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PRODUCING OIL FROM OIL SHALE BY HEATING WITH HOT GASES

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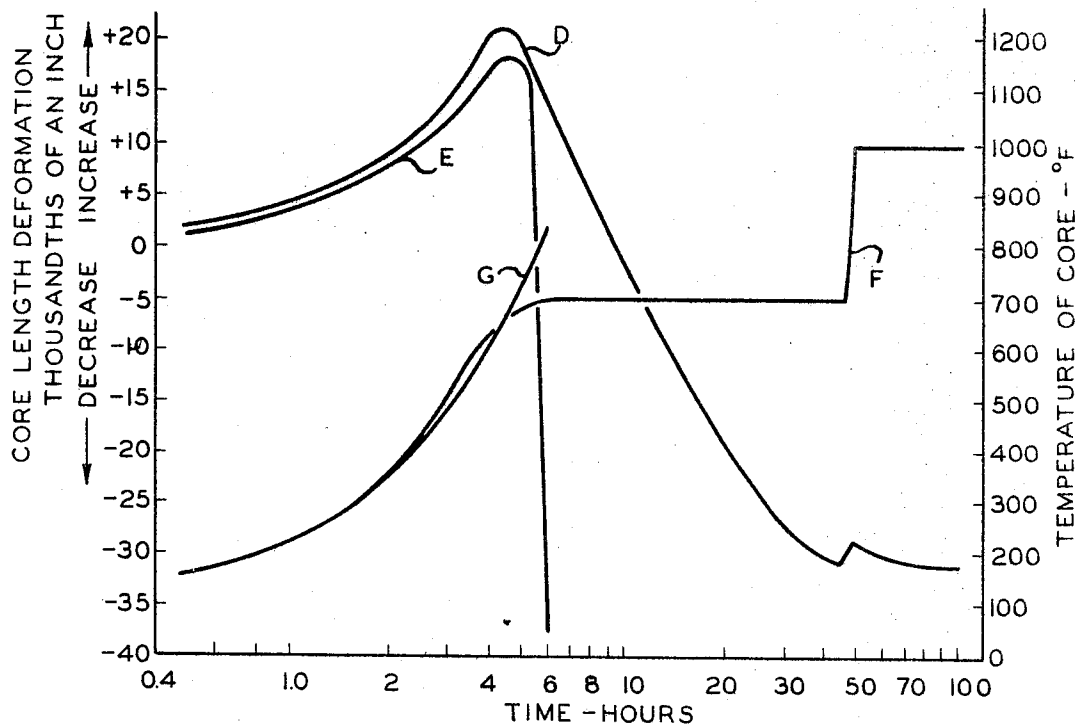


