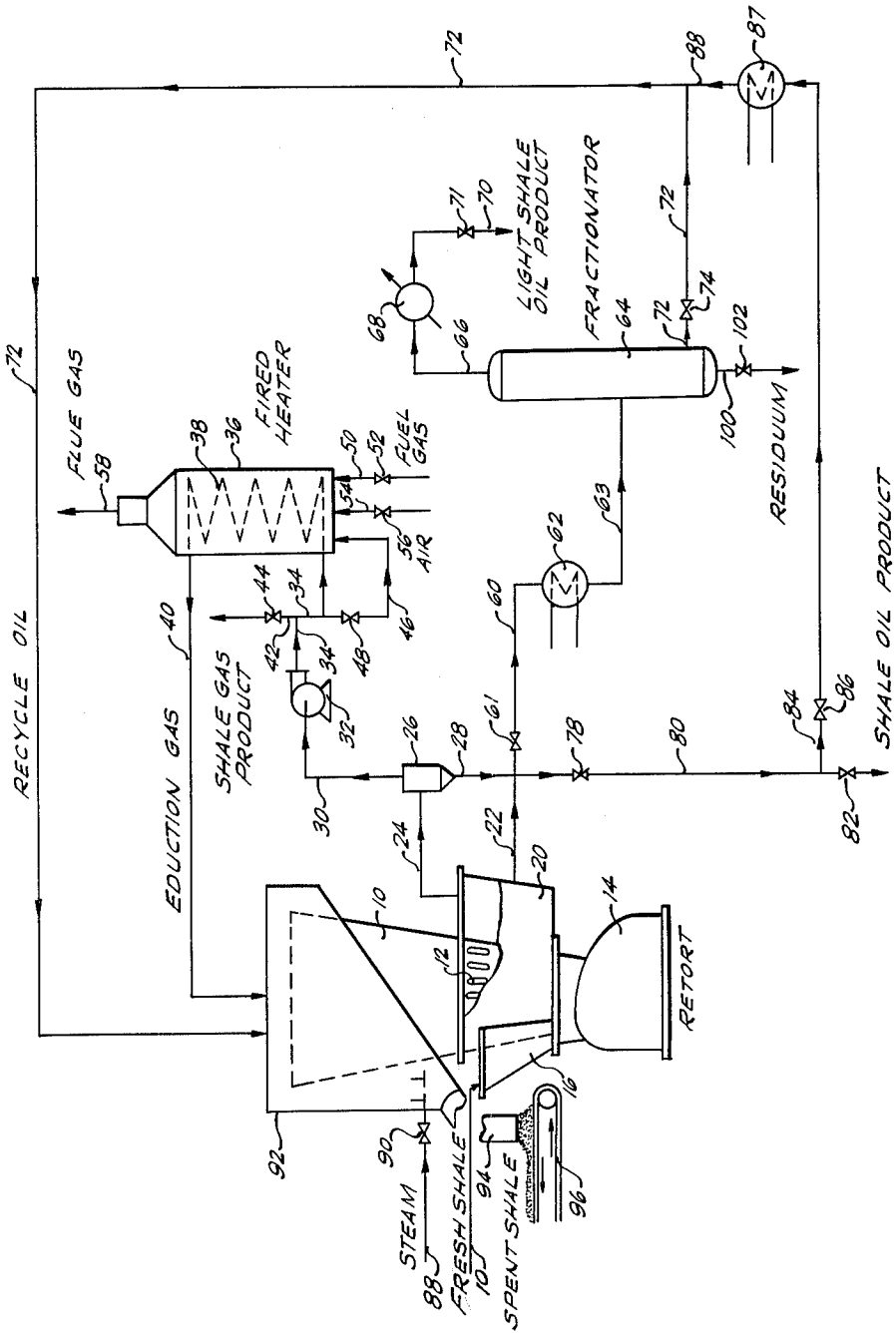
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OIL SHALE RETORTING WITH SHALE OIL RECYCLE

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OIL SHALE RETORTING WITH SHALE OIL RECYCLE

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This application is a continuation-in-part of pending United States Application Serial No. 71,991 filed November 28, 1960, now abandoned.

This invention relates generally to a process for the treatment of oil-containing or oil-producing solids for the extraction of gas and liquid products therefrom. More particularly, this invention relates to a new and improved process for the retorting of oil shale to recover optimum hydrocarbon oil and gas values therefrom.

