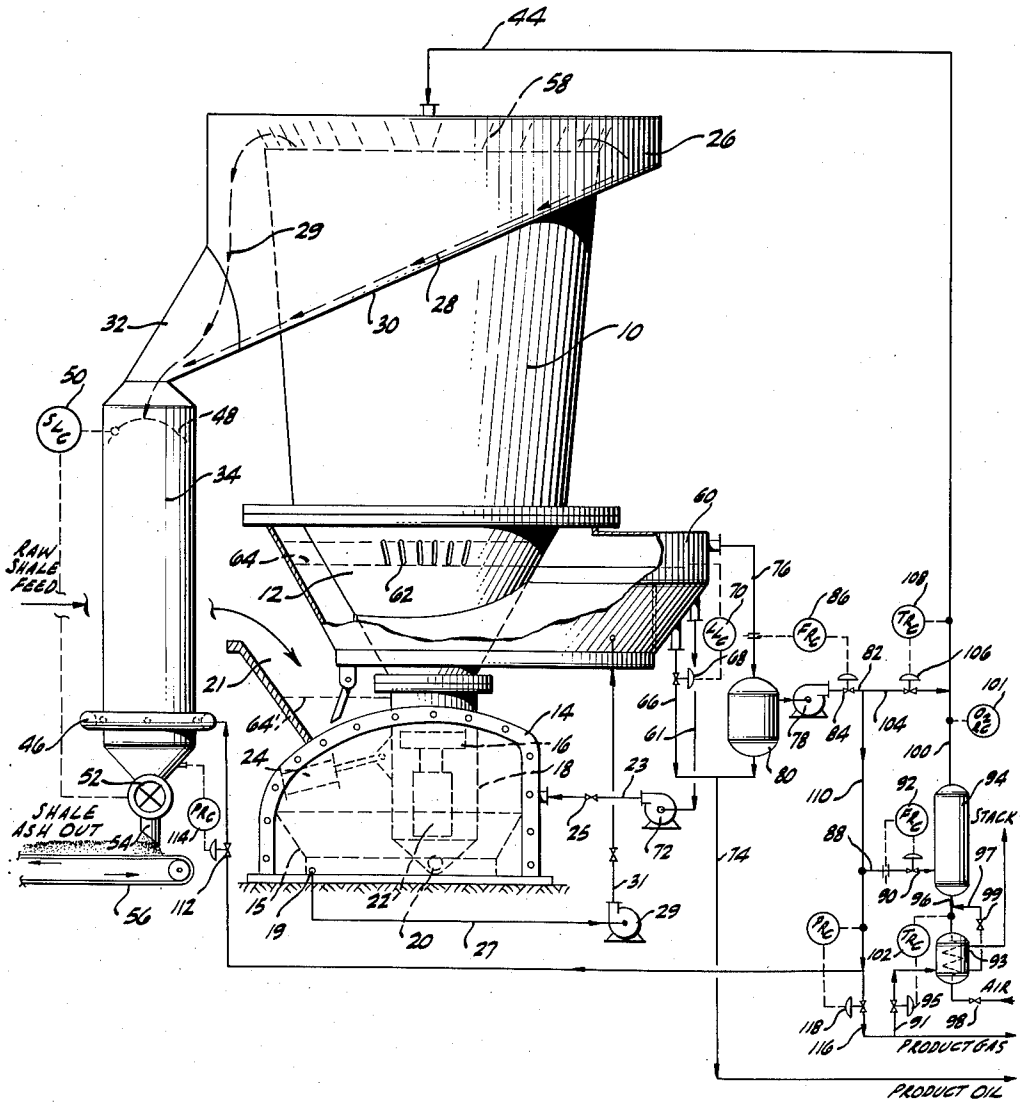
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SHALE RETORTING PROCESS

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SHALE RETORTING PROCESS

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This invention relates generally to a process for solids fluid contacting and it particularly relates to the 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.

