Oct. 31, 1961 J. H. V. FINNEY 3,006,816

OIL SHALE RETORT AND METHOD

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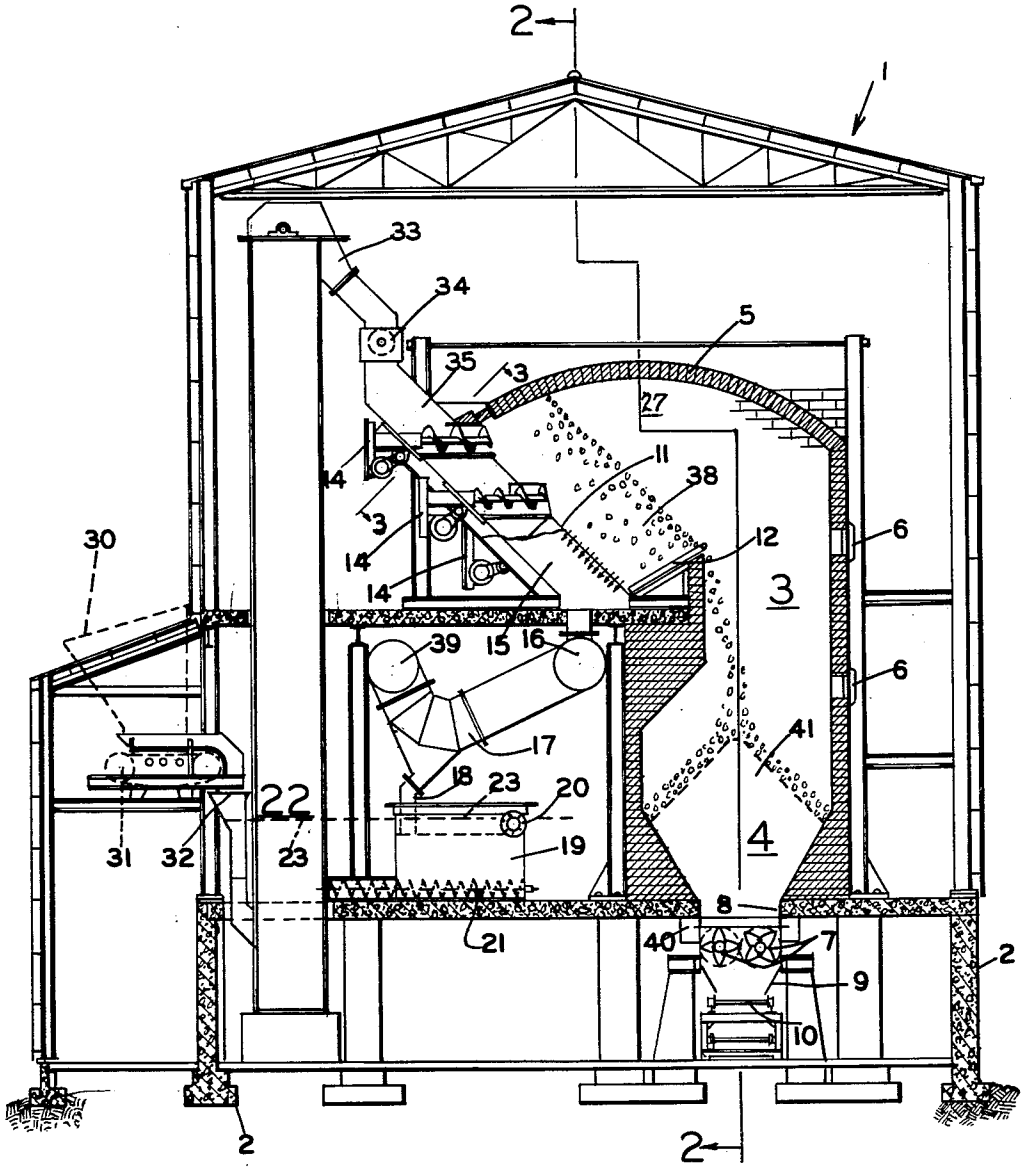


FIG. 1.

