

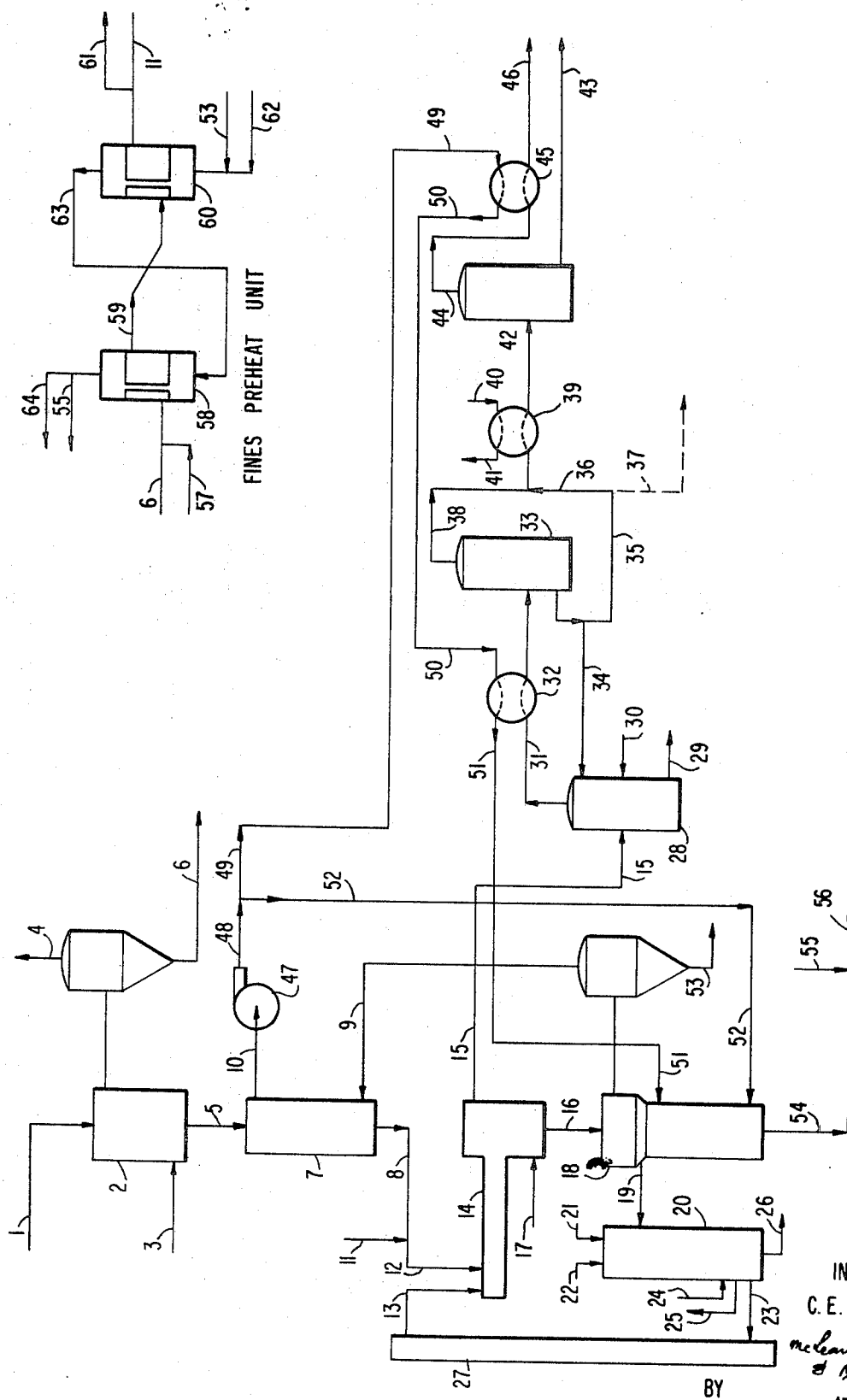
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C. E. GESSNER

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PROCESS FOR RETORTING OIL SHALE

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INVENTOR
C. E. GESSNER
McLean, Math
& Binstadt
ATTORNEYS

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PROCESS FOR RETORTING OIL SHALE
Clyde E. Gessner, Tulsa, Okla., assignor to The Oil
Shale Corporation, New York, N.Y.
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ABSTRACT OF THE DISCLOSURE

