) terminating the supply of said heating gas into the well means only when the inflow of said heating gas is substantially reduced in rate at said first pressure upon a peripheral pressure seal being formed in the fractures in fluid communication with the well means, thereafter,

(d) venting the pressurized fluids contained by the peripheral seal in the oil shale through the well means and recovering hydrocarbons from said fluids until the outflow of said fluids is substantially reduced in rate at a second pressure less than said first pressure,

(e) injecting the heating gas through the well means into the oil shale to promote in situ combustion at a third pressure greater than the second pressure and not greater than about the first pressure until the inflow of said heating gas substantially ceases at said third pressure, and, thereafter,

(f) repeating step (d).

2. The method of claim **1** wherein the steps (e) and (f) are repeated until a substantial part of the oil shale about the well means, which part receives the heating gas contained within the first-formed peripheral seal, is retorted.

3. The method of claim **1** wherein the steps (e) and (f) are repeated until a substantial part of the oil shale about the well means, which part receives the heating gas contained within the first-formed peripheral seal, is retorted; and then supplying heating gas through the well means into the oil shale at a fourth pressure sufficiently in excess of the first pressure to induce fracturing in the oil shale with disruption of the priorly established peripheral seal, reducing the pressure to about the first pressure and practicing steps (b), (c), and (d), and lastly, steps (e) and (f).

4. A retorting method employing in situ combustion of a subterranean deposit of oil shale having interconnected fractures, which fractures are oriented predominantly vertically and aligned with interconnection into a fracture system having permeability to fluids in at least one direction by which fluids can flow through such oil shale, comprising the steps of:

(a) providing well means for conveying fluids between the earth's surface and the oil shale with said means penetrating the oil shale into fluid communication with interconnected fractures in the fracture system and remote from any atmospheric vent through which fracture-contained pressurized fluids suffer appreciable leakage and substantial loss,

(b) fracturing the oil shale adjacent at least one well means into a rubble having a permeability to fluids greater than 1 darcy to provide sufficient flow channels that fluid communication therethrough is maintained while said rubble is subsequently subject to in situ combustion,

(c) supplying a heating gas through the well means into the interconnected fractures in fluid communication therewith and initiating combustion in the oil shale adjacent the well means with the heating gas in maintaining combustion in the oil shale introduced at a first pressure in the fractures greater than atmospheric pressure and less than the pressure at which induced fracturing of the oil shale occurs,

(d) terminating the supply of said heating gas into the well means only when the inflow of said heating gas is substantially reduced in rate at said first pressure upon a peripheral pressure seal being formed in the fractures in fluid communication with the well means, thereafter,

(e) venting the pressurized fluids contained by the peripheral seal in the oil shale through the well means and recovering hydrocarbons from said fluids until the outflow of said fluids is substantially reduced in rate at a second pressure less than said first pressure,

(f) injecting the heating gas through the well means into the oil shale to promote in situ combustion at a third pressure greater than the second pressure and not in excess of about the first pressure until the inflow of said heating gas is substantially reduced in rate at said third pressure, and, thereafter,

(g) repeating step (e).

5. The method of claim **4** wherein the steps (f) and (g) are repeated until a substantial part of the oil shale about the well means, which part receives the heating gas contained with the first-formed peripheral seal, is retorted.

6. A retorting method employing in situ combustion of a subterranean deposit of oil shale having interconnected fractures, which fractures are oriented predominantly vertically and aligned with interconnection into a fracture system having permeability to fluids in at least one direction by which fluids can flow through such oil shale, comprising the steps of:

(a) providing well means for conveying fluids between the earth's surface and the oil shale with said means penetrating the oil shale at horizontally spaced apart locations and in fluid communication with interconnected fractures in the fracture system and remote from any atmospheric vent through which fracture-contained pressurized fluids suffer appreciable leakage and substantial loss,

(b) fracturing the oil shale surrounding said well means into a continuous mass of rubble having a permeability to fluids greater than about 1 darcy to provide sufficient flow channels that fluid communication therethrough is maintained while said rubble is subsequently subject to in situ combustion,

(c) supplying a heating gas through the well means into the interconnected fractures in fluid communication therewith and initiating combustion in the oil shale adjacent the well means with the heating gas in maintaining combustion in the oil shale introduced at a first pressure in the fractures greater than atmospheric pressure and less than the pressure at which induced fracturing of the oil shale occurs,

(d) terminating the supply of said heating gas into the well means only when the inflow of said heating gas is substantially reduced in rate at said first pressure upon a peripheral pressure seal being formed in the fractures in fluid communication with the well means, thereafter,

(e) venting the pressurized fluids contained by the peripheral seal in the oil shale through the well means and recovering hydrocarbons from said fluids until the outflow of said fluids is substantially reduced in rate at a second pressure less than said first pressure,

(f) injecting the heating gas through the well means into the oil shale to promote in situ combustion at a third pressure greater than the second pressure and not in excess of about the first pressure until the inflow of said heating gas is substantially reduced in rate at said third pressure, and, thereafter,

(g) repeating step (e).

7. The method of claim **6** wherein the steps (f) and (g) are repeated until a substantial part of the oil shale about the well means, which part receives the heating gas contained with the first-formed peripheral seal, is retorted.

8. The method of claim **6** wherein the well means adjacent the rubble in the oil shale are employed; one well means for practicing steps (c), (d), and (f), and other well means for practicing steps (e) and (g); and terminating fluid flow therethrough when said well means are not employed in the designated steps.

9. The method of claim **8** wherein the well means after completing the steps in the method of claim **8** are alternated between being employed for practicing steps (c), (d), and (f) on one cycle and steps (e) and (g) on the next cycle.

10. A structure for producing hydrocarbonous shale oil comprising:

(a) an oil shale having interconnected fractures, which fractures are aligned into a fracture system having a fluid permeability at least in one direction through which fluids can flow through the oil shale,

(b) well means for conveying fluids positioned in the oil shale in fluid communication with said fractures and remote from any atmospheric vent through which fracture-contained pressurized fluids suffer appreciable leakage and substantial loss,

(c) a peripheral pressure seal surrounding said well means in the oil shale comprising a blockage of said fractures with products of the in situ combustion reaction of a heating gas and the hydrocarbonous materials in the oil shale under continued injection flow conditions at the well means,

(d) means connected with the well means for supplying a heating gas into the fractures in fluid communication therewith, and

(e) means connected with the well means for recovering hydrocarbons from pressurized fluids in the oil shale as said fluids are vented from the well means.

11. The structure of claim **10** wherein said well means are disposed at horizontally spaced apart locations in the oil shale and the means for supplying said heating gas are connected to one well means and the means for recovering hydrocarbons from the pressurized fluids as they are vented from the oil shale are connected to other of the well means.

12. The structure of claim **11** wherein means for conveying fluids are interconnected between the well means and each of the means for supplying the heating gas and the means for recovering hydrocarbons.

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

STEPHEN J. NOVOSAD, *Examiner*.