The shale oil produced by conventional retorting processes has a number of characteristics which make it difficult to transport and subsequently refine. Among these detrimental characteristics, one of the most bothersome is the high pour-point of the product shale oil which makes handling at ambient temperatures difficult in the retort oil recovery system. Furthermore any subsequent transportation of shale oil from the retorting site to a refinery site is hampered because of the poor flow characteristics of these high pour-point oils. Typical pour-points of shale oils from existing retorting processes are in the range of 75° to 100° F., yet for satisfactory pipeline transportation the pour-point should be lower than 55° F. In the United States, most of the oil shale deposits are located in areas where the temperatures during a good portion of the year are below 50° F. and are often below freezing (32° F.). Another physical characteristic, viscosity, is related to the same problem of ambient temperature influence. These shale oils also have viscosities with related flow characteristics which make them difficult to transport and furthermore which consume substantially greater amounts of transport energy than that required to move the same volume of lower viscosity oil.

It is therefore, an object of this invention to provide an improved oil shale retorting process which achieves a reduction in the pour-point, a reduction in the viscosity of the product oil, and a higher oil recovery than existing retorting processes, yields a high B.t.u. shale product gas, minimizes degradation of the liquid product, and produces an oil product of substantially increased stability and quality. Other objects and advantages of this invention will become apparent to those skilled in the art as the description and illustration thereof proceed.

I have now found that the foregoing objects can be realized in a hot gas retorting process wherein at least a portion of the liquid product oil is recycled to the eduction zone of the retort as a component of the hot eduction fluid. More particularly, the liquid oil recycle stream can be either the liquid oil phase directly from the retort, or, it can be a portion of the retort liquid phase which has been passed through a fractionation column. A heavy fraction obtained from the distillation of the retort oil can be recycled to the retort as the liquid oil recycle, or the oil recycle can be a middle-cut fraction from the aforementioned distillation. Also, any combination of the above streams derived from the retort liquid phase can comprise the liquid oil recycle stream

to the retort eduction zone. Although the recycle of any portion of the retort liquid phase is advantageous, it is most desirable to return to the retort eduction zone the heavier fractions of the hydrocarbons educted from the shale. No matter which stream is recycled to the retort, the essence of my invention is to recycle a sufficient quantity of oil to effect a significant improvement in the quality of the net liquid oil product, particularly as evidenced by a reaction in the pour-point and viscosity. No significant effect on pour-point reduction is apparent at recycle rates lower than about 5 percent, and it is usually uneconomical to recycle more than about 50 percent of the product oil. Therefore, although higher recycle rates can be employed, the preferable embodiment of my process comprises recycle of at least about 5 percent and not more than about 50 percent of the volume of net shale oil product from the retorting process.

Furthermore, it is preferred that the recycled oil fraction have an initial normal (atmospheric pressure) boiling point in excess of 500° F., and more preferably an initial over 600° F. Thus, the recycle stream is essentially comprised of at least a substantial portion of the heavy deleterious materials which contribute markedly to high viscosity and high pour-point of shale oils produced by existing retorting processes. These materials, when recycled to the hot recycle gas retort eduction zone, as hereinafter described, are converted to more desirable products which yield an oil of substantially lower viscosity and substantially lower pour-point with essentially no loss in overall yield. It is essential that the recycle oil be returned to the inlet of the retort with the hot eduction gases for maximum quality enhancement.

The preferred non-combustive recycle gas retorting technique of this invention comprises a substantially continuous upward feed of coarse oil shale particles of up to about 6 inches, preferably in the size range of ⅛-inch to 2 inches, in a vertical retort, the kiln section of which typically has a horizontally enlarging area with an increase in elevation. The retort is enclosed so as to exclude air or any oxygen-containing gas from the interior and from contact with the educted products. Any oxygen present in the eduction zone, or in contact with the recycle oil, causes partial oxidation and degradation of the recycle oil and educted product oil. Shale is fed typically by a vertically acting piston feeder located within a feeder case below the kiln and can be of the form shown in U.S. Patent No. 2,501,153 to Berg, or any satisfactory form which provides uniform solids upflow within the retort. A cylinder containing the raw shale oscillates from alignment with a shale supply hopper into alignment with the vertical solids-fluid contacting zones of the retort. The solids feeder passes the shale upwardly successively through a perforated solids-fluid disengaging zone, a shale preheating and product cooling zone, and a shale oil eduction zone. Shale particles, having had the optimum oil quantity educted therefrom, are removed from the top of the eduction zone. The solids preferably pass through the eduction zone at a solids retorting rate between about 100 and about 600 pounds per hour per square foot of eduction zone horizontal cross-sectional top surface. These spent shale particles are found to be substantially unchanged in exterior physical size and configuration throughout the recycle gas retorting process of this invention. Produced gases, vapors and liquids, along with the eduction fluid are removed just above the bottom entry location of the fresh