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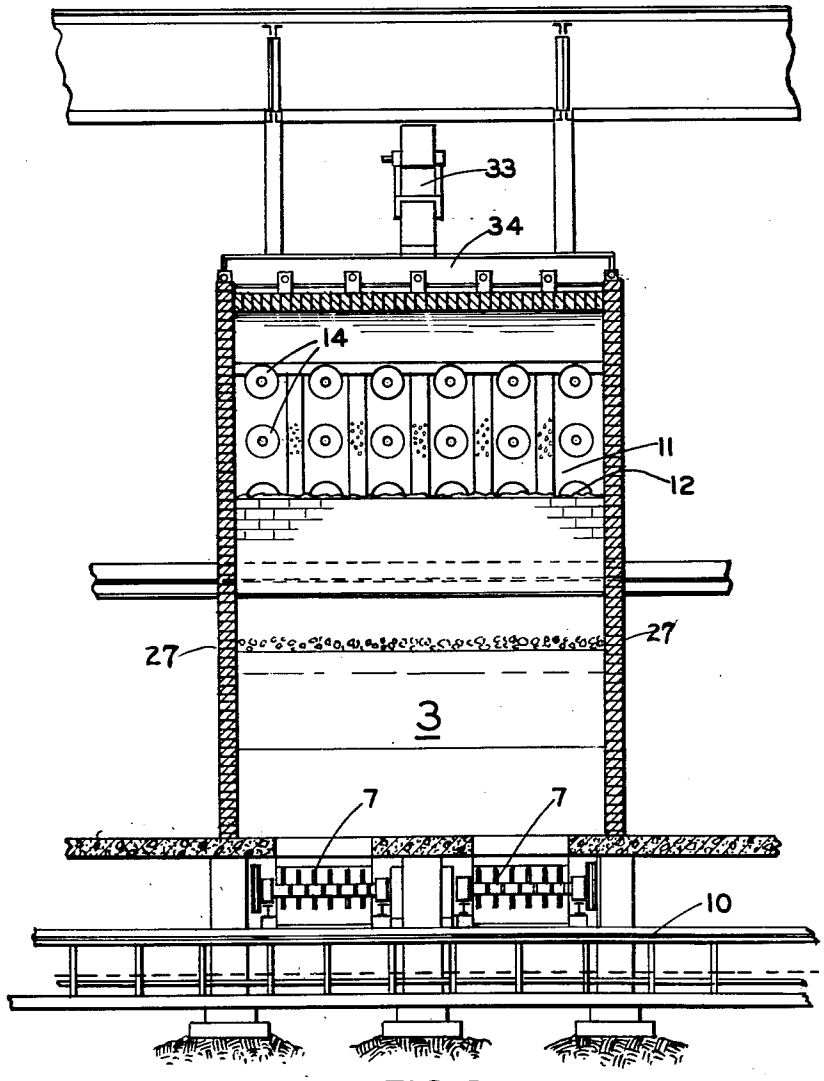


FIG. 2.

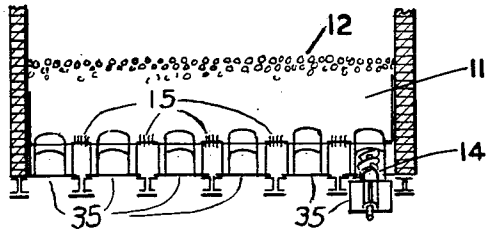


FIG. 3.

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OIL SHALE RETORT AND METHOD

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10 Claims. (Cl. 202—7)

This invention relates to apparatus and methods for the destruction pyrolysis of oil bearing shale.

There are vast deposits of a raw material called oil shale in the western part of the United States, principally in the States of Colorado, Wyoming and Utah. This raw material, which is not a shale but a marl stone, contains organic material in amounts from a trace to over 30% by weight, and generally a commercial deposit should average between 10.5 to 80 gallons of derived shale oil per ton of ore. The organic matter in Colorado oil shale is sometimes called kerogen, which is a high molecular weight substance of largely unknown structure. It is from this complex organic substance that a liquid hydrocarbon mixture, called shale oil, is formed by a pyrolysis. While the shale oil industry antedates production from oil wells by about twenty years, it has not become a commercial process in recent years due to the economy involved. Many designs have been suggested for retorts for performing the pyrolysis of shale oil, but to date none have been commercialized.

