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METHOD AND SYSTEM FOR RECOVERING SHALE OIL AND GAS

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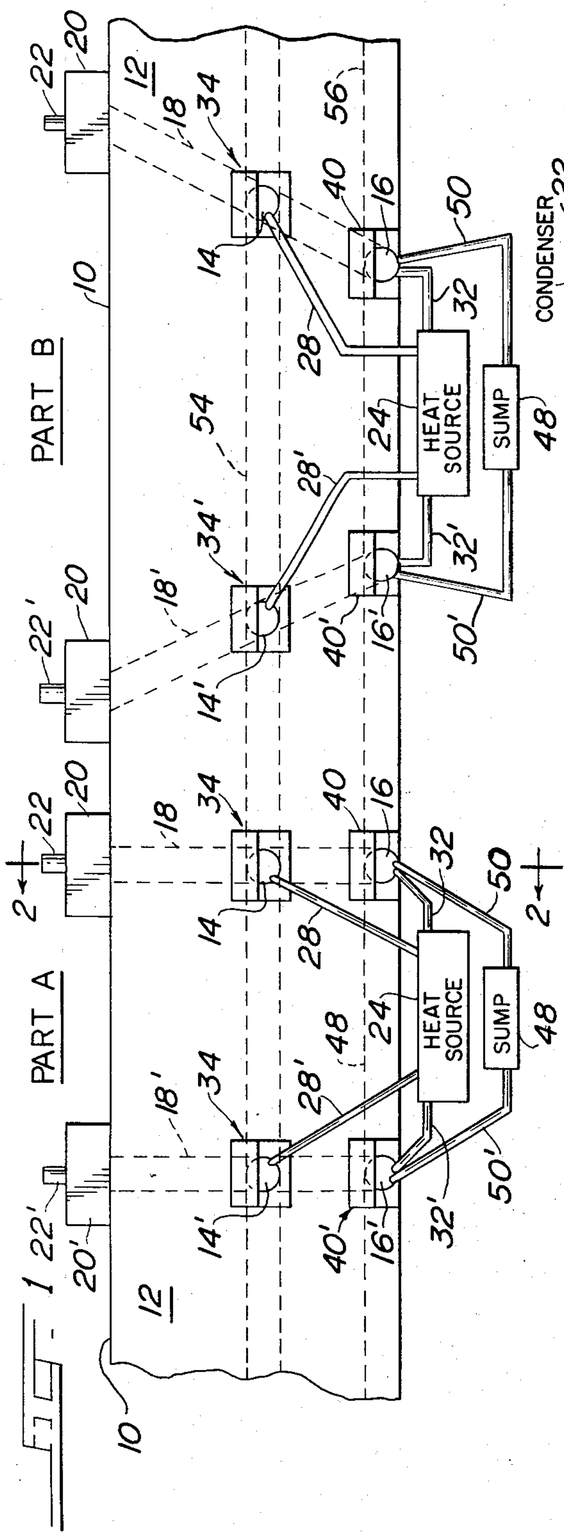

FIG. 1

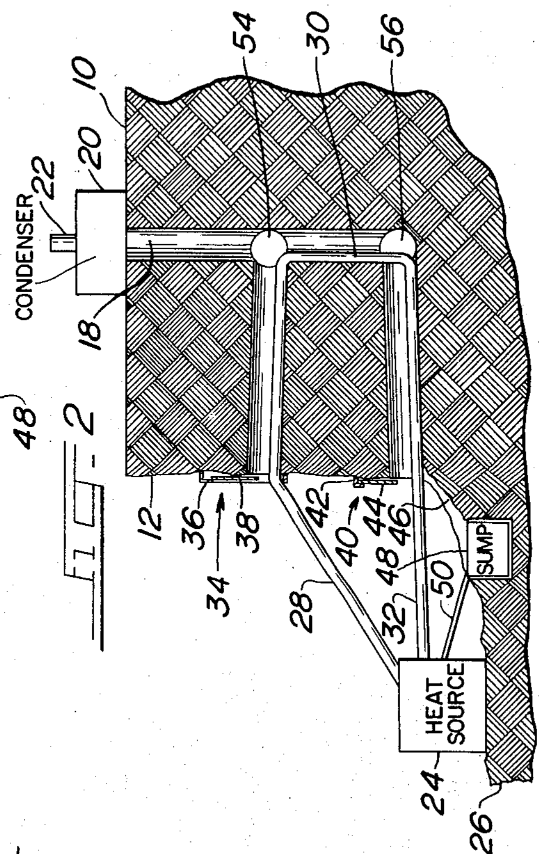

FIG. 2

INVENTOR
WILLIAM TINLIN

BY Rummler & Snow

ATTYS.