FIG. 3

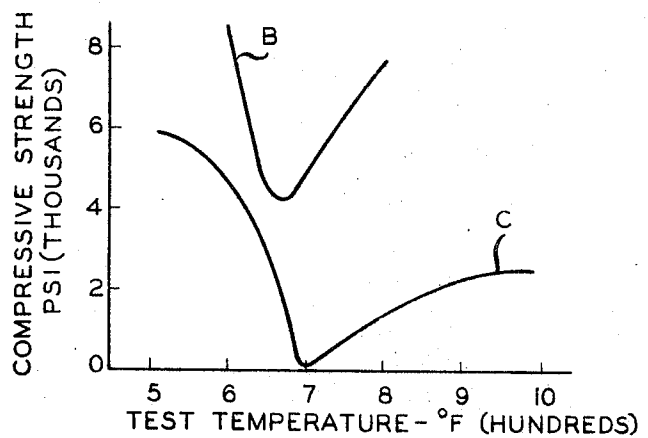


FIG. 2

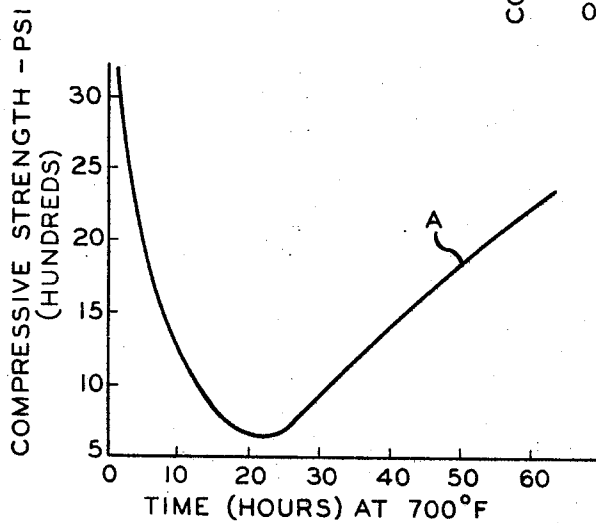


FIG. 1

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**PRODUCING OIL FROM OIL SHALE BY
HEATING WITH HOT GASES****Riley B. Needham, Bartlesville, Okla., assignor to Phillips
Petroleum Company, a corporation of Delaware****Filed Apr. 3, 1967, Ser. No. 628,141****Int. Cl. E21b 43/24, 43/26****U.S. Cl. 166-247****6 Claims****ABSTRACT OF THE DISCLOSURE**

Oil is produced from fractured or broken oil shale by preheating the shale at temperatures in the range of 500-700° F., and below which rapid pyrolysis occurs or compressive strength of the shale fails, for a sufficient period to reach and pass the minimum compressive strength of the shale; and thereafter, rapidly pyrolyzing the shale at temperature above 750° F. to produce oil therefrom.

This invention relates to a process for producing oil from oil shale by contacting the shale with hot gases.

Oil is produced from oil shale by heating the shale to temperatures above 500° F. In order to produce oil from shale in situ, it is essential to fracture and break up the shale to render the process commercially feasible. Various methods of fracturing are known in the art. The use of a nuclear explosion for forming shale rubble has also been proposed. A nuclear explosion within a bed of shale deep in the earth produces a huge chimney containing a mass of shale rubble which has high permeability and is amenable to production by contacting the shale with hot gases. A nuclear chimney may have a diameter of 600 feet and a height of about 1400 feet.

In heating oil shale with hot gases one of the problems encountered is that of plastic flow which greatly reduces or completely eliminates permeability, thereby hindering or terminating the pyrolysis operation. This invention is concerned with the reduction or prevention of plastic flow in the heating of oil shale with hot gases.

Accordingly, it is an object of the invention to provide a process for producing oil from an oil shale by pyrolysis with hot gas which avoids or substantially diminishes plastic flow of the shale. Another object is to provide a process for producing oil from shale rubble in a nuclear chimney by effecting pyrolysis with hot gas while avoiding substantial plastic flow of the shale. Other objects of the invention will become apparent to one skilled in the art upon consideration of the accompanying disclosure.

In accordance with a broad aspect of the invention, a mass of fractured or broken oil shale having a Fischer assay value in the range of 15-50 gallons per ton is first heated at a relatively low preheat temperature in the range of 500-700° F. and below the temperature at which the compressive strength of the shale fails at pressures existing in the mass. The preheating at this relatively low temperature is continued for a substantial period of at least 7 hours and until the minimum strength point of the shale has been reached and passed. Thereafter, the shale is heated to a higher temperature in the range of 750-1000° F. or higher so as to complete the pyrolysis and produce oil from the shale. Usually the oil is re-

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covered from the bottom of the pyrolyzed mass of the shale. The invention makes use of the fact that oil shale can be heated at temperatures lower than the temperatures at which rapid pyrolysis occurs, until the minimum strength point of the shale is passed, without causing plastic flow of the shale.

The preheat temperature to be used depends upon the richness and depth pressure on the shale to be treated. Richer and deeper shales must be treated at lower temperatures and for longer periods of time than leaner and shallower shales.