shale feed and a hot product recycle gas is continuously supplied to the top of the eduction zone along with a liquid oil recycle stream comprising at least a substantial portion between about 5 and about 50 percent of the retort liquid product.

The hot product recycle gas is introduced into the retort at preferably about 1,000° F. to 1,300° F., and less than about 1,500° F., maximum temperature. The liquid oil recycle stream can be supplied at any temperature below the decomposition temperature, but preferably is supplied at a temperature as near as possible to the preferred eduction gas temperature of 1,000° F. to 1,300° F. The hot eduction fluid comprises a combination of recycle gas from the retort gas phase and an oil recycle stream from the retort liquid oil phase. This hot eduction fluid mixture passes downwardly onto and through the upward flow of shale and normally has a superficial mass velocity of about 60 to about 400 pounds per hour per square foot of bed cross-section at the top surface of the eduction zone. These eduction fluid flow rates are particularly applicable to oil shale having a Fischer Assay range of between about 80 gallons per ton and about 10 gallons per ton or lower. The eduction zone temperature required for the proper retorting of shale in the hot recycle gas retort of this invention is usually between about 600° F. and about 1,200° F. and preferably between about 800° F. and 1,000° F., depending upon the type of shale being retorted and the products desired. The highest temperatures exist at the top of the kiln, and decrease down through the eduction zone until the lowest eduction temperature is found adjacent the shale preheating and product cooling zone. Shale in the eduction zone need not, and preferably does not exceed about 950° F. These lower temperatures substantially limit carbonate decomposition while still providing complete hydrocarbon eduction. While the eduction zone pressure is usually near atmospheric, the pressure can be either subatmospheric or superatmospheric with the pressure at the top of the eduction zone always being greater than the pressure in the lower zones.

The recycle gas, being a shale product gas from noncombustive retorting, contains essentially no free oxygen with which recycle or educted oil can combine chemically, nor does it contain many of the conventional diluents found in flue gases such as nitrogen, argon, etc. This recycled product gas, collected with the liquid shale oil product in an accumulation reservoir, is usually withdrawn from the retort at a temperature between about 100° F. and about 200° F., preferably at about 100° F. and consists mainly of hydrogen and light hydrocarbons, e.g., methane, ethane, propane, and the like.

The improved process of my invention can best be understood with reference to the accompanying drawing, which forms a part of this application, and the subsequent description thereof. The illustration is of an elevational view in partial cross-section of the major items of equipment employed, and includes a schematic flow diagram of my shale oil eduction process. For simplicity, and ease of understanding, the conventional associated equipment such as liquid oil pumping means, flow controlling means, shale scraper means, solids pumping means, valves, pumps, recycle lines, heat exchangers, and the like, have for the most part not been illustrated in the drawing since conventional apparatus can be used and form no part of the invention.

Referring now more particularly to the drawing, the process of the present invention is described in terms of a specific example as applied to the retorting of a Colorado oil shale of 0 to 6 inches in average size at a rate of about 1,650 tons per day to produce a low pour-point, low viscosity, high quality shale oil and a high B.t.u. shale gas. The major apparatus consists essentially of a recycle gas retort, a fired heater, and a vacuum distillation column. The recycle gas retort has essentially three part; namely, an upper eduction kiln **10**, and intermediate perforate section **12**, and a lower reciprocating piston shale feeder contained within feeder housing **14**.

