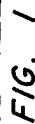


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PRODUCING OIL FROM NUCLEAR-PRODUCED CHIMNEYS IN OIL SHALE

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PRODUCING OIL FROM NUCLEAR-PRODUCED CHIMNEYS IN OIL SHALE

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10 Claims

ABSTRACT OF THE DISCLOSURE

Oil shale rubble in a nuclear chimney is produced by injecting a gas capable of heating and retorting the rubble at an elevated temperature into the rubble through a central borehole, venting produced gases through fractures surrounding the chimney into a ring of surrounding boreholes, and recovering liquid oil from the bottom of the chimney through either the central well or one or more of the ring wells.

This invention relates to a process for the in situ production of oil with hot gases from broken shale or rubble in a nuclear chimney formed in the oil shale.

The in situ retorting of shattered or broken oil shale in nuclear chimneys produced by positioning a nuclear explosive device in the shale and actuating the device is disclosed by M. A. Lekas and N. C. Carpenter in an article entitled "Fracturing Oil Shale With Nuclear Explosives for In-Situ Retorting" presented in the Quarterly of the Colorado School of Mines, volume 60, No. 3, July 1965, pp. 7-30. The nuclear chimney in an oil shale is a highly permeable mass of broken and displaced shale ranging in size from blocks 2 to 3 feet across to hand-size grains. A 250 kiloton explosive device set off in a thick shale formation is estimated to create a collapse chimney 400 feet in diameter and 1000 feet high. The permeability of the chimney shale makes it feasible to produce oil therefrom in situ with hot gas at a temperature of 500 to 1000° F. or by in situ combustion of a portion of the shale oil or kerogen in the shale and driving out another portion with resulting heat and hot gases. One of the problems encountered in retorting and production by in situ combustion is channeling of air or hot retorting gases which result in bypassing substantial areas of the chimney shale.

This invention is concerned with an improved method of in situ production of oil from nuclear chimney oil shale with hot gases which reduces channeling.

Accordingly, it is an object of the invention to provide an improved process for the in situ retorting and production of oil shale in a nuclear chimney. Another object is to provide a process for the in situ production of oil from nuclear chimney oil shale which decreases channeling of gases within the nuclear chimney. A further object is to provide such a process which makes more economical use of retorting gases than heretofore. Other objects of the invention will become apparent to one skilled in the art upon consideration of the accompanying disclosure.

A broad aspect of the invention comprises retorting or burning the rubble in a nuclear chimney horizontally in relatively short vertical sections by injecting the heating gas axially of the chimney and venting produced gases principally through fractures in the oil shale surrounding the nuclear chimney into a ring of boreholes drilled into the immediately surrounding fractured shale, the gaseous hydrocarbons being recovered from the ring wells and the liquid hydrocarbons gravitating to the bottom of the chimney from which they are recovered either through the central well or through one or more of the ring wells. A

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gas is used which is capable of heating the oil shale to a temperature of at least 500° F. and up to 1000° F. In one embodiment of the invention, hot combustion gas which may contain a substantial proportion such as fifty percent or more of recycled gas from the ring wells, is injected through the central well. Another embodiment of the invention comprises igniting a selected area of the rubble adjacent the central borehole and feeding a combustion-supporting, oxygen-containing gas, such as air, into the ignited area so as to move a combustion front substantially radially outwardly from the axis toward the peripheral wall of the chimney.

A more complete understanding of the invention may be obtained by reference to the accompanying schematic drawing of which FIGURE 1 is an elevation in partial section through a nuclear chimney in an oil shale with boreholes or wells arranged for production of the shale and FIGURE 2 is a similar view illustrating a different arrangement of boreholes or wells for producing the shale in the chimney.

Referring to FIGURE 1, a nuclear chimney 10 in an oil shale 12 is penetrated by a central or axial well or borehole 14 and a ring of surrounding boreholes 16 positioned closely adjacent chimney 10. Rubble 18 extends from a solidified melt area 20 in the bottom of the chimney substantially to the top of the chimney, leaving a void space 22 formed by settling of the rubble. The nuclear blast creating the chimney also creates innumerable fractures or fissures 24 extending radially outwardly from the chimney a substantial distance and boreholes 16 penetrate this fractured annulus surrounding the chimney.

Boreholes 16 are cased to the top of the oil shale by casing 26. Boreholes 14 is provided with casing 28 extending into the bottom of the borehole at least to the bottom of the chimney, with a tubing string 30 extending into the bottom of the borehole and terminating in pump 32. A gas injection line 34 connects with casing 28 above ground level for injection of air through the annulus between the casing and tubing. Casing 28 is perforated at 36 below packer 38 to provide for drainage of liquid oil into the bottom of borehole 14 for removal through pump 32 in conventional manner.