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METHOD AND SYSTEM FOR RECOVERING SHALE OIL AND GAS

William Tinlin, 21 Hickory St., Chicago Heights, Ill. 60411

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This invention relates to a method of recovering shale oil and gas from shale oil formations through the application of heat under controlled conditions wherein both the hydrocarbon liquids and vapors are recovered. The invention depends in part upon the excavation of a certain configuration or system of tunnels and galleries having prescribed slopes or elevations in relation to each other in combination with heat conveying means, valve means and condenser means whereby substantially all hydrocarbon liquids and vapors freed by the heat are recovered.

Attention has been direction for sometime to the recovery of hydrocarbon oil from shale formations by various methods. One approach involves mining the shale, crushing the large aggregate and subjecting the comminuted shale to retorting in furnaces of various designs and capacities. The necessity of handling the shale adds greatly to the cost. In situ treatment of shale has been practiced but has not attracted too much attention because of costs informing tunnels, inefficiency in the application of heat and the apparent necessity of using additional expedients, such as pressure, complex tunnel and shaft systems and extreme direct heat or combustion of the shale strata itself to obtain the desired recovery. The prior art processes have not become practical because of the high costs due to least in part to these factors. In addition little attention has been directed to recovery of the vapors that result from the in situ application of heat to a shale oil formation.

Now in accordance with this invention these difficulties are overcome by the provision of a method which is characterized by the use of a simple tunnel and shaft system with tunnels and galleries having certain slopes and elevations, along with the use of heat conveying and recovery means and provision for the continuous flow recovery of substantially all of the oil and vapors as such or in the form of additional heat for the process. The process of this invention is also characterized in one aspect by control of the air passing into the tunnels wherein heat is being applied to the shale in such a manner as to allow complete heat utilization through the application of heat under controlled conditions within a system of convecting tunnels and shafts.

It becomes a primary object of this invention to provide a method of recovering oil from shale oil formations in situ.

Another object of this invention is to provide a system of simple valve-controlled tunnels, shafts and galleries within a shale formation to provide for heat circulation and recovery along with condensers and oil sumps in a particular combination for efficient shale oil recovery.

Another object of this invention is the provision of an interrelated system of converging heating and return tunnels, vertical vapor shafts and interconnecting galleries with cooperating condenser and sumps, whereby heat applied to the shale formation passes upwardly and inwardly therethrough in a manner to drive out oil and vapors into the heating tunnel or tunnels toward at least one vapor shaft whereby the oil descends to a gallery and return tunnel for recovery, and vapors are allowed to ascend the cooler walls for partial condensation and return to the gallery and return tunnel and any uncondensed vapors are trapped in a condenser at the top of the shaft for separate recovery or return thereto.

Another object of this invention is to provide a method of in situ oil and gas recovery from an exposed shale formation which includes the steps of (1) forming at least a pair of converging spaced upper and lower tunnels in a vertical face of the exposed shale formation, (2) forming an interconnected gallery between the lower tunnels, (3) forming at least one vertical shaft extending from an upper portion of the shale formation and communicating with the tunnels and gallery, applying heat to the formation through the tunnels from an external, high temperature, heat source and recovering oil and condensate by direct flow from the lower tunnel.

The invention has as one feature the placement of at least one pair of tunnels one above the other such that the top tunnel is sloped downwardly into the formation and the bottom tunnel is opposite, that is, slopes upwardly into the formation. By connecting the upper and lower tunnels with a vertical shaft, and applying heat to the tunnel system an effective in situ shale oil recovery system is provided.