A novel and thermally efficient process for retorting oil shale is provided which utilizes the heat in the spent shale and in the shale oil vapors to heat the raw shale without condensing shale oil vapors on the raw shale and without contaminating the shale oil vapors with other gaseous material such as flue gas. The novel process of this invention comprises distilling shale oil vapors in a retorting zone from raw shale heated to a retorting temperature, separating hot spent shale from the retorting zone, passing a circulating stream of a normally gaseous hydrocarbon such as natural gas, propane, butane, or mixtures thereof in direct contact with hot spent shale separated from the retorting zone and in indirect heat exchange with the shale oil vapors, thereby heating the normally gaseous hydrocarbon to a high temperature, passing the circulating stream of said normally gaseous hydrocarbon thus heated to a high temperature into direct contact with raw shale, thereby preheating it, heating a particulate solid heat transfer medium, particularly the hot spent shale, to a temperature in excess of the retorting temperature, passing preheated raw shale and the thus heated particulate solid heat transfer medium into direct contact in the retorting zone thereby heating the preheated raw shale to a retorting temperature.

This invention relates to a novel process for retorting oil shale, more particularly, this invention relates to an efficient process for retorting oil shale which utilizes the heat in the spent shale and the shale oil vapors to heat the raw shale without condensing shale oil vapors on the raw shale and without contaminating the shale oil vapors with other gaseous material such as flue gas.

Processes for heating oil shale to liberate desirable hydrocarbons and other organic compounds and less desirable constituents are referred to as retorting processes.

The mined oil shale is crushed and screened to yield a suitable feed to the process which when residing at atmospheric or ambient temperature is termed "raw shale." In most retorting processes the raw shale is heated to some intermediate temperature. Heating of the raw shale to the intermediate temperature is termed "preheating" and the shale at the intermediate temperature is termed "preheated shale."

The maximum temperature that the shale attains while liberating hydrocarbons in any given retorting process is termed the "retorting temperature." Heating the preheated shale to retorting temperature is termed "final heating." During final heating the shale undergoes marked physical change, liberating hydrocarbon and nonhydrocarbon constituents which, together with extraneous amounts of small solid particles, are termed collectively "retort vapor." The shale after liberating retort vapor is termed "spent shale." Utilizing the heating value of the carbon in spent shale by combustion is termed "carbon burn off" and the solid residue remaining from such a step is termed "ash."

The end objective of shale oil retorting is the recovery of liquid hydrocarbon. The hydrocarbon and other organic constituents of the retort vapor which have normal boiling points within the same range as constituents of naturally

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occurring petroleum crude oils together with extraneous solids which may be contained in the retort vapor are collectively termed "raw oil." The remaining constituents of retort vapor other than raw oil are termed "retort gas product."

The novel process of this invention comprises distilling shale oil vapors in a retorting zone from raw shale heated to a retorting temperature, separating hot spent shale from the retorting zone, passing a circulating stream of a normally gaseous hydrocarbon such as natural gas, propane, butane, or mixtures thereof in direct contact with hot spent shale separated from the retorting zone and in indirect heat exchange with the shale oil vapors, thereby heating the normally gaseous hydrocarbon to a high temperature, passing the circulating stream of said normally gaseous hydrocarbon thus heated to a high temperature into direct contact with raw shale, thereby preheating it, heating a particulate solid heat transfer medium, particularly the hot spent shale, to a temperature in excess of the retorting temperature, passing preheated raw shale and the thus heated particulate solid heat transfer medium into direct contact in the retorting zone thereby heating the preheated raw shale to a retorting temperature.

The figure is a schematic representation of a flow sheet illustrating the process of this invention.

Preheating the sized raw shale with a closed circulating system of gas other than air and preferably being natural gas, propane or a propane/butane mixture, as in the present invention, is superior to those processes which preheat with flue gases wherein any desirable constituent evolved from the raw shale during preheating is lost with the flue gases. The method of this invention is superior to those processes which utilize retort vapor for preheating wherein desirable constituents in the retort vapor are condensed on the raw shale and carried back to the final heating section. For a specific oil shale with the present invention, preheating is precisely controlled to a temperature that gives incipient evolution of desirable constituents. Should any desirable constituents be liberated during preheating, they are not lost but are retained in the closed circulating gas system.

The use of propane or a propane/butane mix as the gas for the closed circulating gas system of the present invention is preferred due to the advantageous thermodynamic properties of propane as compared to gases such as air, flue gas, or retort gas product. For a specific oil shale with the present invention, the gas circulation horsepower is substantially lower than is required for other processes. The propane or propane/butane mix is economically recoverable from the retort gas product by conventional gas processing methods. Replenishment of the propane in the present invention to offset seal leakage and to displace those constituents that may be liberated from the shale during preheating is desirable and economical.

Final heating with the heating bodies, as in the present invention, is superior to those processes which use combustion inside the retort device. With the present invention, there is no possibility of retort vapor being lost through combustion. Also, the retort gas product is not diluted by combustion flue gas. Processing the retort gas product of the present invention in a conventional gas processing facility yields a residual gas comparable in quality to natural gas which may be sold or utilized as a feedstock for hydrogen manufacturing as an adjunct to upgrading processes.

