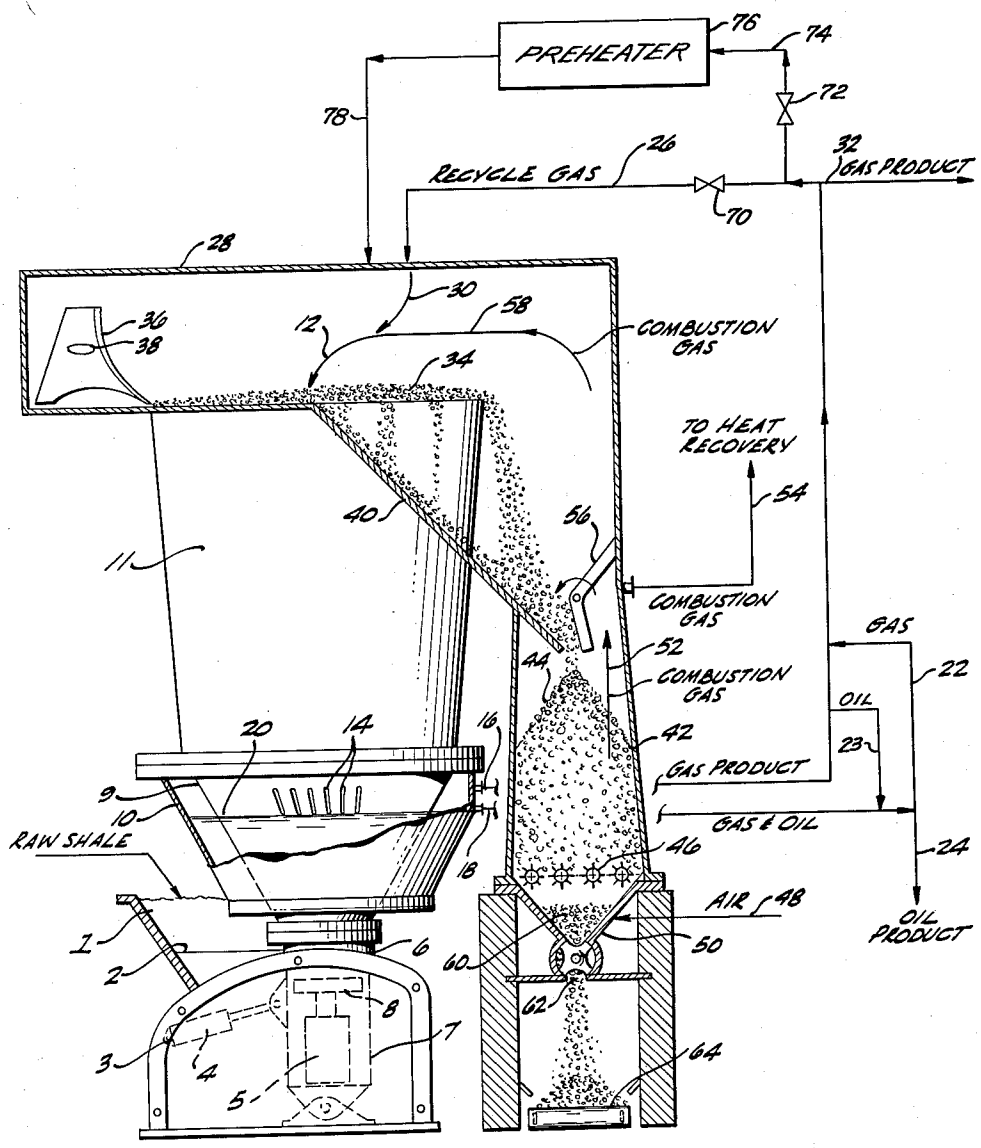
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APPARATUS AND METHOD FOR RETORTING OF OIL SHALE

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APPARATUS AND METHOD FOR RETORTING OF OIL SHALE

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This invention relates generally to a process for heat treating of oil-containing or oil-producing solids to produce hydrocarbon oils and gases therefrom. The invention particularly is well adapted to the retorting of oil shale to produce shale oil and gas.

An excellent process for shale oil production is that shown in the patent to Berg, U.S. 2,501,153, in which combustion of carbonaceous residue at a high zone within an inverted frusto-conical chamber fed with shale solids from the bottom produces combustion gas which moves downward and educts shale oil and gases from raw shale at a lower zone. The educted shale oil and gases are removed through openings in the unitary chamber just above the entry position of raw shale. In this process, since both the eduction step and the combustion step are carried on in the same chamber, it is difficult to vary the conditions of the two steps independently. Thus the temperature, flow rate and composition of the combustion gas largely determine the conditions of the eduction. A process in which the two steps are carried out more independently is shown in U.S. patent to Ogorzaly et al. 2,689,787. In this process however, it is essential that the spent shale produced in the eduction zone be pulverized before being subjected to combustion, since the latter is carried out in the fluidized state. This is not only unnecessary, but makes it impossible to obtain the benefits of moving bed combustion, such as smaller equipment, simpler control, higher temperature, etc.