A feature of this invention is that the application of high temperature heat to the shale formation in the vicinity of the tunnels causes the flow of oil and vapors therefrom, the former being directed by the downward slope of the upper tunnel to a vertical vapor shaft and thence to a lower gallery and through the oppositely sloped return tunnel to a sump for recovery or use, and the latter being directed to said vertical vapor shaft and by the stack effect therein to suitable condensing means for recovery.

Another feature of this invention is the provision of air control locks on the inlet ends of said heating and return tunnels whereby the flow of convection air through said system is controlled for maximum heat utilization and oil recovery.

These and other objects of this invention will become apparent or be described as the specification proceeds.

This invention may be illustrated by various embodiments including those illustrated by the drawings wherein:

FIG. 1 is a diagrammatic illustration of the vertical face of an exposed shale formation showing two forms (Parts A and B) of tunnel, recovery and heating systems; and

FIG. 2 is a cross-sectional view also in diagrammatic form taken along lines **2—2** (Part A) of FIG. 1.

FIGS. 1 and 2 show diagrammatically a shale formation **10** with cliff face **12** as it may appear after removal or stripping of surface material to expose same for treatment. Referring to FIG. 2, tunnels **14** and **16** are drilled into the face of the shale formation to a depth of about 50 to 100 feet. Tunnel **14** is sloped downwardly into the formation. The amount of slope is not as important as the presence of sufficient slope to cause any liquid oil therein to flow freely inward under the influence of gravity. Similarly tunnel **16** is cut or drilled at a lower elevation into the face **12** at a slight upward slope, again for the purpose of free gravitational outward flow therein. Tunnels **14** and **16** are cut at different elevations into the face **12**, that is tunnel **14** is about 30 to 50 feet above tunnel **16**. A shaft **18** is drilled into the top of the shale formation **10** to intersect tunnel **14** and terminate at tunnel **16**. In the simplest form this invention can be practiced with only two tunnels **14** and **16** in combination with a single shaft **18** as will hereinafter be explained. The tunnel and shaft system shown is made possible by modern continuous drilling equipment such as that shown in my Patent #3,005,627, or that disclosed in my copending applications Ser. Nos. 360,585, filed Apr. 1, 1964, now U.S. Patent No. 3,314,724, and 392,484, filed Aug. 27, 1964, now U.S. Patent No. 3,314,725.

At the top of shaft **18** there is provided condenser **20** which may be of any suitable type designed and controlled to provide sufficient cooling to condense the hydrocarbon vapors, except the non-condensible gases, issuing from shaft 18. Flue 22 is provided to collect and convey any uncondensibles for separate recovery or use.

Heat source 24 is located on valley floor 26, preferably a few feet below tunnel 16, i.e. 2 to 6 feet, and may comprise any means for supplying heat to the shale oil formation. Heat source 24 may produce heat in the form of hot gases, or liquids and preferably in the form of superheated stream at a temperature of about 800 degrees F. to 1600 degrees F. With a three stage heater, for example, a temperature as high as 1800 degrees F. can be attained. The heat carrying medium from heat source 24 is conveyed through conduit 28 which extends through tunnel 14 and then, via leg 30 and return line 32 passing through tunnel 16, back to heat source 24.

The open end of tunnel 14 is provided with a valve means indicated at 34 which may comprise any means for opening and closing the entrance to tunnel 14 in a manner so that control of the air flow thereinto is attained. To illustrate a frame member 36 is provided within which a sliding door member 38 operates to attain the desired graduated opening and closing thereof. A similar valve means 40 is illustrated in relation to the open end of tunnel 16 by means of frame 42 and sliding door 44. Other equivalent valve means than a sliding door arrangement can be used.

In order that liquid oil in tunnel 16 is collected there is provided a trough means 46 and sump 48 which later is shown as a sunken tank. Conduit 50 connects between sump 48 and heat source 24 for the purpose of providing a source of fuel for heater 24 where same is an oil burning furnace.