The method of contacting the preheated shale with heating bodies as in the present invention is superior to those processes which utilize heating bodies but cause the preheated shale to be crushed, ground, or milled to very small particle size. The spent shale from the present

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invention being of larger size has two advantages: first, it permits recovery of the spent shale usable heat by direct, intimate contact with a circulating gas in a more economical manner than is possible with very small particles; and second, the amount of extraneous solids contained in the retort vapor is reduced.

The method of carbon burnoff as in the present invention is superior to other known methods. The combination boiler and heating body heater of the present invention permits cold startup of the process without standby boilers. For a specific oil shale with the present invention, the circulation rate of ash versus preheated shale is controlled as is residence time of the ash in the heater, the amount and temperature level of the preheated air, and the amount of external fuel, if any, such that the desired heat content of the ash entering the retort device is attained without undesirable overheating of the ash to the point of excessive carbonate decomposition.

The use of a heat exchange train for recovery of usable heat contained in the retort vapor as in the present invention is more advantageous than the vertical kiln type processes wherein the retort vapor contacts the raw shale for preheating which results in the raw oil being dispersed as a mist or fog requiring special equipment such as electrostatic precipitators for its effective removal from the product gas. For a specific oil shale and a specific upgrading process with the present invention the heat exchanger train is detailed in such a manner that little or no additional processing is required on the raw oil fractions prior to upgrading. Simultaneously, the heat recovered in the train is put to maximum beneficial use in preheating raw shale. In this regard the present invention is more advantageous than those retorting processes which exclude the process step of retort vapor cooling wherein the retort vapor is fed to fractionation equipment for the purpose of preparing oil fractions for upgrading but which result in wasteful rejection of heat to the atmosphere in the form of reflux cooling.

The present invention is not sensitive to the richness (i.e., gallons per ton assay) of the raw shale. Though the equipment detail for a facility to process very lean shale may differ from a facility to process very rich shale, each facility of the present invention would effectively process a wide range of richness due to the capability of controlling the gas flow in the closed circulating system. With increasing shale richness, more circulating gas passes through the heat exchange train and less passes through the sized spent shale cooler.

It is the object of the present invention to provide a method of retorting oil shale which yields a maximum amount of recoverable products such as hydrocarbons, other organic compounds, and valuable byproducts in such a form that their further processing is most economical. It is also an object of this invention to minimize the fuel required for retorting oil shale by the most economical recovery of usable heat contained in the spent shale and retort vapor as they exist at retort temperature.

In the present invention final heating is provided by a system of circulating heating bodies; said bodies may be of a metallic or ceramic nature but preferably are pieces of spent shale and/or ash. In the final heating system, heating bodies are brought into intimate contact with the preheated shale in a retort device, such as a rotating drum or traveling grate which permits the body to heat the shale in such a manner that neither the body nor the shale is significantly changed in size. The retort device includes a soak zone which provides sufficient residence time for the shale at retorting temperature to completely liberate the desirable hydrocarbons and other organic compounds and provides for the injection of steam superheated to approximately retorting temperature in such quantity as to assure that no raw oil fraction resides on the exiting spent shale or heating bodies.

Heat is provided to the heating bodies in a heater device consisting of a traveling grate or downflowing bed

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of heating bodies with the addition of fuel and air in such a manner as to avoid undesirable overheating of the bodies. The heater device can include steam generating coils to provide mechanical power and also serve to moderate the heating body peak temperature.

When spent shale is used as the heating bodies, the heater device utilizes the heating value of the organic carbon on the spent shale in a carbon burnoff step which provides heat for body heating and steam generation such that essentially no additional fuel is required for the retorting process. During carbon burnoff the spent shale is converted to ash so that the heating bodies in this case are essentially ash, and the solids from the retort device are a mixture of spent shale (once through) and ash (recycled). This mixture is proportionally split with part being transferred back to the heater device as spent shale and ash for heating bodies and the remainder being transferred to a "spent shale cooling device" as spent shale and ash.

In the present invention raw shale sizing is accomplished by a raw shale elutriation device wherein the raw shale is contacted with a gas, either air or flue gas, in such a manner that the undesirable smaller sized raw shale particles are removed with the elutriating gas from the larger sized raw shale and then these smaller sized raw shale particles are separated from the elutriating gas to provide a stream of smaller sized raw shale, i.e., "raw shale fines" which are further processed in a "fines preheat unit." The larger raw shale particles not elutriated, i.e., "sized raw shale" is further processed in a "sized raw shale preheater."