Shale feeder housing **14** contains a vertically reciprocating feeder piston which is contained within an oscillating feeder cylinder, not shown. The feeder cylinder oscillates in a vertical plane between a vertical feeding position, in which it is aligned with a vertical axis of kiln **10** and disengaging section **12**, and an inclined feeder charging position in which the feeder cylinder is inclined from the vertical and aligned with the lower outlet opening of shale feed hopper **16**. The feeder piston and feeder cylinder are separately oscillated hydraulically so that raw shale is drawn into the feeder cylinder from feed hopper **16**. The feeder cylinder oscillates into the vertical position, the feeder piston forces the charge of fresh shale upwardly into disengaging section **12** and kiln **10**, displacing shale above it upwardly and displacing spent shale from the top of the kiln. The feeder cylinder then oscillates into the inclined position to accept a fresh shale charge completing the feeder cycle. This cycle is repeated, thereby continuously feeding fresh shale at the bottom of the structure and displacing hot spend shale from the top. In this way, the shale is passed upwardly through the retort countercurrent to the hot eduction fluid subsequently described, wherein it is contacted with the downflowing hot eduction gas and hot recycle oil mixture.

The raw shale feed, at ambient temperature, is introduced at a rate of about 1,650 tons per day through line **10** into shale feed hopper **16** from which it is fed, as previously described, upwardly through the retort. The shale moves successively upwardly through a solids-fluid disengaging zone, a row shale preheating zone, and a shale eduction zone. Surrounding the perforated disengaging section **12**, is a collection manifold **20** which constitutes a reservoir for the product oils and gases. During retorting in kiln **10**, the shale is gradually heated to retorting temperatures, and the organic matter, commonly termed kerogen, decomposes to produce shale oil gases and vapors. These products move downwardly in the eduction fluid flow and are cooled and condensed by direct contact with the upwardly moving cold fresh shale. The cooled gases and condensed vapors collect in manifold **20** from which they are withdrawn. The liquid oil product partially fills feeder case **14** which prevents air from entering the retort through shale feed hopper **16**.

The rich shale gas product of the retorting operation is removed from manifold **20** through line **24** at a temperature of about 140° F. and is introduced into one or more mist and entrainment separators, such as cyclone **26**. Here the gas is freed of residual traces of oil product and the oil is withdrawn from cyclone **26** through line **28** and combined with the oil product which is removed at a temperature of about 140° F. from manifold **20** through line **22**. The mist and entrainment separator can comprise either a cyclone separator, an oil wash such as in an oil absorber, an electrostatic or ultrasonic precipitator, any liquid scrubber used to clean up residual dust and oil mists, or any other suitable separator or combinations thereof for removing finely divided liquid particles from a gas stream.

The substantially oil-free retort gas is withdrawn from separator **26** via line **30** by means of blower **32**. This maintains the downward flow of eduction fluid through kiln **10** and disengaging zone **12** and maintains the lower portion of the retort under a slightly subatmospheric pressure. It is to be understood that the flow of gases through the retort can also be achieved by putting blower **32** into a location such as line **40** and maintaining the retort under a positive pressure above atmospheric. The net production of about 1,300 M s.c.f./d. (thousands of standard cubic feet per day) of dry shale product gas is withdrawn from blower discharge line **34** through line **42** at a rate controlled by valve **44**. This high B.t.u. (950 B.t.u. per cubic foot) shale product gas stream from

line 42 has the following approximate composition (dry basis):

Table 1

Component:	Mol percent
H_2	17
C_1	31
C_2	14
C_3	7
C_4	3
C_5	2
CO_2	20
CO	4
H_2S	2
	100

The recycled portion of the rich shale product gas, about 28,000 M s.c.f./d., is passed via line 34 from the blower discharge into fired heater 36 for heating to eduction temperature. The recycle gas introduced through line 34 passes through recycle gas heating coil 38 to hot recycle gas line 40 and thus into the top of the recycle gas retort at substantially atmospheric pressure. The preheating temperature and gas quantities are controlled so that the recycled retort gas produced from fired heater 36 is at a temperature of about 1,150° F. as it enters the recycle gas retort.