According to the present invention, there is provided a retort which includes essentialy three zones, that is, a combustion zone, a distillation or retort zone, and a preheating zone for combustion air which also cools the ash from the combustion zone. The retort includes the desirable feature of having an upward flow of shale and downward flow of gas and oil in the retort zone, but in the burning and ash cooling zone there is the desirable downward flow of shale and ash and an upward flow of air. The retort includes a lower combustion zone, and an upper retort zone subject to the gases of combustion from the lower combustion zone to perform the pyrolysis and the distillation of shale oil. The retort of the invention includes a simplified design wherein the interior walls of the retort may be made of fire brick in those parts which are subjected to high heat, and which may be constructed so that the depth of the beds of shale in the previous parts are not controlled by the size of the device but may be determined by the optimum operation of the retort. The simplified design of the present invention provides means for distributing the weight of contained shale so that it is easily supported, and so that there is no substantial increase of friction of the shale on the supporting walls of the vessel or an increase of size of the retort.

Included among the objects and advantages of the present invention is a simplified retort design which may be constructed of various sizes and utilize fire brick in the high heat and other desired portions of the retort. The weight of the shale in the various beds of the retort is distributed so that it may be adequately supported. The design of the retort of the present invention permits the distribution of shale beds in the retort to provide optimum depth determined by the process and not by the size of the unit. Further, the retort of the invention is very effective and provides a highly efficient process for economically performing destructive pyrolysis of shale. The retort design permits the use of fire brick or equivalent for economic construction.

These and other objects and advantages of the invention may be readily ascertained by referring to the following description and appended illustration, in which:

FIGURE 1 is a side elevational view in partial section showing the main elements of the retort of the invention;

FIGURE 2 is a front elevational view of the raw shale feed mechanism and bed support for the shale retorting; and

FIGURE 3 is a top plan view of the shale feeders and retort bed.

Generally, the retort of the invention may be described as an inverted U having one short inclined leg and one longer vertical leg. The short inclined leg is arranged to hold a bed of shale for the retort zone, while the longer leg is utilized for the combustion zone and the ash cooling zone. The retort zone, which includes a bed of raw shale, provides an outer pyrolysis zone on the surface of the raw shale and a cooling zone through the mass of the raw shale which condenses and cools the oil produced by the pyrolysis. The combustion zone, likewise, includes several distinct subzones, one of which is combustion space above a mass of spent shale and one of which is on the surface of the spent shale mass which is a combustion zone for residual carbon remaining on the shale after pyrolysis, and another is a cooling zone in the spent shale mass below the combustion zone where air for the combustion is heated and the ash or remaining shale is cooled. An oil lock is provided in the raw shale feeding zone to prevent blow back of the hot gases through the feed system and to prevent entrance of air into the retorting zone.

In the device illustrated in the drawings, a retort is housed in a suitable building **1** mounted on suitable foundations or the like **2**. The retort, which may be of any cross section or shape, but is preferably generally rectangular, includes an upright or combustion leg **3**. The leg **3** includes a lower conical section **4** and an upper arcuate roof **5** leaving a combustion space therebetween. The walls of the upright leg **3** are preferably made of a refractory or fire brick, as is the roof **5**. Inspection doors **6** may be provided in a retort wall for observing the operation of the device. A pair of rotary ash crushers **7** are mounted in the throat **8** of the conical section **4**, discharging through a chute **9** onto a pan conveyor **10**, or other suitable ash removal means. A sloping, foraminous wall **11**, having a bottom support wall **12** mounted substantialy at right angles or at a slight angle thereto, interconnects the left side of the roof **5** with the left upright wall of the chamber **3**. End walls **27** complete the retort.