There is provided in part of the retorting process a closed system of circulating gas, said gas being other than air, preferably natural gas, or propane or a propane/butane mixture, with propane gas being the most preferred. The closed circulating gas system recovers the usable heat which the spent shale contains when it is at retorting temperature by direct, intimate contact of the spent shale with the circulating gas in a sized spent shale cooling device. It should be understood that when ash is used for heating bodies that the solids to the sized spent shale cooling device would actually be a mixture of ash and spent shale per se. The closed circulating gas system provides as a part of the sized spent shale cooling device a section wherein: (a) the spent shale, or mixture of spent shale and ash, is elutriated to remove the undesirable smaller sized particles of spent shale (and ash) with the exiting circulating gas; and (b) the smaller sized particles are separated from the circulating gas to provide a stream of smaller sized particles, i.e., "spent fines" which are further processed in a "fines preheat unit."

The closed circulating gas system further recovers the usable heat which the retort vapor contains when it is at retorting temperature by a heat exchanger train wherein the retort vapor is cooled and partially condensed by indirect exchange with the circulating gas, each stream—the retort vapor and circulating gas—flowing through a side of a conventional tubular heat exchanger, or heat exchangers either in series or parallel flow patterns. The closed circulating gas system provides as part of the heat exchanger train a quench tower device, similar to a conventional distillation tower, wherein the retort vapor is partially condensed by refluxed liquid resulting in a bottom liquid product that contains the extraneous solid particles contained in the retort vapor. The content of retort vapor with refluxed liquid in the quench tower in addition to separating out the extraneous solids also reduces the temperature of the retort vapor (i.e., quenches) such that the vapor going through the tubular exchangers is reasonably thermally stable (i.e., has little tendency to coke) with the result that the exchangers operate in a reasonably efficient, unfolded manner.

The closed circulating gas system provides a sized raw shale preheater device wherein the usable heat contained

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in the circulating gas, principally comprised of heat recovered from the retort vapor and spent shale, is exchanged to the sized raw shale by direct, intimate contact of the circulating gas with the sized raw shale. The closed circulating gas system provides "trim heat" to the composite hot circulating gas by direct, intimate contact with the heating bodies from the retort device. The composite hot circulating gas is a blend of the hot circulating gas from the sized spent shale cooler and the hot circulating gas from the retort vapor heat exchanger train.

The present invention provides a "fines preheat unit" in which raw shale fines are fluidized and are preheated by indirect contact with fluidized spent fines in devices resembling tubular heat exchangers with the shell and tubes erected in a vertical position. The fines preheat unit provides at least two "shells" in each of which the one side, the shell side or tube side, contains raw shale fines which are fluidized preferably with a side stream of the closed circulating system gas (preferably propane), and the other side, the tube side or shell side, contains spent fines fluidized preferably with superheated steam. Within a given shell, for example, shell A, all flows, i.e., the raw shale fines, its fluidizing gas, the spent fines, and its fluidizing gas, are all cocurrent upflow. However, when there are two or more shells, for example, shells A and B, the flows are counter-current in that the raw shale fines and its fluidizing gas first flow to shell A, then shell B, while the spent fines and its fluidizing gas first flow to shell B, then shell A.

The drawing is a process flowsheet of the present invention.

Referring to the figure, the raw shale 1 having an actual size distribution that is dependent upon actual crushing equipment selection but generally having maximum particle size of $\frac{1}{2}$ inch to 3 inches and preferably $\frac{3}{4}$ inch maximum, is fed to the raw shale elutriation unit 2 at ambient temperature of from 20° to 110° F., preferably 50° to 90° F.

The purpose of the elutriation unit 2 is to remove those particles of raw shale that are smaller than some critical size (i.e., raw fines) that would otherwise tend to fluidize during shale preheating with flowing hot gas. For a particular oil shale, known raw shale particle size distribution, and desirable hot gas rate the critical particle size can be predicted and the elutriation appropriately designed and operated.

Elutriating gas 3, either air or flue gas, at ambient or higher temperatures, but preferably at 80° to 120° F., and at 1.0 to 10.0 p.s.i.g., preferably 2.0 p.s.i.g., enters the elutriation unit in sufficient quantity to carry with it fine raw shale. In turn, the fine raw shale is separated from the elutriating gas to give dust free exhaust gas 4 and a fine raw shale stream 6 which is further processed in a fines preheat unit discussed in detail below.