The liquid shale oil from the retort flowing through line 22 from manifold 20 at a rate controlled by valve 61 is passed into feed heater 62. This withdrawn shale oil is usually substantially free of shale fines, however, fines separation facilities may be optionally installed if required. Within feed heater 62, the retort shale oil temperature is raised to about 800° F. at atmospheric pressure and thence the hot oil stream is passed via line 63 into vacuum distillation column 64. Vacuum fractional distillation column 64, operating at a pressure of about 100 mm. of Hg absolute pressure, separates the retort shale oil into two fractions. A light shale oil fraction is produced overhead through line 66 to cooler 68 which condenses and cools the light oil product. This light oil product then flows from cooler 68 via line 70 at a rate, controlled by valve 71, of 1,350 barrels per day to suitable storage as the shale oil product of the process. A quantity of the light shale oil is returned to column 64 as reflux. The reflux system is deleted from the drawing for clarity. This net shale oil product has characteristics as shown in Table 2.

Table 2

Pour point, ° F.	40
Gravity, °API at 60° F.	25
Viscosity at 100° F. cs.	60
Pentane insolubles, wt. percent	0.5
Carbon residue, Conradson, wt. percent	1.0
Distillation (ASTMD–1160 at atmospheric), ° F.:	
10 wt. percent	260
50 wt. percent	600
90 wt. percent	770

The bottoms fraction, with a normal boiling point above 800° F., is withdrawn from fractional distillation column 64 through line 72 at a rate controlled by valve 74. This bottom shale oil fraction is the recycle oil which is passed at a temperature of about 800° F. via line 72 to the top of the hot recycle gas retort at the rate of 610 barrels per day. This hot recycle oil, introduced through enclosed spent shale hopper 92 onto the spent shale top surface of the eduction zone located in the upper part of kiln 10, is vaporized and converted upon contact with the spent shale. This contacting of the hot recycle oil with the spent shale particles apparently has a beneficial effect similar to visbreaking with a minimum of cracking evidenced by little or no loss in yield and no additional gas make. Although it is not fully understood, it appears that spent shale, educted under non-combustive hot recycle gas retorting conditions, is particularly effective as a contact material in the production of a light, high quality oil from a low grade heavy residual recycle shale oil stream. The inclusion of a substantial portion of the liquid product oil in the eduction fluid has a beneficial solvent effect whereby a superior liquid oil product is recovered.

The eduction fluid, comprising hot recycle gas from line 40 and vaporized hot recycle oil from line 72, flows downwardly through kiln 10 countercurrently to the upwardly moving shale. There the shale is heated to a retorting temperature of about 950° F. and hydrocarbon gases and vapors are retorted from the shale solids stream. This retorting normally occurs in the upper half of kiln 10. The educted oils and gases, along with the eduction fluid, continue downwardly through the eduction zone and then through the shale preheating and product cooling zone countercurrent to the rising fresh shale, thus heating this fresh shale stream, cooling the eduction fluid, and partially condensing the educted products. Since the gases and liquids contact the solids directly, a highly efficient interchange of heat is effected in which the gases are cooled and additional liquids are condensed as well as sub-cooling the liquid products previously condensed. This produces the cooled product gas and condensed oils, previously referred to, which collect in manifold 20. In this direct contact, the upwardly rising raw oil shale is preheated in the shale preheating zone to temperatures as high as 300° F. to 600° F. at which temperature they enter the eduction zone.

At the top of kiln 10, spent shale accumulates and is discharged into enclosed spent shale hopper 92 by means of rotating or reciprocating scrapers, not shown, mounted in the top of spent shale hopper 92. The educted shale discharges at a temperature of about 950° F. from spent shale hopper 92 through line 94 and is removed to suitable disposal facilities by means of spent shale conveyor 96 at the rate of about 1,350 tons per day. To prevent the entrance of air into the enclosed hot gas recycle retort system, steam or other seal gas is usually introduced through line 88 at a rate controlled by valve 90 into the lower portion of spent shale hopper 92. A rotary airlock or equivalent devices can also be used at the ash outlet to prevent air introduction. Under some retorting conditions it is desirable to introduce the hot recycle gas to the retort through the lower portion of spent shale hopper 92 at a point above the introduction of the seal gas entering via line 90. The hot recycle gas then passes through the spent shale bed in hopper 92 stripping the spent shale of the last traces of retained recycle oil, thus eliminating this possible source of yield loss.