Some processes for the eduction of shale oils and gases involve the downward passage of shale rock as a moving bed by gravity through a vertical heat treating kiln. During this passage they are heated to eduction temperatures by direct or indirect means. From a thermal efficiency standpoint the direct heating means is preferred in which a countercurrent contact of hot gases with the shale rock is employed. To avoid the large fuel consumption otherwise required, most of these processes involve the direct injection of air or other oxygen-containing gas into the bottom of the kiln to burn the carbonaceous residue from the spent shale. This generates hot flue gases needed to heat the rock. However, some difficulties are encountered with the fusion of the spent shale due to this burning, and frequently the fused or partially fused rock plugs the air inlet requiring a shutdown. Since all of the hydrocarbon product is removed at the top of the kiln, in most processes it must be removed as a vapor and this requires extensive cooling and condensing facilities. In the rest of these processes the oil is condensed as a mist and is carried out by the gas stream. However, this also causes frequent operating difficulties because of agglomeration and run-back of the oil into the kiln where it is decomposed or otherwise lost.

Other shale eduction processes have successfully avoided the large fuel and condensing water requirements and the difficulties resulting from refluxing or run-back of oil by utilizing an upflow of shale rock and a downflow of heating gas. The shale is fed upwardly successively through a perforated disengaging section and a heat treating or kiln section. Air or other oxygen-containing gas enters the top and moves downward through the heat treating section, is first preheated in cooling the hot shale ash at the top, burns carbonaceous residue from the spent shale at a lower level, and the hot flue gases continue downwardly to still lower levels where they heat the shale rock and educt hydrocarbon oils and gases. The whole vapor phase passes downwardly in direct contact with the raw shale, and is cooled thereby condensing the hydrocarbon oil and preheating the raw shale near the bottom of the kiln section. The liquid and gaseous products are drawn off at the disengaging section and are thus separated from the upwardly moving shale rock. A solids feeder passes the shale rock upwardly through the disengaging and heat treating sections and displaces the shale ash out the top of the unit. The process supplies its own fuel in the form of carbonaceous spent shale. It cools and partially condenses its own product in preheating the raw shale rock.

Several problems however are involved in the latter

upflow solids process which are occasionally troublesome. Because the process derives its heat from the burning of a solid hydrocarbonaceous residue on the educted or retorted solids by contacting it with an oxygen-containing gas, the burning temperatures are necessarily of the order of 2000° F. to 2500° F. inside the apparatus and the shale feed rate is limited by the rate at which this residue can be burned. With some oil-producing solids, specifically Colorado oil shale, as much as 30% to 50% of the heat so generated is consumed in uselessly decomposing calcium carbonate to calcium oxide or lime and carbon dioxide. These high temperatures also result in incipient fusion of the shale ash causing the formation of clinkners or partially sintered agglomerates which adversely affect the upflow of solids as well as the flow of gas down through the retort. One way of solving these problems is to employ some means for agitating the burning solids so as to prevent formation of these agglomerates or break up those which do form. In the past this agitation has been accomplished by plows which rotate through the top of the upwardly moving solids bed. Because of the high temperatures and the high stresses involved, these plows require large quantities of power to move them, are necessarily constructed of alloy steel with rather elaborate supporting and rotating structures, and must be cooled to prevent high temperature failure. An additional problem involves the presence of oxygen in the system to support the combustion of the carbonaceous residue on the spent shale. Unavoidably a part of this oxygen reacts with the educted materials to form partially oxygenated or partially oxidized materials which apparently render the liquid portion of the product rather unstable.

The present invention successfully overcomes these and other problems and provides a new retorting process that achieves high oil recovery at substantially higher retorting rates, permits accurate control of retorting temperatures which are substantially reduced over those wherein the spent shale is burned with oxygen, minimizes degradation of the liquid product, and produces an oil product of substantially increased stability.

It is therefore a primary object of this invention to provide a new process for the separation or production of hydrocarbon gases and liquids from oil-containing or oil-producing solids such as oil shale.

A more particular object is to provide a process in which the oil shale is passed upwardly through a retorting zone countercurernt to a flow of hot eduction gas produced by the combustion of part of the product gas so as to eliminate any substantial quantities of oxygen therefrom and provide a substantially inert heating medium.

It is a further object of this invention to provide a shale retorting process of the type indicated in which the maximum retort temperatures are of the order of 1000° F. below those characteristic of the spent shale combustion processes.

It is a more specific object of this invention to produce by low temperature retorting a hydrocarbon-containing gas from oil shale, burning one portion of this gas under controlled conditions with air in a burning zone external to the retort to produce a hot first recycle gas, introducing this gas into the top of the retort, passing a second portion of the hydrocarbon-containing gas countercurrent to the hot spent solids discharged at the top of the retort to provide a cool spent shale and a preheated second recycle gas, introducing this second recycle gas directly into admixture with the first recycle gas in the top of the retort to form a hot eduction gas mixture, and passing this gas downwardly through the oil shale to effect eduction thereof.