A plurality of screw feeders **14** arranged in tiers extend through the sloped wall **11**, and provide shale feed from one side to the other of the wall **11** and from top to bottom thereof. Such screw feeders are well known and detailed description is not believed necessary. As shown in FIGURE 2, there are three horizontal banks of the screw feeders **14** and six vertical banks providing a total of eighteen screw feeders. The wall **11** is perforated between the several chutes **35** to permit oil and gas flow through and into the gas chambers **15** and to effectively prevent passage of shale. Gas chambers **15** interconnect the perforated wall and communicate with a manifold **16**. The manifold **16** collects gas and liquid passing through the wall **11**, and the mixture may then be passed through a gas and oil separator **17**. The treatment provides a countercurrent flow of gas and shale. Oil or liquid which is separated out of the mixture drops through a feed nozzle **18** into a settling tank **19**. An oil production outlet **20** adjacent the top of the tank provides a discharge for the clarified oil produced. Sludge, which settles out of the oil in tank **20**, is conveyed by a screw conveyor **21** into an elevator shaft **22**. The elevator shaft **22** is connected to the tank **19** by conveyor **21** so that an oil level **23** may be maintained in the elevator at the same height as the oil level in the tank **19**. This oil in the shaft provides a seal through which raw shale must pass before being charged into the retort, thus effectively

preventing the passing of air into the retort with the raw shale feed.

The wall **11** with its bottom support wall **12** is placed at an angle which is substantially equivalent to the angle of repose of crushed shale. The width of wall **12** generally controls the thickness of the shale bed. The angle of repose, for purposes of this specification, is that angle at which the shale particles on the surface of a pile of such shale slide down the pile. As shale is forced into the bed, the surface of the shale extends beyond the repose surface and so the surface particles must slide down the pile. The angle of repose of the shale surface after pyrolysis is about 45°. By sloping the wall **11** at about 45°, a bed of shale **38** of relatively uniform thickness may be maintained. Optimum efficiency of the operation is achieved by maintaining the bed **38** at a uniform thickness determined by the width of wall **12**, and by feeding shale substantially uniformly across the extent of the under surface of the raw shale bed.

Crushed ore in a minus four inch size, that is all to pass a four inch opening, is fed from a crusher (not shown) into a hopper **30**. The hopper or ore bin **30** feeds onto an apron or other suitable feeder **31**, which is provided with a variable speed drive for varying the feed rate into a chute **32** discharging into the elevator shaft **22**. The top of the chute **32** is above the oil level **23**, but passage to the elevator shaft is well below the oil level thus effecting an air seal. The oil shale drops into the oil in the bottom of the elevator shaft **22**, and an elevator, not shown but which may be any suitable type conveyor such as a bucket conveyor or the like, picks up the oil shale in the elevator shaft. The shale is moved upwardly in the shaft, while preferably the shale is drained of excess oil, to the top where it drops over the top into a chute **33**. The chute **33** discharges into a shale distributor **34** which is a screw conveyor for uniformly distributing the shale from the elevator into feeder chutes **35** leading to the individual feed conveyors **14**. The elevator shaft **22**, the distributors, and the feeders should be air-tight to prevent introducing air with shale.

Air for combustion is drawn into the retort by an induction fan, not shown, which draws the air through a pile of spent shale **41** in zone four. The air, heated as it passes through the shale bed **41**, is the air for burning carbon or the like on the shale in bed **41**. The products of combustion then pass through the shale bed **38**, resting on walls **11** and **12**, thus pyrolyzing the shale. The fluid materials passing through raw shale bed **38** are drawn through the foraminous wall **11** into the manifold, and gases are separated from the oil and are ultimately discharged through an exhaust pipe **39** which leads to the fan (not shown). As air is drawn into the bottom of the retort, which may be through a chamber **40** or through the grate **7**, it passes up through the ash **41** (the residue after burning residual carbon on the shale). The pile of ash not only heats the air but the air cools the ash. The air cools the ash sufficiently so that it is discharged at a temperature of about 800° F. The incoming air is simultaneously heated sufficiently to cause burning of the residual carbon or organic matter remaining on the spent shale falling from bed **38**. The spent shale from the pyrolysis is low grade fuel on the order of 500–600 B.t.u. per pound. The air must be heated to cause combustion, and an effective design requires the air to be heated to about 1390° F. before it enters the top layer of bed **41** for combustion. Hot gases resulting from the combustion pass upwardly through chamber **3** and are directed through the raw shale bed **38**. The gases of combustion, which are at a temperature of about 1650° F., heat the raw shale bed which in turn cools the gases and products of pyrolysis. This heating is sufficient to cause an efficient pyrolysis of the kerogen to form "shale oil." The resultant shale oil and gases pass through the pile of raw shale, thereby being cooled and condensing the shale oil. The cooled products are recovered at a temperature of 150° F. which is cool enough to insure optimum recovery of oil. Spent shale slides from the surface of the bed **38** (being pushed by incoming shale) and falls on the bed **41**.