In the embodiment of the invention illustrated in FIGURE 1, heating gas such as hot combustion gas is introduced through line 34 and the annulus between casing 28 and tubing 30, passing through perforation 40 extending over a restricted vertical section of the casing. The hot gases resulting from contacting the rubble in the section of the chimney extending radially outwardly from perforations 40, including hot combustion gases and produced gases from the shale, pass through the fractures adjacent the chimney into boreholes 16 and are taken to processing equipment above ground. The hot gas injected through perforations 40 gives up heat to the surrounding shale and is cooled to a relatively low temperature before passing into the fractures and the surrounding ring wells. A hot retorting zone is created and moves outwardly toward the ring wells or boreholes. In accordance with one embodiment of the invention, this hot retorting zone is moved out radially from the central borehole a distance in the range of about 10 to 50 feet after which either perforations 40 are plugged or another packer is set above the uppermost perforations and a new set of perforations are formed in the next adjacent limited vertical section of casing. The next adjacent section of rubble is then produced in the same manner as the lowermost section with the gases moving radially outwardly to the ring boreholes. After extending the retorted zone to the desired radial distance from the axis of the chimney, injection through the next set of perforations is effected to

again extend the retorting zone to the desired depth. The vertical height of the individual sections sequentially produced is in the range of about 20-50 or 60 feet. Eventually a core of retorted or produced shale designated 42 is established surrounding central well 14. The residual shale in this core is consolidated and provides a ready flow path for oil produced from the surrounding unspent shale in the next phase of the process.

In the next phase of the operation, utilizing perforations in casing 28 within void space 22, the heat-producing gas is injected into the upper end of the annulus of rubble surrounding core 42 so as to progressively move a retorting zone downwardly through the annulus. During this phase of the operation, it might appear that the injected gases would bypass the annulus to be retorted, bypassing through the fractures radially opposite the retorting area. However, as the retorting area reaches the periphery of the chimney adjacent the fractures of the surrounding annulus, the gases leaving the retorting area are sufficiently hot to seal the fractures leading into the ring boreholes. As the fractures at the retorting area level are sealed off, the hot gases are forced into the subjacent unretorted shale, thereby progressively moving the retorting zone downwardly through the unspent shale until substantially the entire annular mass of shale surrounding core 42 has been produced.

In accordance with another embodiment of the invention, the horizontal section of shale or rubble extending radially outwardly from perforations 40 is produced progressively from the central well outwardly to the walls of the chimney, the hot gases sealing off the fractures at this level as the retorting zone reaches the periphery of the chimney. The next adjacent superimposed section is then produced in the same manner with the retorting zone moving radially outwardly from the perforations in casing 28 to the chimney wall. Near the end of this retorting phase, the fractures opposite the retorting zone leading into the ring boreholes are sealed off by the hot gases and the next adjacent section is produced in the same manner. Again, the operational steps are repeated until substantially the entire mass of shale in the chimney is produced.

Referring to FIGURE 2, the arrangement shown is similar to that of FIGURE 1; however, borehole 14 extends into the top of chimney 10 without extending to the bottom of the chimney. Passageway 44 connects the bottom of the chimney with one of the surrounding ring wells which is provided with a tubing string 46, terminating in a downhole pump 32.

Using the arrangement of FIGURE 2, the retorting or combustion-supporting gas is injected through line 34 into central borehole 14 from which it enters the top of the chimney and retorts or burns the rubble 18 as the gas progresses through the chimney. Packer 48 above pump 32 prevents flow of gas through the annulus of this well, thereby forcing the gases from chimney 10 through the fractures into the ring boreholes. As the hot retorting area in the rubble approaches the periphery of the chimney, the effluent gases from the retorting area are sufficiently hot to seal off the fractures at the level of the retorting area. This sealing effect pushes the retorting area deeper into the chimney and thus forces a progressive and sequential production of the oil shale in the chimney. The liquid oil produced by the hot gases gravitates through the rubble in the chimney and is produced through passageway 44 by means of pump 32 in conventional manner. Eventually the retorting zone is moved completely through the chimney to the bottom thereof with production of substantially all of the oil in the shale or rubble in the chimney.

In the event that the fractures do not heat seal as the shale is retorted at a given level, it is feasible to provide each of the ring wells with a casing and perforate the casing at successive intervals to provide for ingress of fluids during the retorting of a selected horizontal section

of the rubble of limited height. Such a perforated section is illustrated at 50. As the uppermost section of the rubble in the chimney has been substantially spent, cement is squeezed through the perforations in section 50 to seal off that section of the casing and prevent ingress of gases therethrough. The injected gases are then forced through a lower section of the rubble and egress through perforations in section 52 and as the boundary 54 between the hot spent shale and the unspent shale moves downwardly, another perforated section 54 is provided for egress for produced gases. Thus, the path for withdrawing gases from the chimney is progressively moved downwardly along the ring boreholes and the boundary 54 between the hot spent shale and the unspent shale is advanced essentially to the bottom of the chimney.