Other objects and advantages of this invention will

become apparent to those skilled in the art as the description and illustration thereof proceed.

The improved process and apparatus of this invention will be more readily understood by reference to the accompanying drawing and the subsequent description thereof in which:

Figure 1 is an elevation view in partial cross section of the major items of the equipment employed in this invention and including a schematic flow diagram of the process.

Referring now more particularly to Figure 1, the process of the present invention will be described in terms of a specific example of the present invention as applied to the retorting of oil shale of 0 to 6 inches in average size and at a rate of 700 tons per day to produce shale oil and shale gas. The apparatus consists essentially of three parts; namely an upper heat treating or eduction kiln **10** about 14 feet high and averaging 15 feet in diameter, an intermediate perforate disengaging section **12** about 11 feet high and having upper and lower diameters of about 13 feet and 5.5 feet respectively, and a lower reciprocating piston shale feeder contained within feeder housing **14**.

Shale feeder housing **14** contains a vertically reciprocating feeder piston **16** which is 5.5 feet in diameter and is contained within feeder cylinder **18**. Cylinder **18** oscillates in a vertical plane about trunnion **20** so that it may be moved between the vertical feeding position shown and an inclined cylinder charging position not shown but in which the upper outlet opening of cylinder **18** is disposed to the left and immediately below the lower outlet opening of shale feed hopper **21**. A hydraulic actuating cylinder **22** disposed within cylinder **18** reciprocates feeder piston **16** in cylinder **18** vertically a distance of 2.0 feet. A second hydraulic cylinder **24** contained within feeder case **14** oscillates feeder cylinder **18** between the filling and feeding positions. A V-shaped trough **15** runs along the bottom of the case and has a screw conveyor at its lower apex to move settled fines toward outlet **19**. A stream of product oil is introduced by pump **72** into case **14** through line **23** controlled by valve **25** and serves to flush the fines slurry from outlet **19** through line **27**. This slurry is returned to settler **60** by pump **29** and line **31** to settle the recycled fines.

Raw shale is introduced by any convenient conveyor means not shown in the direction indicated into feed hopper **21** at a rate of 700 tons per day. With feeder piston **16** disposed at its upper extremity immediately after its up stroke, cylinder **18** is moved to a point in alignment with feed hopper **21**. Cylinder **22** retracts piston **16** drawing a charge of shale rock into the upper part of feeder cylinder **18**. Hydraulic cylinder **24** is then extended returning feeder cylinder **18** to the vertical position shown. Then hydraulic cylinder **22** is extended forcing piston **16** upwardly thereby moving the charge of rock into disengaging section **12** and displacing the rock therein and in kiln **10** upwardly. This cycle is repeated, thereby continuously feeding fresh shale at the bottom of the structure and displacing hot spent shale from the top.

The shale ash is displaced by rotating rakes **58** from the top of kiln **10** inside housing **26**. It falls by gravity through the paths indicated as by arrows **28** and **29** downwardly on to the bottom **30** of housing **26** and discharges through outlet **32** into spent shale cooling and second recycle gas preheating zone **34**. Here the spent shale passes downwardly as a dense moving bed countercurrent to a rising stream of the second recycle gas produced as hereafter described and introduced through ring manifold **46**. This gas is introduced at a rate of 11,550 M s.c.f./d. and a temperature of about 160° F. and is preheated by direct contact with the cooling spent shale to a temperature of about 950° F. The spent shale is simultaneously cooled from a temperature of about 1050° F. to about 450° F. The spent shale forms solids level **48** in the upper portion of cooling zone **34** which is detected by means of solids level controller **50**, which in turn controls the rate of discharge of cooled spent shale from the bottom of cooler **46** by means of solids flow controller **52**. The latter may be a valve or a star feeder or a vane feeder, the solids discharge rate of which is controlled by controller **50** to equal that at which spent shale discharges from the top of kiln **10** so as to maintain an approximately constant solids level **48**. The spent shale is discharged through outlet line **54** on to spent shale disposal conveyor **56** and is removed from the system at a rate of 581 tons per day.

The preheated second recycle gas is passed upwardly through outlet **32** into housing **26** wherein it directly mixes with the first recycle stream introduced thereto through line **44**. This mixture forms the hot eduction gas which heats the upwardly moving shale and educts the oil and gas therefrom.