For a commercial operation a retort should preferably be able to retort about 1000 tons of shale per twenty-four hours. For such an operation, the retort has a width of about 15 feet and a length of about 24 feet, with a height of about 36 feet from ash crusher to roof. Using shale which produces not less than about 25 gallons of oil per ton, the shale throughout rate ranges from about 135 to 300 pounds per hour per square foot of retort cross section, depending on the size of the raw shale fed to the retort. Estimating that oil shale contains about 2% surface moisture and the shale contains about 15% organic material in the form of kerogen, the following table shows the operational rates on an hourly basis.

Quantities—hourly rates

		Lbs./hr.
(1)	Weight of wet feed @ 1,000 tons/day	83,400
(2)	Weight of mositure	1,670
(3)	Weight of dry feed	81,730
(4)	Weight of kerogen in feed 15% of (3)	12,260
(5)	Weight of inorganics in feed (3)–(4)	69,470
(6)	Weight of CaO in feed 28% of (5)	19,450
(7)	Weight of $CaCO_3$ equivalent to (6)	34,700

Retort yield

(8)	Shale oil 85% of (4)	7,970
(9)	Shale gas 10% of (4)	1,225
(10)	Carbonaceous residue 25% of (4)	3,065

Passing into combustion zone

(11)	$CaCO_3$ (7)	34,700
(12)	Silicious and metallics (5)–(7)	34,770
(13)	Total inorganics (5)	69,470
(14)	Carbonaceous resin (10)	3,065
(15)	Total passing into combustion zone	72,535

Combustion

(16)	Carbon burned—assume 85% of (14)	2,600
(17)	Carbon unburned—15% of (14)	465

Carbon burns as per chemical reastion:

$$C+O_2=CO_2$$

Mol wts.: 12+32=44.

(18) Wts. reacting: 2,600+6,930=9,530 lbs./hr.
But air is used for oxygen: Air=23% O+77% N.

(19) Air required=30,130 lbs./hr.; air=6,930 oxygen+23,200 nitrogen.

Note.—Item (8) is equivalent to 587 barrels/24 hr. day.

The marlstone contains carbonates which decompose at the temperature of the burning zone, and the decomposition is endothermic so that in fully considering the material and heat balance of the retort, the decomposition of the carbonates must be taken into consideration.

In providing a typical operation as shown in the table, average temperatures are considered in the operation of the retort, that is, the ambient temperature of air is taken at an average of 60° F., the shale feed temperature is taken at 60° F., and the temperature of the combustion zone is 1650° F. The temperature of the gas leaving the retort through wall **11** is maintained at 150° F. which is sufficient to condense the shale oil. The optimum temperature of the ash discharge is about 800° F., which is controlled by the rate of ash discharge and the throughput rate of air through the bed **41**. The spent shale falling from the bed **38** onto the bed **41** is approximately 1035° F.

The wall **11** of FIGURE 1, for a 1000 ton per day retort, is about 13.7 feet wide by 23 feet long between the sidewalls, and wall **12** is about 5 feet so that the

depth of the bed **38** may be maintained about 5 feet with a slope of about 45°. The approximate area of wall **11** is 300 square feet providing approximately 1500 cubic feet of retort bed.

Since the shale is crushed to about four inch lumps, a twenty inch diameter screw is required for effective feeding. The feeders **14**, mounted in three banks of six, effectively cover the area, and these eighteen screw feeders satisfy the requirement of uniformly feeding the entire area of the bed **38**. Each of the screw feeders requires about a one horsepower motor. Other types of feeders may require different power consumption. The size of the burning zone on bed **41**, assuming that the carbon residue on the spent shale may be burnt at the rate of about twenty pounds of carbon per hour per square foot, requires about 153 square feet of area, taking into account the slope of the bed.