The combustion chamber of fired heater 36 is supplied with fuel gas via line 50 at a rate controlled by valve 52. This fuel gas is burned in sufficient air, entering fired heater 36 via line 54 at a rate controlled by valve 56, to produce a substantially inert flue gas which is expelled to the atmosphere via stack 58. A portion of the gas product from line 34 can also be used as fuel for fired heater 36 and can be introduced either alone or to supplement the fuel gas entering through line 50. If a portion of the shale gas product is used, it is introduced through line 46 at a rate controlled by valve 48. This fuel gas combustion provides the heat required to bring the recycle product gas flowing through fired heater coil 38 to eduction temperature. It is to be understood that any substantially equivalent form of heating is satisfactory for raising the eduction fluid to retorting temperatures.

The contact time required for substantially complete eduction in my recycle gas retort can be as low as 10



The undistilled portion from the Engler column, 54 weight percent, was slowly poured over the top of the shale bed in run B–120 during retorting, i.e., after the shale at the top of the bed had reached a temperature of 1,000° F. The overhead from the Engler distillation of run B–118 product oil was added to the product oil of run B–120 before the inspection tests were made. Retorting conditions and product characteristics of these three runs are summarized in Table 6.

Table 6

Run Number	B–118	B–119	B–120
	Preparation Of Recycle Oil	Standard Run	Oil Recycle Run
Conditions:			
Recycle Gas flow, lb./hr./ft.²	291	291	287
Pressure, p.s.i.g.:			
Top of retort	2.0	2.0	2.0
Bottom of retort	1.0	1.0	1.0
Solids retorting rate, lb./hr./ft.²	374	354	369
Oil Yields:			
Rundown Oil, wt. percent shale	10.37	10.31	10.33
Rundown Oil, wt. percent Assay	91.2	90.7	90.9
Rundown Oil, vol. percent Assay	88.1	87.7	88.0
C_4+Oil, wt. percent Shale	10.50	10.43	10.54
C_4+Oil, wt. percent Assay	92.4	91.8	92.7
Oil Properties:			
Gravity, ° API at 60° F		18.6	18.9
Pour point, ° F		75	55
Pentane Insolubles, wt. percent		3.11	2.78
Carbon Residue, Conradson, wt. percent		5.60	4.86
Composition (wt. percent):			
Carbon		84.7	84.8
Hydrogen		12.4	11.2
Sulfur		0.87	0.84
Nitrogen		2.15	1.98
Oxygen		1.2	1.3
Viscosity at 100° F.:			
Cs		78.4	72.5
SSU		363.4	336.0
Gas Yields and Properties:			
Yield, s.c.f./ton	631	630	613
Molecular wt. avg	24.6	24.6	24.2
Heating Value (dry), B.t.u./s.c.f	846	846	891
Gas Evolution Rate, s.c.f./hr./ft.²	118	111	113
Composition (percent by by volume):			
H_2		15.8	17.4
CH_4		32.3	32.3
C_2–C_5 saturates		8.2	10.2
C_2–C_5 unsaturates		14.5	13.7
CO		9.0	9.8
CO_2		19.5	16.4
H_2S		0.7	0.2
		100.0	100.0

It should be particularly noted that little additional coking took place in the oil recycle run as illustrated by the almost identical rate of gas evolution for the three runs. Although the gas quality did not change as a result of oil recycle, there was a marked advantageous alteration of the properties of the shale oil produced. The property most affected was pour-point which was reduced from 75° F. to 55° F. by this single pass recycle. Other properties, pentane insolubles, Conradson carbon, and viscosity were affected to a slightly less extent, although in all of these a substantial beneficial change was observed. Overall, the product of the oil recycle run (B–120) is slightly lighter than that of (B–119), but the difference is inappreciable. Thus, from the above tabulated results, it can be concluded that while oil recycle has a beneficial effect on the properties of the shale oil, oil yield is not diminished.

Although much of the foregoing detailed description of my invention has been expressed in terms of the production of shale oil and gas from oil shale, the present process is applicable to other solids-fluid contacting processes in which a liquid hydrocarbon product is produced from solids. Thus, the process is applicable to the treatment of such particulate oil-producing hydrocarbonaceous solids as oil shale, tar sands, bituminous and sub-bituminous coals, bitumen-saturated diatomite, lignite, peat and the like.

Various other changes and modifications of this invention are apparent from the description of this invention and further modifications will be obvious to those skilled in the art. Such modifications and changes are intended to be included within the scope of this invention as defined by the following claims.