Tunnels 14 and 16 may be provided with a suitable shoring, not shown, to prevent collapse as the removal of liquids and gases proceeds within the shale formation surrounding tunnel 14. Galleries connecting the junctures of a series of the tunnels and shafts, one to the other are shown at 54 and 56 (see FIG. 1).

In one aspect of this invention one pair of tunnels 14 and 16 can be used with one shaft 18 and one heat source 24. However, in a preferred embodiment one heat source is used with a plurality of tunnels as illustrated in FIG. 1 wherein corresponding parts to FIG. 2 bear the same numerals.

In addition, FIG. 1 shows that the shafts 18 and 18′ may be substantially vertical with tunnels 14 (and 14′) and 16 (and 16′) being similarly aligned (Part A) or may be (as shown in Part B) arranged so that shafts 18 and 18′ converge downwardly or are not vertical and tunnels 14 and 14′ and 16 and 16′ are likewise arranged. In each instance, the tunnels intersect with the shafts at the point of intersection with the galleries 54 and 56.

In order to illustrate this invention the following examples are given:

EXAMPLE I

Two tunnels and one shaft

After exposure of shale formation 10 and cliff face 12 by removal of surface rock and other covering, tunnels 14 and 16 are drilled therein using a boring machine which cuts a hole about six feet in diameter. When necessary, suitable shoring means is installed in tunnel 14 as the bore progresses. Shaft 18 is then drilled from the top of the cliff to connect the ends of tunnels 14 and 16. Tunnel 14 is cut so that it slopes into the shale formation at the rate of about 1 to 2 inches per foot. Tunnel 16 is cut so that it slopes in the opposite direction, that is, out of the shale formation, and at about the same slope as tunnel 14. With this size tunnel and shaft there is no difficulty in the installation of heat conduit 28 therein and connected back to heat source 24, which may be a three stage furnace capable of producing super heated steam at 800 degrees F. to 1600 degrees F. and as high as 1800 degrees F. Condenser 20 is installed and valve members 34 and 40 are attached over an open ends of tunnels 14 and 16. Trough 46, and sump 48 are installed to provide gravity flow of oil from tunnel 16. Line 50 is connected to sump 48 for auxiliary fuel.

Heat in the form of super-heated steam at about 1200° F. is sent through conduit 28 and valves 34 and 40 are closed. As the heat permeates the shale formation, oil begins to flow therefrom and gravitate into tunnel 14. The backward slope thereof causes this collected oil to flow into shaft 18, downward into tunnel 16 and out tunnel 16 to sump 48. To hasten the initial heating, valve 34 is closed and valve 40 is opened. As the heating continues, vapors of lower boiling hydrocarbons and uncondensible gas C_1 and C_3 are collected in shaft 18 and rise to condenser 20 for recovery. Any uncondensible gases are conveyed to a suitable separate recovery system (not shown) by means of off-gas flue 22. Gradual removal of vapors from the system is controlled so that there is substantially no flow of air into tunnel 16 via valve 40. As removal of oil from the formation 10 continues, valve 40 is gradually closed and valve 34 gradually opened to allow more air to enter tunnel 14. This carries heat from conduit 28 and the surrounding partially denuded shale further into the formation and increases over-all recovery. The temperature in the shale will reach about 1000° F. Control of air intake from this point on to maximize the transfer of heat to the shale formation is accomplished by the operation of condenser 20 and flue 22 and manipulation of the values 34 and 40. Finally, the shale around and above tunnel 14 is denuded of oil and begins to crumble and cavitate. Valve 34 can be fully closed to drive the heat from the cavities and crumbled shale into the formation still further. The pocket of denuded shale so created may also be removed to recover the conduit 28 and to expose a new cliff face and the process steps repeated.

EXAMPLE II

Four tunnels, two shafts and one or more galleries

The steps of Example I are repeated and each pair of tunnels is connected at its rearward end with a shaft and a substantially horizontal gallery. As heat is applied, this time in the form of a molten metal, the valves are operated in the same manner as in Example I to control by natural convection the flow of air through tunnels 14 and 14′ so as to transfer the heat to the surrounding shale body. The temperature of the shale may rise to about 1800 degrees F. In using a molten metal as the heating medium care must be taken not to allow too great a rate of heat transfer on the one hand and freeze-up in the conduit on the other. Oil passes into tunnels 14 and 14′, drains into gallery 56 and thence through tunnels 16 and 16′ into sump 48.