The particles of raw shale that are not elutriated are defined as sized raw shale 5 and at a flowing temperature of 20° to 110° F., preferably 50° to 90° F. enter the sized raw shale preheater 7 wherein the downflowing sized raw shale is brought into intimate contact with upflowing hot circulating propane gas 9 entering the bottom of the sized raw shale preheater at 500° to 1000° F. but preferably 550–900° F. and at 1.0 to 10.0 p.s.i.g., or higher, preferably 1.0 to 3.0 p.s.i.g. The hot circulating gas is cooled by contacting the sized raw shale and cooled circulating gas 10 exits at a temperature of 50° to 250° F., preferably 60–200° F. and at 0.0 to 4.0 p.s.i.g., preferably 0.2–2.0 p.s.i.g. In turn the sized raw shale is heated by the hot circulating gas and the preheated sized shale 8 exits at a temperature of 500° to 800° F., preferably 650° to 750° F.

Preheated sized shale 8 joins with preheated fine shale 11 as flowing from the fines preheat unit discussed in detail below, and the resultant total preheated shale 12 at 400° to 1000° F., preferably 500° to 800° F. enters the retort

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device 14. Heating bodies 13 are illustrated in the drawing as being ash, and are discussed here in detail as being ash but are representative of the other heating bodies that are the subject of this invention which could be similarly illustrated and discussed. Ash heating bodies 13, flowing at 900° to 2000° F., preferably at 1000° to 1500° F. and in an amount approximately equal to the amount of preheated shale on a volumetric basis, also enter the retort device 14 wherein the heating bodies and total preheated shale are brought into intimate contact either by rotation of a drum or by depositing in alternate thin layers upon a traveling grate. Heat is transferred from the heating bodies to the preheated shale, thereby performing final heating. Still within the retort device the heating bodies and preheated shale layers are discharged to a soak zone with the result that both the heating bodies and now retorted, spent shale attain essentially the same temperature herein designated the retort temperature which may be 700° to 1400° F. but preferably is 800° to 1000° F. A small amount of superheated steam 17 at approximately retort temperature and 3.0 to 7.0 p.s.i.g., preferably 4.0 to 6.0 p.s.i.g., is introduced into the soak zone, thereby stripping off any hydrocarbon or organic liquid that may reside on the heating bodies or spent shale.

The combined flow 16 of liquid free heating bodies and spent shale exits the retort device and enters the sized spent shale cooling device 18. The top section of this device is intended to elutriate the particles of ash and spent shale that are smaller than some critical size (i.e., spent fines) that would otherwise tend to fluidize in the bottom section of this device. The total flow (51 plus 52) of circulating propane gas elutriates the spent fines from the top of the sized spent shale cooling device 18 and in turn the spent fines are disengaged from the circulating hot propane gas 9. The spent fines 53 flow to the fines preheat unit discussed in detail below.

The sized spent shale and ash residing in the sized spent shale cooler 18 after elutriation of spent fines, is essentially a uniform mixture of spent shale with ash a portion of which is withdrawn 19 as feed to the heating body heater 20.

The configuration of the heater 20 depends upon the type of heating body and type of fuel used in the process. For purposes of illustration, the preferred method of using spent shale/ash as heating bodies and the carbon on spent shale as fuel is discussed. Spent shale/ash 19 enters the top of the heater 20 and forms a slow moving bed flowing downward. Preheated air 22 is injected into the top of the heater and flows concurrently with the spent shale. Most of the carbon contained in the spent shale is combusted, causing a temperature rise in the bodies and the surrounding combustion gases. The heated bodies 23 exit the heater at the desired temperature level and are lifted by a conventional bucket elevator device 27 for entry to the retorting device. The hot combustion gases 26 exit the heater and may be used for preheating combustion air or generating steam.

In all configurations of the heater 20 provision is made for steam generation wherein, as illustrated, boiler feed water 24 is vaporized to high pressure steam 25. Provision is also made for the addition of fuel 21 in the form of natural gas, propane, oil and/or coke.

Design of the final heating system of the present invention and specifically the heater 20 recognizes the need for three distinct operating modes. The initial startup mode requires that a one-time charge of crushed rock or gravel is introduced to the system prior to initial startup. The cold restart mode requires that the total desired heat input to the heating bodies must be provided by external fuel until such time as the facilities are heated up, retorting commences, and spent shale is available in the heating bodies 19. The operating mode permits the reduction of external fuel since the major portion, if not all, of the desired heat input to the heating bodies is provided by carbon burnoff of the spent shale in the feed 19. Super-

imposed on each of these modes is the desirability of generating high pressure steam for efficient usable mechanical power on certain services such as a steam turbine driver on the circulating propane compressor 47.