I claim:

1. A method of improving the transportability of the liquid product from a non-combustive retorting process for retorting particulate oil-producing hydrocarbonaceous solids which comprises:

educting hydrocarbons from said solids by contacting said solids with a substantially oxygen-free hot eduction fluid in an eduction zone, said hot eduction fluid comprising a mixture of hot gases and recycled product oil;

collecting liquid product oil and gas from said eduction zone; and

recycling to the inlet of said eduction zone as a component of said hot eduction fluids, a quantity of said liquid product oil sufficient to effect a reduction in the pour point of the net recovered liquid product oil of at least 5° F. over that obtained without said recycle of liquid product oil, said recycled liquid product oil not exceeding about 50 percent of the net recovered liquid product oil, and said recycled liquid product oil component of said eduction fluid being essentially completely vaporized on contact with said solids.

2. The method of claim 1 wherein said liquid product oil recycle is at least about 5 percent of said net recovered liquid product oil.

3. A method of improving the quality of the liquid product from a non-combustive retorting process for retorting particulate oil-producing hydrocarbonaceous solids which comprises:

educting hydrocarbons from said solids by contacting said solids with a substantially oxygen-free hot eduction fluid in a retorting zone, said hot eduction fluid comprising a mixture of substantially oxygen-free hot gases and a recycled heavy product oil fraction;

collecting liquid product oil and gas from said retorting zone;

separating at least a substantial portion of said liquid product oil into a heavy liquid fraction and a light liquid fraction; and

recycling said heavy liquid fraction to said retorting zone as a component of said hot eduction fluid, said recycled heavy liquid fraction being recycled in sufficient quantity to effect a reduction in the pour-point of the net recovered liquid product oil of at least 5° F. over that obtained without said recycle of liquid product oil, said recycled product oil not exceeding about 50 percent of the net recovered liquid product oil, and said recycled liquid product oil component of said eduction fluid being essentially completely vaporized on contact with said solids.

4. The method of claim 3 wherein said recycled heavy liquid fraction is at least about 5 percent of said net recovered liquid product oil.

5. A process as defined in claim 3 wherein a portion of said liquid product oil collected from said retorting zone is recycled directly to said retorting zone along with said heavy liquid fraction.

6. A method of improving the quality of liquid product from a non-combustive retorting process for retorting particulate oil-producing hydrocarbonaceous solids which comprises:

educting hydrocarbons from said solids by contacting said solids with a substantially oxygen-free hot eduction fluid in a retorting zone, said hot eduction fluid

comprising a mixture of substantially oxygen-free hot gases and a recycled product oil high-boiling fraction;

collecting product oil and gas from said retorting zone;

separating at least a substantial portion of said product oil into a low-boiling fraction, a high-boiling fraction, and a residuum fraction boiling above said high-boiling fraction; and

recyling said high-boiling fraction to said retorting zone as a component of said hot eduction fluid, said high-boiling fraction being recycled in sufficient quantity to effect a reduction in the pour-point of the net recovered liquid product oil of at least 5° F. over that obtained without said recycle of liquid product oil, said recycled liquid product oil not exceeding about 50 percent of the net recovered liquid product oil, and said recycled liquid product oil component of said eduction fluid being essentially completely vaporized on contact with said solids.

7. A process as defined in claim 6 wherein said recycled high-boiling fraction is between about 5 percent and about 50 percent of said net recovered liquid product oil.

8. A process as defined in claim 6 wherein said residuum fraction has a normal boiling point above about 850° F.

9. A method of lowering the pour-point of the liquid product from a process of retorting particulate oil-producing hydrocarbonaceous solids which comprises:

contacting said solids with a substantially oxygen-free hot eduction fluid in a non-combustive retorting zone;

collecting oil and a high B.t.u. gas from said non-combustive retorting zone;

separating a substantial portion of said oil into a heavy fraction and a light fraction;

recycling said heavy fraction, amounting to between about 5 and 50 percent of said net product oil, to said retorting zone, said heavy fraction of said oil essentially completely vaporizing on contact with said solids in said retorting zone;

heating a portion of said high B.t.u. gas to eduction temperature; and

passing said heated portion of said high B.t.u. gas to said non-combustive retorting zone to combine with said recycled heavy fraction as said hot eduction fluid.

10. A process as defined in claim 9 wherein said solids comprise oil shale particles of sizes up to about 6 inches in diameter.