In preheating and retarding oil shale rubble with hot gases, it is feasible to utilize steam (including saturated and super saturated steam), combustion gases, gases containing oxygen concentrations less than spontaneous ignition mixtures, etc. It is preferred to inject the hot gas into the top of the chimney and move the heat front downwardly thru the rubble. The advantages of using down-flow of gases instead of up-flow are:

(1) Gas density gradients due to the temperature gradient aid the flow of gases;

(2) The shale at the gas inlet is heated in less time to a higher temperature, thus producing a weaker rock structure, therefore the inlet should be at the top where the rock needs to support the smallest overburden load;

(3) As the gas cools on its path down thru the chimney, liquid oil will collect due to gravity at the bottom of the chimney where it is readily removed. This oil results from minor pyrolysis occurring at the relatively low preheat temperatures used.

It is also feasible to utilize a direct drive combustion starting from either the top or the bottom of the chimney, preferably from the top, wherein the preheating of the shale is effected by the hot gases emanating from the combustion zone and flowing downstream thru the oil shale. The combustion zone temperature is preferably maintained at or near the selected preheat temperature by controlling the oxygen concentration of the gas fed into the combustion zone and/or the rate of flow of combustion-supporting gas. The degree of preheating can be increased by either increasing the amount of recycled gases (off gas from the operation) or by the introduction of steam or water to the combustion-supporting gases. By the introduction of steam or water under pressure, the heat of condensation causes a large portion of the shale ahead of the combustion front to be heated to the saturation temperature of the steam at the system pressure. The amount of added gas (recycle steam or water) is normally in the range of about 5-50 weight percent of the injected air.

After completion of the retorting of a nuclear chimney, the rubble in a second nuclear chimney may be retorted with hot gas obtained from passing a cool gas thru the previously retorted hot chimney. Normally, the gas to be heated is passed upwardly thru the hot retorted chimney and introduced to the upper end of the unretorted nuclear chimney.

An important aspect of the invention is depicted in the accompanying drawing of which FIGS. 1, 2 and 3 are graphs showing various curves representing heat treatment of shale. Curve A of FIG. 1 demonstrates the change in compressive strength of a Green River shale having a Fischer assay of 27 gallons per ton when heated at 700° F. for varying periods. It will be noted that the compres-

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sive strength of the shale reaches a minimum of about 640 p.s.i. after heating at 700° F. for about 22 hours. As heating is continued after reaching this minimum compressive strength, the strength of the shale rapidly increases. Using a lower preheat temperature, such as 600° F., a higher minimum strength can be attained. Also, by utilizing a higher preheat temperature such as 750° F., a lower minimum strength would be obtained.

Curve B of FIG. 2 demonstrates the compressive strength at different preheat temperatures of an oil shale having a Fischer assay value of 19 gallons per ton. A core of this shale was held for 20 hours at the various test temperatures. In each case, the rate of heating to test temperature was 150° F. per hour. The core represented by Curve B reached a minimum strength of about 4100 p.s.i. at about 675° F.

Curve C represents compressive strength of a shale core having a Fischer assay value of 35 gallons per ton when heated in the same manner as the core of Curve B. This core suffered complete structural failure and reached zero compressive strength when heated for 20 hours at 700° F. It is quite clear from a consideration of Curve C that the preheat temperature for this rich shale must be maintained substantially below 700° F. such as at 600 or at 650° F. Curves B and C clearly demonstrate that shales of higher oil content must be preheated at lower temperatures in the range of 500–750° F. in order to maintain a minimum strength high enough to withstand compressive forces in the shale mass.

In obtaining Curves D, E, F, and G of FIG. 3, cores 10 and 12 of oil shale having Fischer assay values of 29.3 and 29.8, respectively, were maintained under a load of 500 p.s.i. while heating the cores at a rate of rise of 150° F. per hour in temperature. Curves D and E show the core length deformation-time relationship. Curves F and G show the time temperature treatment of the two cores. It can be seen that core 12 was heated to 840° F. where it failed or ruptured. Core 10 was heated to 700° F. and held at this temperature for about 40 hours after which it was raised in temperature to 1000° F. at a rate of rise of 150° F. per hour and held at 1000° F. for over 50 hours. Core 10 did not rupture but withstood the pressure of 500 p.s.i. during the entire heating sequence. Thus, FIG. 3 demonstrates that if the richest shale present in a shale mass in any appreciable extent is 30 gallons per ton and 500 p.s.i. is a sufficient compressive strength for the particular chimney to be retorted, then the shale can be heated to 700° F. for about 50 hours after which the temperature can be increased to 1000° F. without failure of the shale. The other data presented demonstrate that the strength of the shale increases after reaching the minimum strength point. Hence, after about 50 hours of heating at 700° F. a shale of 30 gallon per ton assay passes the minimum strength point and becomes stronger as it is retorted at a temperature of 1000° F., for example.