It is, therefore, an object of the present invention to provide an improvement of the above oil shale retorting processes, in both flexibility and efficiency.

Briefly, the invention is carried out in a process comprising a substantially continuous upward feed of coarse oil-producing particles of up to about six inches, preferably in the size range of ¼ inch to 4 inches, in a retort having a horizontally enlarging area with increase in eleveation. Produced gases, vapors and liquids along with eduction fluid are removed just above the bottom entry location of the particles. An eduction gas mixture of controlled temperature not greater than about 1500° F., a controlled composition, and of a volume sufficient to maintain the desired solids temperatures and the desired product gas, is supplied to the top of the eduction zone. Particles, having had optimum oil quantity produced therefrom in the eduction chamber but containing a combustible carbonaceous residue, are transferred substantially unbroken in size from the top of the eduction chamber to the upper part of an adjacent combustion chamber having downward and outward flared interior sidewalls. The particles flow downward in a compact moving mass through the combustion chamber. Combustion supporting gas, such as air, is provided to the lower part of the combustion chamber to burn the carbonaceous residue and to produce hot combustion gas at a temperature greater than about 2100° F. This, when selectively mixed with cooler recycle gas obtained from the bottom of the eduction zone, provides the desired eduction gas.

The process of the invention will be more readily understood from the following detailed description and accompanying drawing showing apparatus with a schematic representation of material flow for practice of the process.

Referring to the figure, rich coarsely crushed oil shale, preferably all of which is one-fourth to 4 inches in size and not greater than six inches in size, is introduced from crushers into shale hopper 1 and is then passed down through a hopper oil liquid level 2 to a conventional upward forcing solids feeding apparatus contained in feeder case 3. The feeder apparatus in feeder case 3 may take the form of that shown in Berg, U.S. 2,501,153, or it may be of the form substantially as represented in which tilt controlling hydraulic cylinder 4 and vertical feeding hydraulic cylinder 5 have respective pistons operated therein in properly timed sequence so as to take on a shale charge at hopper 1 and then position vertically to force raw shale upward through vertical throat 6. Large cylinder 7 holds the fed shale charge supported on large feeder piston 8 therein. The shale solids comprise a minimum of smaller size particles. The larger size particles remain preferably as unchanged as is possible in exterior physical size and configuration throughout the retorting process. Shale moves upward through throat 6 and through frusto-conical section 9 which is surrounded by an outer chamber 10 shown in cut-away section. From section 9 shale moves upward into and through eduction chamber 11, having the form of an inverted conical section. Spent shale is removed at the top of eduction chamber 11 by means as will be hereinafter explained.

Hot eduction gas, preferably at about 1050° F. to 1250° F., and less than about 1500° F. maximum temperature, represented by the arrow 12, passes downward into and through the counter-current upward flow of shale. Shale in the eduction zone preferably need not exceed 970° F. when contacted by the hot gas. These lower temperatures substantially limit carbonate decomposition while still providing complete eduction.

The eduction gas 12 is generally effectively supplied at a superficial mass velocity of 135 to 535 pounds each hour per square foot of bed cross section at the surface of the eduction zone for oil shales having a Fischer assay range of about 70 gallons per ton to as low as 25 gallons per ton. The shale which has been previously heated to a large extent by hot oil flowing into frusto-conical section 9 is further heated to a temperature approaching that of the eduction gas 12 coming in contact with the shale. In any event, the temperature in the eduction zone is low enough to avoid substantial carbonate decomposition therein. Over the vertical distance of the eduction chamber 11, substantially all producible oil is educted from the shale along with volatile hydrocarbons which together pass out through equally spaced peripheral slots 14 in frusto-conical section 9 which may be designated a separation section.