11. A process as defined in claim 9 wherein said solids are passed upwardly in the form of a dense bed, and said hot eduction fluid is passed downwardly through said non-combustive retorting zone.

12. A non-combustive retorting process for retorting particulate oil-producing hydrocarbonaceous solids which comprises:

passing said solids successively through a fluid-solids disengaging zone, a solids preheating and product cooling zone, and an eduction zone;

passing a hot, essentially oxygen-free eduction fluid through said eduction zone thereby educting liquid and gaseous hydrocarbons from said solids therein;

cooling said liquid and gaseous hydrocarbons in said solids preheating and product cooling zone thereby obtaining a gas phase and a liquid phase;

withdrawing said liquid phase and said gas phase from said fluid-solids disengaging zone;

separating said liquid phase from said gas phase;

heating a portion of said gas phase to eduction temperature;

passing said heated portion of said gas phase to said eduction zone;

removing spent solids from said eduction zone;

separating said liquid phase into a low-boiling fraction and a high-boiling fraction;

withdrawing said low-boiling fraction as the liquid oil product of the process; and

recycling said high-boiling fraction to said eduction zone, said high boiling fraction being essentially completely vaporized on contact with said solids, said hot eduction fluid comprising said heated portion of said gas phase and said recycled high-boiling fraction amounting to between about 5 percent and about 50 percent of said liquid oil product.

13. A process as defined in claim 12 wherein said solids comprise oil shale particles of sizes up to about 6 inches in diameter.

14. A process as defined in claim 12 wherein said heated portion of said gas phase recycled to said eduction zone is at a temperature between about 1,000° F. and about 1,300° F. whereby said solids in said eduction zone are maintained at a temperature no greater than about 950° F.

15. A process as defined in claim 12 wherein said hot eduction fluid is provided to said eduction zone at a rate between about 60 and about 400 pounds per hour per square foot of eduction zone horizontal cross-sectional top surface, and wherein said solids are an oil shale having a Fischer Assay range of between about 10 and about 80 gallons of shale oil per tone.

16. A process as defined in claim 12 wherein said high-boiling fraction of said liquid phase recycled to the eduction zone has a normal boiling point in excess of 600° F.

17. A process as defined in claim 12 wherein said solids are passed upwardly in the form of a dense bed, and said hot eduction fluid is passed downwardly through said eduction zone.

18. A non-combustive retorting process for retorting oil shale which comprises:

passing a raw oil shale feed comprising shale particles at ambient temperature of sizes up to about 6 inches in diameter upwardly at a rate between about 100 and about 600 pounds per hour per square foot of eduction zone horizontal cross-sectional top surface in the form of a dense bed from a solids feeder zone successively through a fluid-solids disengaging zone, a solids preheating and product cooling zone, and an eduction zone;

passing an essentially oxygen-free hot eduction fluid downwardly through said eduction zone at a rate between about 60 and 400 pounds per hour per square foot of eduction zone horizontal cross-sectional top surface, which rate is sufficient to educt oil and gas from said oil shale, but is insufficient to heat any substantial portion of said eduction zone top surface to a temperature greater than about 950° F.;

withdrawing said gas phase and said liquid oil phase from said disengaging zone, separating said liquid oil phase from said gas phase;

heating a portion of said gas phase to a temperature between 1,000° F. and about 1,300° F. by indirect heat exchange;

recycling said heated portion of said gas phase to said eduction zone;

recycling a substantial portion of said liquid oil phase to said eduction zone, said portion being between about 5 percent and about 50 percent by volume of said liquid oil phase, and said recycled liquid oil being essentially completely vaporized on contact with said solids, said hot eduction fluid comprising said recycled portion of said liquid oil phase and said heated portion of said gas phase; and

removing spent shale from said top surface of said eduction zone.

19. A process as defined in claim 18 wherein said liquid oil phase is separated into a low-boiling fraction and a high-boiling fraction, said recycled portion of said liquid oil phase comprising said high-boiling fraction, and said

high-boiling fraction having a normal boiling point in excess of about 600° F.

20. A process as defined in claim **18** wherein said liquid oil phase is separated into a low-boiling fraction, a high-boiling fraction, and a residuum fraction boiling above said high-boiling fraction, said recycled portion of said liquid oil phase comprising said high boiling fraction, and said residuum fraction having a normal boiling point above about 850° F.

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