The data presented also demonstrate that with richer shales and greater loads, temperatures less than 700° F. are required to maintain the rock strength. As the temperature used to preheat the shale decreases, then the time necessary to get past the minimum strength point increases.

In direct drive combustion, the temperature to which the shale in advance of the combustion front is heated depends upon the gas flow rate and the oxygen content. By adjusting the amount of recycle gases, a low temperature zone (in the 500–700° F. range) can be created and maintained. This zone length and temperature can be adjusted to obtain the desired amount of preheating to cause the shale to develop the required strength. After this low temperature zone has been established and the minimum strength passed, the amount of recycled gases can be decreased to create a high temperature (750–1000° F. range) zone behind the low temperature zone.

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This high temperature zone then pyrolyzes a substantial portion of the shale and produces oil therefrom.

The table below sets forth the approximate minimum heating time required when preheating Green River oil shale of different assay values at different temperature levels.

TABLE I

Temperature (° F.)	Richness (gal. per ton)	Min. heating time at temp.
750.....	15-25	7 hours.
750.....	50	Do.
700.....	15-25	20 hours.
700.....	50	Do.
600.....	15-25	12 days.
600.....	50	70 days.
550.....	15-25	50 days.
550.....	50	700 days.
500.....	14-25	150 days.
500.....	50	2,000 days.

It can be seen from the table that the minimum heating period for reaching or passing the minimum strength of the shale is 7 hours for shales of 15–50 gallons of oil per ton even at 750° F. Heating for periods longer than the minimum heating time shown at the selected preheat temperature for a specific shale is not deleterious and can be practiced but it prolongs the total retorting time since the sooner the shale is raised to the relatively high retorting temperature, the sooner the retorting is completed.

Certain modifications of the invention will become apparent to those skilled in the art and the illustrative details disclosed are not to be construed as imposing unnecessary limitations on the invention.

I claim:

1. A process for producing shale oil in situ from a subterranean mass of fractured oil shale having a Fischer assay value in the range of 15 to 50 gal./ton, which comprises the steps of:

- (a) passing a stream of heating gas thru said mass of shale to preheat same;
- (b) controlling the heating in step (a) so as to preheat said shale to a temperature in the range of 500 to 700° F. and below that at which compressive strength of the shale fails at pressures existing in said mass;
- (c) continuing the heating of steps (a) and (b) for at least 7 hours and until the minimum strength point of the shale has been reached;
- (d) thereafter, continuing the heating of said shale at a temperature in the range of 750 to 1000° F. so as to pyrolyze same and produce oil therefrom; and
- (e) recovering the produced oil from the foregoing steps.

2. The process of claim 1 applied to a mass of shale rubble in a nuclear chimney, said gas being introduced to one end of said chimney and said oil being recovered principally from the bottom thereof.

3. The process of claim 2 wherein said gas comprises essentially combustion gas.

4. The process of claim 2 wherein said gas comprises essentially combustion-supporting, O₂-containing gas and a combustion zone is passed thru said mass.

5. The process of claim 1 applied to a mass of shale rubble in a nuclear chimney wherein a substantial section of said rubble is one end of said chimney is preheated to a combustion-supporting temperature substantially below the selected temperature of step (b) and ignited with air, thereafter air is fed to the resulting combustion zone at a controlled rate to maintain the preheat temperature in advance of the combustion zone at the selected level.

6. The process of claim 5 wherein H₂O is injected into the combustion zone to increase the heat capacity of the resulting gas.

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