Where desired, a gas separator, such as a cyclone separator, may be installed in the gas line leading from the manifold **16** so as to provide an efficient separation of oil from the oil-gas mixture passing from the bed **38**. Also, in place of settling tank **19**, a standard thickener may be used for separating sludge from oil. While an elevating device is shown having an oil seal to prevent air from entering the feeders, other types of devices for conveying shale to the feeders may be used, especially such devices in which it is possible to seal air from the raw shale bed. The screw feeders as illustrated provide a simple and economical means for feeding the bed **38**, however, ram feeders may also be used for feeding the bed. In certain instances, it may be desirable to recycle some of the separated gases into the combustion zone, and this may be easily accomplished by passing a portion of the gas into the duct **40**. In the operation of the retort the stream of gas through the beds is described as air induced draft from a suction fan, however, it may be a forced draft from the air inlet side.

While the invention has been illustrated by reference to a specific device, there is no intent to limit the spirit and scope of the invention to the precise details so set forth, except insofar as defined in the appended claims.

I claim:

1. A shale oil retort comprising an upright combustion chamber having means for supporting a bed of spent shale in its lower portion and having an air inlet at its bottom, means in the upper portion of said chamber for supporting a relatively shallow biased bed of raw shale of substantially uniform thickness, said shale bed supporting means comprising (1) a sloped foraminous rear wall defining the under surface of said raw shale bed and forming a common outlet for oil and eduction gases and (2) an intersecting support wall extending forwardly therefrom, said support wall being juxtaposed above the combustion chamber in position to permit shale to fall from the raw shale bed substantially centrally of said spent shale bed, means for feeding raw shale substantially uniformly into the entire under surface of said biased shale bed so as to push shale from the upper biased surface thereof, means for directing air through said inlet and through said spent shale bed for burning contained residual carbon and then directing the hot gases of combustion substantially uniformly through said biased raw shale bed generally countercurrently to the shale feed so as to cause a pyrolysis of the shale for oil recovery, and means for discharging ash and oil separately from said chamber.

2. A shale oil retort as defined in claim 1 wherein said means for feeding raw shale comprises a plurality of feeders.

3. A shale oil retort as defined in claim 1 wherein said means for feeding raw shale includes an air seal to prevent the induction of air with the raw shale feed.

4. A shale oil retort comprising an upright combustion chamber of substantial vertical extent having means in its lower portion for supporting bed of spent shale and

having means for the introduction of air for combustion arranged to pass through such a bed of spent shale, a sloped foraminous wall in the upper portion of said combustion chamber arranged to support a relatively shallow bed of raw shale of substantially uniform thickness at substantially the angle of repose of the shale resting on said foraminous wall, said foraminous wall forming a common outlet for oil and eduction gases, a support wall extending forwardly from said foraminous wall and being juxtaposed above the combustion chamber in position to permit shale to fall from the raw shale bed substantially centrally of said spent shale bed, means for feeding raw shale into said raw shale bed substantially uniformly across the extent of said foraminous wall, means for sealing said raw shale feed to prevent the passage of air with fed shale into said bed of raw shale on said foraminous wall, means inclusive of at least one chamber below said foraminous wall for inducing a draft of air through said bed of spent shale for combustion of contained residual carbon and then directing the resultant gases of combustion substantially uniformly through said bed of raw shale from the upper to the lower surface thereof to cause a pyrolysis of the shale for oil recovery, and means for separately removing ash and oil from said chamber.

5. A shale oil retort comprising an upright combustion chamber of substantial vertical extent, having a combustion grate in the lower portion of said chamber arranged to support a substantial bed of spent shale and arranged to admit air for combustion through such a bed of spent shale, a biased foraminous wall mounted in the upper portion of said chamber arranged to support a relatively shallow bed of raw shale of generally uniform thickness and arranged with the surface of such a bed disposed at its angle of repose, said foraminous wall forming a common outlet for oil and eduction gases, a support wall extending forwardly from said foraminous wall and being juxtaposed above the lower portion of the combustion chamber, means for feeding raw shale substantially uniformly across said foraminous wall into the lower surface of said raw shale bed, so as to push shale through the bed and to cause shale to fall by gravity from the upper surface of said raw shale bed to substantially the middle of said spent shale bed, means for sealing said feed means to prevent entrance of air with raw shale feed, means for inducing a draft of air through said grate and said bed of spent shale for combustion of contained residual carbon and then directing the resultant gases of combustion substantially uniformly countercurrently through said bed of raw shale from the upper to the lower surface thereof, means associated with said draft inducing means for separating oil and eduction gas, means for recovery of separated oil, and means for removing ash from said bed of spent shale.