Outer chamber 10, which receives the volatile hydrocarbons through the top of slots 14 and which receives the liquid oil through the bottom of the slots 14, may be designated a separation chamber from which gas product is removed through line 16 and oil product is removed through line 18, respectively, above and below a controlled liquid level 20 in chamber 10. For simplicity of illustration, gas blower means, liquid oil pumping means and controlling means for product removal are not shown, as conventional apparatus may be used and such form no part of the invention. Line 18 contains some entrained gas and line 16 contains some entrained oil. The respective minor contaminating gases and oils in oil line 18 and in gas line 16 may be separated by any, or a combination of, conventional means and joined with like product lines by means of lines 22 and 23, respectively. Oil product passes off through line 24 to storage facilities, not shown. A substantial portion of gas product is recycled via line 26 through a pressure tight hood enclosure 28 and comprises the principal portion of gas 30 which makes up the eduction gas 12. Alternatively, this re-

cycled portion of product gas can be preheated prior to mixing with the combustion gases by closing normally open valve **70**, opening normally closed valve **72**, and conducting the recycled portion of product gas through line **74**, preheater **76** and line **78** into hood enclosure **28**. A lesser portion of product gas is taken off at line **32** which it is necessary to remove due to normal gas formation in the system and to combustion gas additions thereto, as will be shown.

Solids **34** at the top of the eduction chamber **9** are pushed off the central area of the rising solids mass by a scraper blade **36** which is driven by electric motors, or the like, mechanically connected to attachment means such as **38** at the ends of the scraper. The scraper blade **36** may be operated to tip out of engagement with the solids **34** when returning in the reverse direction to the original scraping position shown. The solids **34** collected by the scraper are removed by gravity by way of a surrounding spillway **40** which transfers the solids to a central area of a combustion chamber **42**. The spillway **40** may, if desired, have an upper terminus which commences 180 degrees around the eduction chamber with respect to the central area of its lower terminus so that scraper apparatus may be constructed to scrape in both directions. The scraper blade **36** preferably has a slope such that, with its forward movement during scraping, solids **34** are forced forward and slightly upward which minimizes agitation of solids on the bed surface by way of rolling and abrading against one another. Preferably the scraper blade **36** moves in a constant direction path rather than along a curved or a partially curved path. It is also preferred that scraping means moves with a straight thrust rather than with a rotary sweeper type action. The preferred movement of the scraper recited above provides for a minimum of particle agitation in comparison to the more involved diverse scraping movements. It is apparent that variously modified scraper blades and shallow scoop devices may also provide such minimal agitation movement of shale particles.

The combustion chamber **42** has interior sidewalls which flare outward so that solids **44**, substantially unbroken in size from the eduction chamber, may settle downward to be ejected from the bottom of the combustion zone by mechanically moved supporting grates **46**. The combustion chamber may be lined with heat-withstanding refractory brick, or may be constructed as shown of heat-withstanding and corrosion-proof metal. The combustion chamber **42** preferably has a solely rounded configuration in cross-section, either a circular or an oval shape being most suitable, so as to minimize edge resistances to downward movement of hot solids. Sufficient height is provided the combustion chamber to give it a hot combustion bed volume adequate to burn all, or as much as desired, of the carbonaceous deposits which are left on the shale solids **34** at the top of the eduction chamber. The burning takes place with the aid of a controlled volume of air which enters hopper **50** below the grates **46** through one or more lines **48**. Air volume is carefully controlled so that no excess of oxygen is available in the combustion gas **52** which moves upward from the burning coarse particles of solids **44**. If desired, the recycle gas **26** from the bottom of the eduction chamber may be pre-heated, prior to entry into hood **28**, to a temperature within the range of about 500° F. to about 1,000° F. by indirect contact with these hot combustion gases, or with part of them, such as the gases withdrawn through line **54** or those that are passed through damper **56**, or by indirect contact with hot shale ash. With such an arrangement, a lesser amount of combustion gas **52** is required to obtain sufficient eduction gas **12** with adequate heat content than in the instance where the recycle gas **26** is not pre-heated.

As an alternative to burning the carbonaceous shale, or in combination therewith, steam may also be introduced into hopper **50**, as for example through line **48**, with or without air, to give a water-gas reaction with the hot carbon residues on solids in chamber **42**. The gases produced in the water-gas reaction of steam and carbon may then form a part of the eduction gas **12**. The burning of carbonaceous solid residue on the shale in combustion chamber **42** takes place at upwards of 2100° F. which gives a high temperature combustion gas. Combustion gas is drawn off in controlled amounts through line **54** exiting from within the chamber below a pivoted damper **56**. Damper **56** is designed, as shown along a pivot view, to substantially block passage of gas between the combustion chamber and eduction chamber, if desired, while still admitting shale solids from the spillway **40**. Damper **56** may be rotated by external control counterclockwise, as viewed, so as to admit controlled amounts of combustion gas **58** on either side of its pivot, which gas then mixes with the recycled product gas **30** to form the controlled volume and temperature eduction gas **12**.