For illustrative purposes, the operating conditions are now stated for the heater 20 when the system is in the operating mode. Air 22 at 100° to 700° F., but preferably 400° F., enters the top of the heater. The mixture of spent shale with ash 19, being about 50 weight percent of each, enters the heater at 800° to 1000° F. but preferably at 900° F. The percentage of organic carbon contained in the spent shale is in the range of 2.0 to 6.0, but preferably 4.0 weight percent. Most of this carbon on contacting the air is combusted thereby converting the spent shale to ash, now having an organic carbon content of approximately 1.0 weight percent, and the total heating bodies, now ash 23, are heated by the carbon combustion to 1100° to 1500° F., preferably 1200° F. The combustion gases are also heated to about the same temperature as the ash, preferably 1200° F., and exit the heater as flue gas 26.

It was previously mentioned that the heating bodies 13 are brought in contact with the total raw shale 12 on a traveling grate within the retort device 14, that final heating occurs therein and is completed in a soak zone, and that steam 17 is introduced to strip residual liquid from the heating bodies and spent shale. Sufficient vapor disengaging space is provided in the top of the soak zone such that the retort vapor 15 exits the retort device with a minimum of extraneous solids entrained. It is noted, for convenience, that the previous definition of retort vapor is broadened to include the small amount of superheated steam 17 introduced into the retort device.

The retort vapor 15 at retort temperature, previously stated to be at the preferred level of 800° to 1000° F. and at 3.0 to 5.0 p.s.i.g., preferably 4.0 p.s.i.g., enters the quench tower device 28 wherein the upflowing retort vapor contacts descending cooler liquid, thereby causing a portion of the retort vapor to condense. The downflowing liquid carries with it the condensed portion from the retort vapor and also the extraneous solids that were contained in the entering retort vapor. The resultant bottom distillation product herein designated a heavy oil fraction 29 exists the quench tower at 700° to 1000° F., preferably 800° to 900° F.

For the purpose of illustration it is presumed that the upgrading processes include coking in which case the heavy oil fraction 29 would be suitable direct coker feed and ideally the coker off gases would be returned to the quench tower device as stream 30 on the flowsheet. In such event the coker off gases would join and become a part of uncondensed retort vapor and no further distinction is made of them in this discussion.

The uncondensed retort vapor and some vaporized reflux at exit 31 the top of the quench tower at 600° to 900° F., preferably 700° to 800° F. and 1.0 to 5.0 p.s.i.g., preferably 2.0 to 4.0 p.s.i.g., and pass through a reflux condenser-gas exchanger device 32 wherein heat is exchanged to the circulating propane gas whose flow is reviewed below. The vapor stream 31 is partially condensed in the exchanger 32 and the liquid phase is separated in a conventional reflux accumulator 33 from which now remaining retort vapor 38 exists at 350° to 700° F., preferably 400–600° F. and approximately 1.0 to 3.0 p.s.i.g. The liquid phase from the accumulator 33 about 400° to 600° F., is pumped to the quench tower as reflux 34 is quantity that is needed for a desirable degree of fractionation and any excess liquid condensed is pumped from the accumulator as a medium-heavy oil fraction 35.

Depending upon the upgrading processes chosen, the medium-heavy oil fraction could be utilized as a feedstock to a hydrogenation process as designated stream 37 needing little or no additional feed preparation steps. The flow-sheet indicates, for purpose of illustration, that the medium-heavy oil fraction rejoins 36 with the remaining retort vapor 38, and both flow to a low pressure steam

generator 39 wherein heat is exchanged to entering boiler feed water 40 generating saturated steam 41 in the range of 50 to 100 p.s.i.g.

Additional condensation of the retort vapor occurs in the steam generator and a conventional separator 42 provides for removal of the liquid phase as a medium oil fraction 43 at 350° to 450° F., preferably 400° F. The medium oil fraction, with little or no additional preparation steps, would be a suitable feedstock for a hydrogenation process. The aggregate of the heavy oil fraction 29 and medium oil fraction comprise, essentially the "raw oil" of the retorting process and if upgrading was not desired could be cooled and blended as final product.

The vapor effluent from the separator 42 now being devoid of raw oil is designated retort gas product 44 which, also flowing at the preferred temperature of 400° F., enters a gas-to-gas exchanger device wherein heat is exchanged to the circulating propane gas which flow is summarized below. The effluent cooled retort gas product 46 at 150° to 400° F., preferably 200–300° F., and at approximately atmospheric pressure is, upon further cooling and compression, a suitable feed for a gas processing facility.

The total circulating propane gas 10, after preheating the sized raw shale, was previously mentioned as having preferable conditions of 60° to 200° F. and 0.0 to 2.0 p.s.i.g. A conventional gas compressor, or blower 47 compresses the total circulating propane gas to approximate conditions of 100° to 200° F., preferably 125° to 160° F. and 4.0 to 10.0 p.s.i.g., preferably 5.0 to 9.0 p.s.i.g. A portion of the total cool circulating propane gas 48 is diverted 49 to the heat exchanger train wherein it passes through the gas-to-gas exchanger device 45 and exits 50 at 150° to 400° F., preferably 200° to 300° F., then passes through the reflux condenser-gas exchanger device 32 and exits 51 at 450° to 700° F., preferably 550° to 650° F.