6. A shale oil retort as defined in claim 5 wherein said means for feeding raw shale comprises a plurality of feeders.

7. A shale oil retort as defined in claim 5 including means for mixing a portion of the eduction gases with the gases of combustion prior to directing said gases of combustion through said raw shale bed.

8. A process for the continuous retorting of oil shale for the pyrolysis of organic material contained therein which comprises maintaining a spent shale bed of substantial thickness in the lower portion of a combustion zone, maintaining a biased relatively shallow uniform depth raw shale bed in the upper portion of said combustion zone, the angle of the surface of said raw shale bed being maintained at the angle of repose of the shale under treatment, continuously feeding raw shale into the under surface of said raw shale bed uniformly throughout the extent thereof to thereby maintain a relatively uniform depth raw shale bed and to progressively move upper layers of said raw shale bed beyond the angle of repose whereby surface shale of said raw shale bed falls

by gravity onto said spent shale bed, directing a stream of air through said spent shale bed to simultaneously cool the spent shale and to heat air for the combustion of residual carbon in the spent shale bed, drawing hot gases of combustion from said combustion zone substantially uniformly through said raw shale bed generally countercurrently to the raw shale feed to said raw shale bed to pyrolyze the organic material contained therein for oil recovery, removing oil and eduction gases from said raw shale bed through the same outlets, said outlets distributed substantially coextensively over the under surface of said raw shale bed, removing the recovered oil from the treatment, and removing ash from the bottom of said spent shale bed at a rate sufficient to maintain a desired depth therein.

9. A process for the continuous retorting of oil shale for the pyrolysis of organic material contained therein which comprises maintaining a spent shale bed of substantial thickness in a lower portion of a combustion zone, maintaining a biased relatively shallow uniform depth raw shale bed in the upper portion of said combustion zone, the angle of the upper surface of said raw shale bed being maintained at the angle of repose of the shale under treatment, continuously feeding raw shale substantially uniformly into the under surface of said raw shale bed throughout the extent thereof to thereby maintain a relatively uniform depth raw shale bed and to progressively move upper layers of said raw shale bed beyond the angle of repose whereby exhausted shale slides along the raw shale bed surface and falls by gravity onto said spent shale bed, directing a stream of air through said spent shale bed to simultaneously cool the spent shale and to heat air for the combustion of residual carbon in said spent shale bed, drawing hot gases of combustion from said combustion zone generaly countercurrently to the feed thereto to pyrolyze the organic material contained therein for oil recovery, removing oil and eduction gases from said raw shale bed through the same outlets, said outlets distributed substantially coextensively over the under surface of said raw shale bed, separating resulting oil from the gas, and continuously

removing ash from the bottom of said spent shale bed at a rate sufficient to maintain a desired depth therein.

10. A process for the continuous retorting of oil shale for the pyrolysis of organic material contained therein which comprises maintaining a relatively shallow biased uniform depth raw shale bed in the upper portion of the chamber subject to continuous feed throughout the extent of the lower surface thereof so as to push shale from the upper biased surface of said raw shale bed, the bed of raw shale being maintained at a relatively uniform thickness and its upper surface being maintained at substantially the angle of repose of the shale under treatment, maintaining a spent shale bed in the lower portion of the chamber in position to receive shale falling from said raw shale bed, discharging ash from said spent shale bed at a rate to maintain a uniform thickness thereof, directing a draft of air through said spent shale bed for combustion of residual carbon therein, whereby the air for combustion is heated on its passage through the spent shale, directing the gases from combustion and a portion of the hereinafter defined product gases substantially countercurrently to the raw shale feed to said raw shale bed so as to pyrolyze the organic material in said raw shale bed and to simultaneously cool resultant product gases and condense resultant oil products on passage through said raw shale bed, removing said condensed oil products and said cool gases from said raw shale bed through the same outlets, said outlets distributed substantially coextensively over the under surface of said raw shale bed, and separating oil from the gas-oil mixture passing through said raw shale bed.

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