Shale ash **60** collected in hopper **50** is removed by a star feeder **62** and is then carried away by a belt conveyor **64** to a refuse pile. Combustion gas **54** removed from the system is also at a temperature of about 2100° F., or above, and may be used to preheat recycle gas as described above, or sent to waste heat boilers for the production of auxiliary power, or the like.

The burning of carbonaceous solid residue on relatively unbroken coarse particles of solids **44** provides not only a combustion bed which is relatively open and having a greater over-all average density than a fluidized bed, but also a combustion gas substantially free of fine solids in the form of finely divided fly ash, such as is produced by a fluidized bed.

The foregoing process provides for high oil yield at a low temperature eduction which is very exactly controlled by the temperature modifying hot combustion gas added to the recycle eduction gas between the combustion zone and the eduction zone. The eduction gas contains no excess free-oxygen with which the educted oil can combine chemically to reduce oil quality. Eduction gas is primarily made up of recycle gas which is natural and compatible with the eduction zone since it is produced there as well. Combustion of carbonaceous shale residues takes place in a separate combustion zone which permits easier generation of hot modifying combustion gas without risk of oxygen contamination of the eduction zone oil. The combustion is accomplished on solids of substantially unbroken coarse particle size producing an open uncompacted bed with little or no production of fine solids in the combustion gas. A specific example of the process as applied to Colorado oil shale is shown in the following tabulated data:

Eduction chamber solids entry	5.5 ft. diameter.
Eduction chamber solids exit	17 ft. diameter.
Eduction chamber height (total including product separation slot area)	25 ft.
Solids feed rate	1000 tons (dry weight) per day.
Solids size range	+8 mesh to −6 inches.
Shale solids (Fischer assay)	35 gal. per ton.
Oil recovery	100% F.A.
Combustion gas temperature	2100+° F.
Recycle gas temperature	160° F.
Eduction gas temperature	1050 to 1250° F.
Gravity of recovered oil	22° API.
Eduction gas volume	1600 ft.^{3} per ton shale (dry weight).
Combustion chamber: [1]	
Combustion chamber top cross-section	240 ft.^{2}.
Combustion chamber bottom cross-section	270 ft.^{2}.
Combustion chamber solids bed height	9 ft.

Total combustion gas produced	700 ft.³ per ton shale (dry weight).
Volume of eduction zone per volume of combustion zone	0.7 ft.³/ft.³.
Particle size distribution (raw shale) by weight:	
Less than ½ inch	5%.
½–2 inches	45%.
2–4 inches	45%.
4–6 inches	5%.

[1] Optional combustion chamber dimensions:
Top cross-section—190 to 300 ft.².
Bottom cross-section—210 to 350 ft.².
Solids bed height—1 to 15 ft.

Advantages of the invention resulting from a separate combustion zone in the foregoing process for eduction of nonfluidized oil shale includes the opportunity to more exactly determine and control optimum conditions of eduction as indicated by resulting oil yield. The eduction zone is separate and may therefore have its conditions such as eduction fluid volume, temperature, and the like, selectively maintained for best results rather than as dictated by the requirements of the process step of another zone, such as for generation of an eduction fluid. Advantage of the invention over a fluidized process includes reduced equipment size per unit of oil shale processed. Such reduced equipment size results from the fact that fluidization of particles generally includes some means of expansion of the overall volume occupied by oil shale particles so as to insure effective contact of all particles with the fluidized process conditions.

Although the above specification and specific example in the tabulated data indicate the preferred apparatus and mode of practice comprising the invention, it is to be understood that others skilled in the art may devise modifications still within the spirit and scope of the express limitations included in the following claims which define the invention.

I claim:

1. An apparatus adapted for the continuous eduction of shale oil and the independent combustion of spent shale to furnish hot gases for said eduction which comprises: a vertically disposed eduction chamber which increases in cross-section with increase in elevation, said eduction chamber having means in its lower peripheral sidewall for removal of fluids without substantial removal of solids, means for passing a substantially compact moving bed of said oil shale particles upwardly through said eduction chamber, a vertically disposed combustion chamber having a construction such as to increase in cross-section with decrease in elevation, said combustion chamber being disposed lateraly from and below the top of said eduction chamber, means for transfer of upwardly fed oil shale particle solids from the top of said eduction chamber to said combustion chamber with a minimum of agitation, means for withdrawing solids from the lower part of said combustion chamber so as to maintain a compact bed of substantially uniformly flowing particles therein, means for introducing oxygen-containing gas at the bottom of said combustion chamber substantially uniformly across its cross-section, means for removing a first stream of hot combustion gases from the top of the combustion chamber, means for transferring a second stream of combustion gases to said eduction chamber top, means for separating a portion of gaseous product removed from said eduction chamber, and means for mixing said portion of gaseous product with said second stream of hot combustion gases and passing the mixture into the top of said eduction chamber.