The remaining portion of the total cool circulating propane gas flows 52 to the bottom section of the sized spent shale cooler device 18, wherein by intimate direct contact between the particles of sized spent shale (being actually a mixture of spent shale and ash particles as previously noted) and the circulating propane gas, the spent shale is cooled and exits 54 at a temperature of 150° to 250° F., preferably 160° to 220° F.

The now hot circulating propane gas 51 from the heat exchanger train enters a mid-section of the sized spent shale cooling device 18 and joins with the hot circulating propane gas upflowing from the sized spent shale cooling bed. The resultant total hot circulating propane gas contacts the total spent shale and ash mixture in the top section of said device 18 performing the elutriation of spent fines previously discussed, but the total hot propane gas also gains a final "trim" heat from the solids mixture such that it exits 9 said device at a precise controlled temperature, previously stated to be preferably in the range of 500° to 900° F., and flows to sized shale preheating to complete the circulation loop.

It is noted that designed flow features of the present invention are particularly advantageous during the cold restart mode of operation, wherein the circulating ash being heated by the heater 20 is maintained at a high level in the top section of device 18, and the total circulating propane gas, now cool because of the absence of hot retort vapor and hot sized spent shale in this mode, is heated by the circulating ash in the top of said device 18, thereby permitting rapid, efficient preheat of sized raw shale in device 7.

The fines preheat unit, shown as an inset on the attached flowsheet, is now discussed. The raw fines 6 flowing at ambient temperature from the raw shale elutriation unit 2 are fluidized by a small amount of fluidizing gas 57 which preferably is a small side stream from the total cool circulating propane gas 48 at its preferred condition of 100° to 200° F. and 5.0 to 9.0 p.s.i.g. For purpose of illus-

tration, the combined raw fines and its fluidizing gas is said to enter the shell-side of the vertical shell and tube device, herein designated the "first stage fines preheater" 58.

Simultaneously, the spent fines 53, flowing from the elutriation section of the sized spent shale cooling device 18 at approximately retorting temperature, previously stated to be preferably 800° to 1000° F., are fluidized by a small amount of hot fluidizing gas 52 which preferably is a portion of the low pressure steam generator effluent 41. The combined spent fines and its fluidizing gas as illustrated enter the tube side of the "second stage fines preheater" 60.

Heat is transferred through the tube walls of both stages from the fluidized spent fines to the fluidized raw fines, which when leaving the first stage 59 are at 300° to 600° F., preferably 400° to 500° F., and upon leaving the second stage are at 600° to 800° F., preferably 650° to 750° F. The fluidized spent fines exit the second stage 63 at 650° to 900° F., preferably 700° to 800° F., and exit

product is further cooled in a gas-to-gas exchanger 45 to give cooled retort gas product 46 at 210° F.

The total circulating propane gas 10 exits the sized shale preheater at 110° F. and 0.0 p.s.i.g., is compressed to 7.0 p.s.i.g. at 140° F., and a portion 49, about 40% of the total, flows through the gas-to-gas exchanger 45, exiting at 240° F., then passes through the condenser-exchanger 32, exiting at 600° F. The remaining portion of propane 52, about 60% of the total, enters the spent shale cooler 18, is heated to 850° F., joins with the 40% portion, elutriates the spent fines, then the total hot propane 9 at 750° F. enters the sized shale preheater.

The fines preheat unit consists of two stages; in the first stage raw fines are heated to 450° F. by spent fines being cooled from 750° F. to 500° F.; in the second stage the raw fines are heated from 450° F. to 700° F. by spent fines being cooled from 900° F. to 750° F.

An analysis of various feed and product streams of the process is shown in the table below. All figures are in pounds.

TABLE

Stream number.....	1	10	13	15	29	43	46	56	
Stream name.....	Shale feed	Propane	Hot ash	Retort vapor	Coker feed	Oil	Gas	Spent shale	Total out
Raw shale.....	2,000								
Gas.....		1,040		62			62		62
Oil.....				160		160			160
Coker feed.....				63	63				63
Carbon (to fuel).....									35
Spent shale/ash.....			1,700					1,680	1,680
Total.....	2,000	1,040	1,700	285	63	160	62	1,680	2,000

the first stage at 400° to 600° F., preferably 450° to 550° F.