EXAMPLE III

A plurality of tunnels, shafts and galleries

The steps of Example II are continued by drilling a plurality of tunnels 14 and 14′ into the face of a shale cliff. Interconnecting vertical and slanting shafts are sunk to connect with the extended ends of the tunnels. The interconnecting galleries are drilled. The conduits, condensers, valves, perforated pipe, heat sources and sumps are installed. Heat is applied to the shale formation for about two days over about 1500 linear feet of cliff face 50 feet high. Oil is continuously recovered in the sumps and condensate from the condensers. At the end of this time the conduits are removed and a fresh cliff face exposed by removal of denuded shale.

From the foregoing examples and description, it is apparent that the process of this invention has several unforeseen advantages. First, the provision of the control of the air flow helps to retain the heat in the upper tunnel for a sufficient time to drive the heat into the formation by natural convection and aids in regulating the conveyance of oil and vapors from the top tunnels. Secondly, the withdrawal and recovery of vapors is also in the direction of natural convection through the system which further aids and augments heat utilization and oil recovery. Recovery of the vapors immediately as they form prevents further breakdown or cracking and reduces losses due to decomposition. The over-all system mitigates losses and waste of heat and oil and vapors. The rate that oil is taken from any shale bed will be determined by the heat used, by the number of tunnels and shafts and the control of the air allowed to enter the system.

Having thus described this invention, it should be understood that details thereof may be altered or omitted without departing from the spirit of the invention as defined by the following claims.

I claim:

1. The method of recovering shale oil and gas from an exposed shale formation which comprises

(a) forming at least one pair of vertically spaced tunnels into the face of said formation, the uppermost of said tunnels being inwardly sloped and the lowermost of said tunnels being outwardly sloped,

(b) forming an interconnecting shaft between the top of said formation and said tunnels,

(c) passing a heating medium at a temperature sufficient to cause the separation of oils and gases into indirect contact with said shale formation surrounding said spaced tunnels, said heating medium being sent first through said uppermost tunnel, through said vertical shaft and out through said lowermost tunnel, and

(d) recovering liquefied oil from said tunnels and recovering said gases from said shaft.

2. The method according to claim 1 wherein the air entering the said tunnels is regulated to control the stack effect of said shaft.

3. The method in accordance with claim 1 in which said heating medium is maintained at a temperature within the range from about 800° F. to about 1600° F. in the said uppermost tunnel and the air flow entering said upper tunnel is regulated to control the stack effect of said shaft.

4. The method in accordance with claim 1 in which a plurality of said tunnels and shafts are formed in said shale formation, interconnecting galleries are formed between the ends of said tunnels and their points of intersection with said shafts, said heating medium is maintained at a temperature sufficient to produce a space temperature of at least about 800° F. within the upper of said tunnels, and said vapors are recovered by condensing the effluent from said shafts.

5. A system for recovering shale oil and gas from a shale oil formation comprising a pair of vertically spaced tunnels in said formation, a shaft interconnecting said tunnels adjacent their inner ends and opening to the top of said formation, a high temperature heat source, conduit means for transmitting heat from said heat source into the upper of said tunnels, said conduit means leading through said shaft to the lower tunnel and thence returning to said heat source, adjustable gate means at the entrance to each tunnel for regulating the volume of air entering thereinto, and means at the top of said shaft for trapping and condensing vapors and gas issuing therefrom.

6. A system for recovering shale oil and gas from a shale oil formation as defined by claim 5 wherein a series of spaced tunnels and shafts are created in said formation to provide a series of pairs of vertically spaced tunnels each pair having an interconnected shaft, said conduit means leads into each of the upper tunnels, down the respective shaft and out through the respective lower tunnel to return to said heat source, and wherein a sump means is provided for collecting liquefied oil and vapors flowing from the lower tunnels.

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STEPHEN J. NOVOSAD, *Primary Examiner.*