2. Apparatus as defined in claim 1 wherein said means for transferring said second stream of combustion gases to said eduction chamber top comprises: a pivoted damper means and a surrounding hood disposed over both said eduction chamber top and said combustion chamber top,

said damper means having an arranged relationship with the interior of said hood and with solid particle flow entering said combustion chamber so as to selectively limit volume passage of said second stream of combustion gases with the pivoted rotational position of said damper.

3. Apparatus as defined in claim 1 wherein said means for transfer of oil shale particles from eduction chamber to combustion chamber comprises a spillway with a gravity feed and a scraper blade for minimal agitating movement of oil-educted particles from the top of said eduction chamber to said spillway which is directed to said combustion chamber top.

4. Apparatus as defined in claim 3 wherein said scraper blade slopes in the direction of its movement in a manner so as to provide an upward lift to solids particles while moving said solids particles.

5. In a continuous shale-retorting process wherein a moving compact bed of shale is first subjected to hot gas eduction to generate oil, and the carbonaceous residue is then burned to generate gas for said eduction, the improved method for maintaining independent control over said eduction and burning steps, which comprises passing raw shale particles of varying sizes up to about six inches diameter upwardly as a substantially compact bed through an eduction zone, passing a hot eduction fluid downwardly through said eduction zone to contact said particles and educt liquid and gaseous hydrocarbons therefrom leaving educted carbonaceous particles, withdrawing liquid and gaseous products from the lower portion of said eduction zone, moving said educted carbonaceous particles from the upper surface of said eduction zone to the upper level of a combustion zone without substantial comminution thereof, said combustion zone being disposed laterally from and below the top of said eduction zone, passing said educted particles downwardly through said combustion zone in the form of a compact bed of substantially uniformly flowing particles, introducing oxygen-containing gas upwardly through said combustion zone for supporting combustion of carbonaceous particles to produce a hot combustion gas and mixing at least part of said hot combustion gas with at least part of the gaseous product removed from the lower portion of said eduction zone to form said hot eduction fluid.

6. A continuous method of retorting carbonaceous solids as defined in claim 5 wherein said gas removed from said eduction zone is preheated prior to being mixed with said combustion gas.

7. A method according to claim 5 in which steam is also introduced into said combustion zone to react with part of said carbonaceous residue to form carbon monoxide and hydrogen.

8. In a continuous shale-retorting process wherein a moving compact bed of shale is first subjected to hot gas eduction to generate oil, and the carbonaceous residue is then burned to generate gas for said eduction, the improved method for maintaining independent control over said eduction and burning steps, which comprises passing raw shale particles of varying sizes of less than about six inches diameter upwardly into an upwardly enlarging eduction zone in countercurrent contact with a hot eduction fluid, moving substantially unbroken fluid educted carbonaceous particles from the upper surface of said eduction zone to the upper level of an adjacent but laterally removed combustion zone by way of a spill zone having gravity effected movement therethrough moving said carbonaceous particles downwardly as a compact bed in said combustion zone, providing oxygen-containing gas to the bottom of said combustion zone so as to burn carbonaceous material on said particles at a minimum temperature of about 2100° F., removing burned particles from the bottom of said combustion zone, removing hot combustion gas from the top of said combustion zone, removing liquid oil and product gas from said eduction zone at the bottom thereof, mix-

ing a portion of said hot combustion gas with a portion of said product gas to form a gas mixture having a temperature between about 1050° F. and about 1500° F., and passing said mixture into the top of said eduction zone to act as said eduction fluid.

9. A method as defined in claim 8 wherein said solids range from ¼ to 4 inches in size.

10. A method as defined in claim 8 wherein said combustion zone increases in cross-section at successively lower elevations.

11. A method as defined in claim 8 wherein said gas mixture passed to the top of said eduction zone is at a temperature of about 1050° F. to 1250° F. and said solid particles are maintained at about a temperature of 970° F. for the hottest of said upwardly moving solids.

12. A method as defined in claim 8 wherein said oil shale contains carbonates and the solid particles are retorted at temperatures which substantially avoid carbonate decomposition in said eduction zone, and wherein said combustion gas is produced in said combustion zone at temperatures high enough to decompose carbonates extensively therein.

13. A method as defined in claim 8 wherein said gas mixture passed to the top of said eduction zone is provided thereto at a rate of about 135 to 535 pounds each hour per square foot of eduction zone top surface for oil shales having a Fischer assay range of about 70 gallons per ton to as low as 25 gallons per ton.

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