The preheated raw fines 11, after separation of the fluidizing gas 61, are fed combined with the sized preheated shale as previously mentioned. The fluidizing gas 61 is advantageously returned to the circulating propane gas system by blending into stream 9 entering the sized raw shale preheater.

The cooled spent fines 55, after separation of the fluidizing gas 64 are blended with the cooled sized spent shale 54 to yield total spent shale 56 suitable for disposal with little or no further treatment. The fluidizing gas 64 being a small amount of spent steam is most advantageously vented to the atmosphere.

The invention is illustrated by the following example:

EXAMPLE

Raw shale 1 crushed to one inch maximum particle size enters an elutriation unit 2 where air 3 elutriates particles less than 0.005 inch giving raw fines 6 and exhaust air 4. The sized shale 5 enters the sized shale preheater 7, wherein it is heated to 700 F. by direct contact with hot circulating propane gas 9.

Total preheated shale 12 at 700° F. is contacted by hot ash 13 at 1200° F. in the retort 14, liberating retort vapor 15 at 900° F., and spent shale and ash 16 also at 900° F.

Spent shale and ash 16 is elutriated by hot circulating propane 9 in the top section of the spent shale cooler 18 to give spent fines 53. Part of the sized spent shale and ash 19 is diverted to a heater-boiler 20 where carbon burn-off of the spent shale portion yields hot ash 23 which is elevated 27 for return to the retort.

The portion of spent shale an dash in the spent shale cooler 18 that is not diverted is cooled in the bottom section to 190° F. by circulating propane gas 52 entering at 140° F.

The retort vapor 15 at 900° F. is partially condensed in a quench tower 28 yielding heavy oil 29 at 850° F. containing suspended solids. The uncondensed portion at 750° F. is cooled in a condenser-exchanger 32 to 500° F. to provide reflux 34, excess condensate 35 and uncondensed retort vapor 38. Further cooling occurs in a low pressure steam generator 39, to give medium raw oil 43 and retort gas product 44, both at 400° F. The retort gas

It is claimed:

1. A process for retorting oil shale which comprises:
 - (a) distilling shale oil vapors in a retorting zone from raw shale heated to a retorting temperature,
 - (b) separating hot spent shale from the retorting zone,
 - (c) passing a circulating stream of a normally gaseous hydrocarbon in direct contact with hot spent shale and in indirect contact with retort vapor separated from the retorting zone thereby heating the normally gaseous hydrocarbon to a high temperature,
 - (d) passing the circulating stream of normally gaseous hydrocarbon thus heated to a high temperature into direct contact with raw shale thereby preheating it,
 - (e) heating a particulate solid heat transfer medium to a temperature in excess of the retorting temperature,
 - (f) passing preheated raw shale and the thus heated particulate solid heat transfer medium into direct contact, and into the retorting zone thereby heating the preheated raw shale to a retorting temperature.
2. A process for retorting oil shale as set forth in claim 1 wherein said normally gaseous hydrocarbon is selected from the group consisting of propane, butane, and mixtures thereof.
3. A process for retorting oil shale as set forth in claim 1 wherein the particulate solid transfer medium is spent shale removed from contact with the circulating stream of normally gaseous hydrocarbon.
4. A process for retorting oil shale as set forth in claim 3 wherein the spent shale is heated to a temperature in excess of retorting temperature by burning off the residual carbon thereon with an oxygen containing gas.
5. A process for retorting oil shale as set forth in claim 1 wherein fine spent shale ash is separated from the circulating stream of normally gaseous hydrocarbon after passing in direct contact with hot spent shale and prior to direct contact with raw shale.
6. A process for retorting oil shale as set forth in claim 1 wherein at least a portion of the circulating stream of normally gaseous hydrocarbon from the preheated raw shale is passed into indirect heat exchange with shale oil vapors and then circulated into direct contact with hot spent shale separated from the retorting zone.

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7. A process as set forth in claim 1 wherein steam, superheated to approximately retorting temperature, is injected into contact with the shale in the retorting zone thereby facilitating the distillation of raw shale oil fractions from the raw shale and particulate solid heating medium.

8. The process as set forth in claim 1 wherein fines are removed from the hot spent shale, are fluidized, and passed in indirect heat interchange with the fluidized fines from said raw shale thereby preheating said raw shale fines, said preheated raw shale fines are then contacted with the particulate solid heating medium in the retorting zone.

9. The process as set forth in claim 1 wherein the shale oil vapors are separated into liquid fractions and vapor fractions, at least a portion of the circulating stream

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is passed in indirect heat interchange with said vapor fractions and subsequently in indirect heat interchange with said shale oil vapors prior to recirculation into direct contact with spent shale.

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CURTIS R. DAVIS, Primary Examiner

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