The raw shale is passed by means described above upwardly through perforated disengaging section **12** in which the cool eduction and shale gases and the condensed shale oil are disengaged from the upwardly moving shale mass. In kiln **10** the upwardly moving shale passes successively through a fresh shale preheating and product cooling and condensing zone, and a preheated shale eduction zone. These two zones occupy kiln **10** from top to bottom. The spent shale, expelled at the top of kiln **10**, is moved radially by means of rotating rakes **58** which maintains a flat solids surface at the top of kiln **10**, and introduces the spent shale at a more or less constant rate through housing **26** and outlet **32** into spent shale cooler **34**. This spent shale is removed from the system as previously described and simultaneously preheats the second recycle gas stream.

The hot eduction gases produced pass downwardly first through the preheated shale eduction zone and then through the shale preheating and product cooling and condensing zone in kiln **10**. This mixture of eduction gases and educted fluids passes downwardly into disengaging zone **12** which is surrounded by an integrally attached product settling and separating zone **60**. Disengaging zone **12** is provided with a plurality of apertures **62** opening into separator settler zone **60**. Through these apertures the condensed liquid product overflows forming a body of liquid having level **64**. The gas flows therethrough into the top part of separator settler **60** above the liquid level. The net liquid product is removed by means of line **66** at a rate controlled by valve **68** in accordance with liquid level controller **70**, and is passed as a product of the process through line **74** to further processing or storage facilities not shown. Part of the liquid oil produced is recirculated from settler **60** through line **61** as previously described into feeder case **14** by means of pump **72**. For the feed rate of 700 tons per day of Colorado oil shale, whose Fischer Assay is 28 gallons per ton, the liquid product flow rate through line **74** is 448 barrels per day of 20.4° API gravity corresponding to a retorting efficiency of 96.0%.

The gas phase is withdrawn from separator settler **60** through line **76** under the influence of recycle gas blower **78** and is drawn through one or more mist separators indicated generally at **80**. This separator may comprise a cyclone separator, an oil wash such as in an oil absorber, or an electrostatic precipitator, or any other suitable separators or combinations thereof for removing finely divided liquid particles from a gas stream. Any recovered liquid is combined with the product liquid flowing through line **74**.

The thus treated gas stream is pumped by blower **78** through line **82** at a rate of 22,680 M s.c.f./d. controlled by valve **84** in accordance with flow recorder controller **86**. This gas is divided into several streams to provide and transfer the heat required for retorting the shale in the retorting system. This gas contains about 5.4% carbon monoxide, about 5.8% hydrogen, about 3.8% hydrocarbon, and has a gross heating value of about 98 B.t.u. per cubic foot. It may be burned in burners adapted to

combustion of low heating value fuel gases. A first portion of this shale gas is passed through line **88** at a rate of about 4900 M s.c.f./d. controlled by valve **90** and flow recorder controller **92** into gas burner **94**. Simultaneously introduced through line **96** at a rate controlled by valve **98** is 2100 M s.c.f./d. of air preheated in preheater **93**. The air is heated to about 1200° F. by burning part of the make gas flowing through line **91** at a rate controlled by valve **95** in a part of the preheated air flowing through line **97** controlled by valve **99**. Temperature recorder controller **102** regulates the gas rate to air preheater **93**. The shale gas is burned in burner **94** to provide hot flue gases having a temperature on the order of 1500° F. to 2500° F. These gases are removed therefrom through line **100** and the combustion in burner **94** is controlled so that substantially no excess oxygen remains as indicated by oxygen recorder controller **101**.

The first recycle gas stream is produced by mixing these hot flue gases flowing through line **100** with about 2660 M s.c.f./d. of unburnt shale gas flowing through line **104** at a rate controlled by valve **106** in response to the temperature of the first recycle gas as detected by temperature recorder controller **108**. Preferably the blend is controlled so as to maintain the first recycle gas stream at a temperature of between about 900° F. and about 1800° F. This first recycle gas stream has been referred to previously and flows at a rate of 9660 M s.c.f./d. through line **44** into the top of housing **26** in which it is mixed with the second recycle gas stream preheated in spent shale cooler **34** flowing at 11,550 M s.c.f./d. This mixture is the eduction gas stream which heats the shale and educts further quantities of shale oil and gas therefrom. It flows downwardly through the rising shale bed at a rate of about 21,200 M s.c.f./d.