There may be any number of ring wells but four or more are preferred. A larger number of ring wells is more desirable with a larger nuclear chimney and vice versa. A maximum practical size of a nuclear chimney is about 600 feet in diameter and about 1,400 feet in height. Usually, a nuclear chimney will have a minimum diameter of about 100 feet.

Table I below illustrates the characteristics of a typical nuclear chimney.

TABLE I

Chimney characteristics for a 50-kiloton nuclear explosion at 3,000 feet

Radius -----	feet--	133
Height -----	do----	655
Bulk porosity (fractional) -----		.267
Void volume -----	feet ³ --	9.85×10^6
Total volume -----	do----	36.90×10^6
Oil shale rubble volume -----	do----	27.05×10^6
Oil shale rubble mass -----	tons--	1.86×10^6
Volume shale oil (kerogen) contained in rubble (assumed 25 gallons/ton) -----	bbbls--	1.10×10^6

Table II below illustrates process parameters for production of shale oil from a typical nuclear chimney using hot combustion gas with recycle in the embodiment of the invention illustrated in FIGURE 2.

TABLE II

Description of process

Shale oil yield (percent of Fischer assay) -----	70
Time to retort nuclear chimney (years) -----	1
Retorting temperature (F) -----	900
Injection pressure (p.s.i.a.) -----	100
Injection well diameter (inches) -----	26
Six production wells diameter (inches) -----	10
Recycle gas composition (vol. percent):	
Nitrogen -----	73
Carbon dioxide -----	13.5
Water -----	13.5
Recycle gas rate s.c.f./day -----	1.6×10^8

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 from the shale rubble in a nuclear chimney formed in an oil shale and immediately surrounded by an annulus of fractured shale having a plurality of vertically spaced apart generally radially extending fractures therein, there being provided a ring of boreholes within said annulus and communicating with said chimney through said fractures in said shale, and an axial borehole leading into the top of said chimney, which comprises the steps of:

(a) passing a gas capable of heating said shale to a temperature of at least 500° F. thru said central borehole into said rubble at a locus opposite only a portion of said fractures to effect said heating and produce liquid and gaseous hydrocarbons;

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(b) passing resulting gases from step (a) generally thru said rubble and said fractures into said ring boreholes thereby moving a hot zone of limited vertical expanse generally radially thru said rubble toward the upright periphery of said chimney and gravitating said liquid hydrocarbons to the bottom of said chimney;

(c) recovering said gases from said ring boreholes; and

(d) recovering said liquid hydrocarbons from the bottom of said chimney.

2. The process of claim 1 including the steps of:

(e) after substantial production in accordance with step (b), sealing off said fracture opposite said hot zone so as to force said gas to a new level in said rubble and extend said hot zone to said new level; and

(f) progressively extending said hot zone as in step (e) so as to substantially complete production of said rubble.

3. The process of claim 2 wherein said fractures are heat sealed by said hot gases.

4. The process of claim 2 wherein said fractures are sealed by a cement squeeze.

5. The process of claim 1 wherein said axial borehole is extended to the bottom section of said chimney and provided with a casing and a tubing string extending substantially to the bottom of said chimney; step (a) comprises injecting said gas thru perforation in said casing in a first restricted longitudinal section thereof adjacent one end of said chimney until substantial production of the rubble opposite said section is effected; thereafter injection thru said first section is terminated and injection of said gas thru a second adjacent perforated section is effected to produce the rubble opposite said second section; and production through additional sections in like manner is progressively effected toward the opposite end of said chimney.

6. The process of claim 5 wherein said chimney is at least 100 feet in diameter and each section of rubble opposite the several sections of perforated casing is produced only to a distance from said casing in the range of about 10 to 50 feet to form a central core of produced rubble and leave a surrounding annulus of substantially unproduced rubble; and said surrounding annulus is produced by injecting said gas thru perforations in said casing in the top section of said chimney while withdrawing produced gases thru said ring boreholes.

7. The process of claim 5 wherein said gas is a combination-supporting, oxygen-containing gas and said rubble is ignited and partially burned to produce hydrocarbons therefrom.

8. The process of claim 5 wherein said gas comprises essentially hot combustion gas.

9. The process of claim 1 wherein said gas is a combustion-supporting, oxygen-containing gas and said rubble is ignited and partially burned to produce hydrocarbons therefrom.

10. The process of claim 1 wherein said gas comprises essentially hot combustion gas.

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