The aforementioned second recycle gas stream is pumped by means of blower **78** through line **110** at a rate controlled by valve **112** and pressure recorder controller **114** which measures the gas pressure existing at the bottom of spent shale cooler **34**. By this means a gas flow up through cooler **34** is of sufficient magnitude to generate a pressure differential therein which is equal to that existing between the top of kiln **10** and apertures **62** in disengaging section **12** and thus prevents the entry of atmospheric air into the system through cool ash outlet **54**. The kiln thus operates at slightly below atmospheric pressure because hopper **21** having oil level **64'** is open to the air. However with slight and obvious modification the process and apparatus can be operated at superatmospheric pressures as well.

The excess gas product is discharged through line **116** at a rate of about 3660 M s.c.f./d. controlled by valve **118** and pressure recorder controller **120**. Part of this off gas is burned in air preheater **93** at a rate of 1010 M s.c.f./d.

In the modification of product shale gas combustion above described, the products of combustion are used to transfer heat through line **44** into shale kiln **10**.

In some cases, such as with shale producing below about 20 gallons of oil per ton, it is desirable to use supplemental fuel. This supplemental fuel may be introduced into line **88** to maintain good combustion.

The primary advantages of all modifications of the above described invention include the realization of very high burning rates and very high heating rates in the kiln, the complete elimination of oxygen in the system which causes product liquid degradation, and the availability of the entire height of the retort for heat transfer required to retort the solids. No structural height is necessary therefore to provide a separate zone for the burning of the spent shale. Also shale throughput is not limited by coke combustion rates and throughput can be more than doubled for a given retort size. The required retort height is thus reduced for a given shale feed rate, or the shale capacity of a given retort is correspondingly increased. Plowing of the shale is unnecessary and the heavy equipment needed to effect such plowing and the high power requirements are thus eliminated. Thermal efficiency is substantially increased as compared to other types of gas fired retorts through a reduction in maximum operating temperature to one at which only a minor proportion of the naturally occurring carbonates are decomposed.

A particular embodiment of the present invention has been hereinabove described in considerable detail by way of illustration. It should be understood that various other modifications and adaptations thereof may be made by those skilled in this particular art without departing from the spirit and scope of this invention as set forth in the appended claims.

I claim:

1. In a process wherein (1) oil shale solids are passed upwardly and successively through a disengaging zone, a solids preheating zone and an eduction zone, (2) a hot eduction gas is simultaneously introduced into the top of said eduction zone and is passed downwardly and successively through said eduction zone, said solids preheating zone and said disengaging zone in direct contact with said solids, (3) within said eduction zone said hot eduction gas educts hydrocarbon products from the said solids therein, (4) within said solids preheating zone the said solids therein are preheated by heat exchange against said hydrocarbon products and said eduction gas, (5) within said disengaging zone the said hydrocarbon products and said eduction gas are separated from the said solids therein, (6) the said separated hydrocarbon products and eduction gas are withdrawn from said disengaging zone and introduced into a separation zone wherein the gas phase is separated from the liquid phase, and (7) spent solids are withdrawn from the top of said eduction zone and are passed downwardly through a spent solids cooling zone; the improvement which consists in withdrawing the gas phase from said separation zone, introducing a first portion of said gas phase into a combustion zone and therein burning said first portion in the presence of an oxygen-containing gas and out of contact with said solids and said spearated liquid phase to form a first hot recycle gas, introducing a second portion of said separated gas phase into said spent solids cooling zone and passing said second portion upwardly therethrough in direct countercurrent contact with the spent solids therein, whereby said second portion is heated by heat exchange against said spent solids to form a second hot recycle gas, and introducing said first and second hot recycle gases into the top of said eduction zone as said hot eduction gas, the amount of oxygen-containing gas supplied to said combustion zone being such that substantially no coke combustion and carbonate decomposition occurs in said eduction zone and the flow rates of said first and second recycle gases being controlled so as to maintain an eduction temperature within said eduction zone.

2. A process as defined by claim 1 wherein said oxygen-containing gas is air.

3. A process as defined by claim 1 wherein a third portion of said separated gas phase is admixed directly and without further treatment with said first and second hot recycle gas and the resulting gas mixture is introduced into the top of said eduction zone as said hot eduction gas.

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