

May 12, 1964

G. E. IRISH ETAL

3,133,010

FEED SEGREGATION IN OIL SHALE RETORTING

Filed Nov. 17, 1960

2 Sheets-Sheet 1

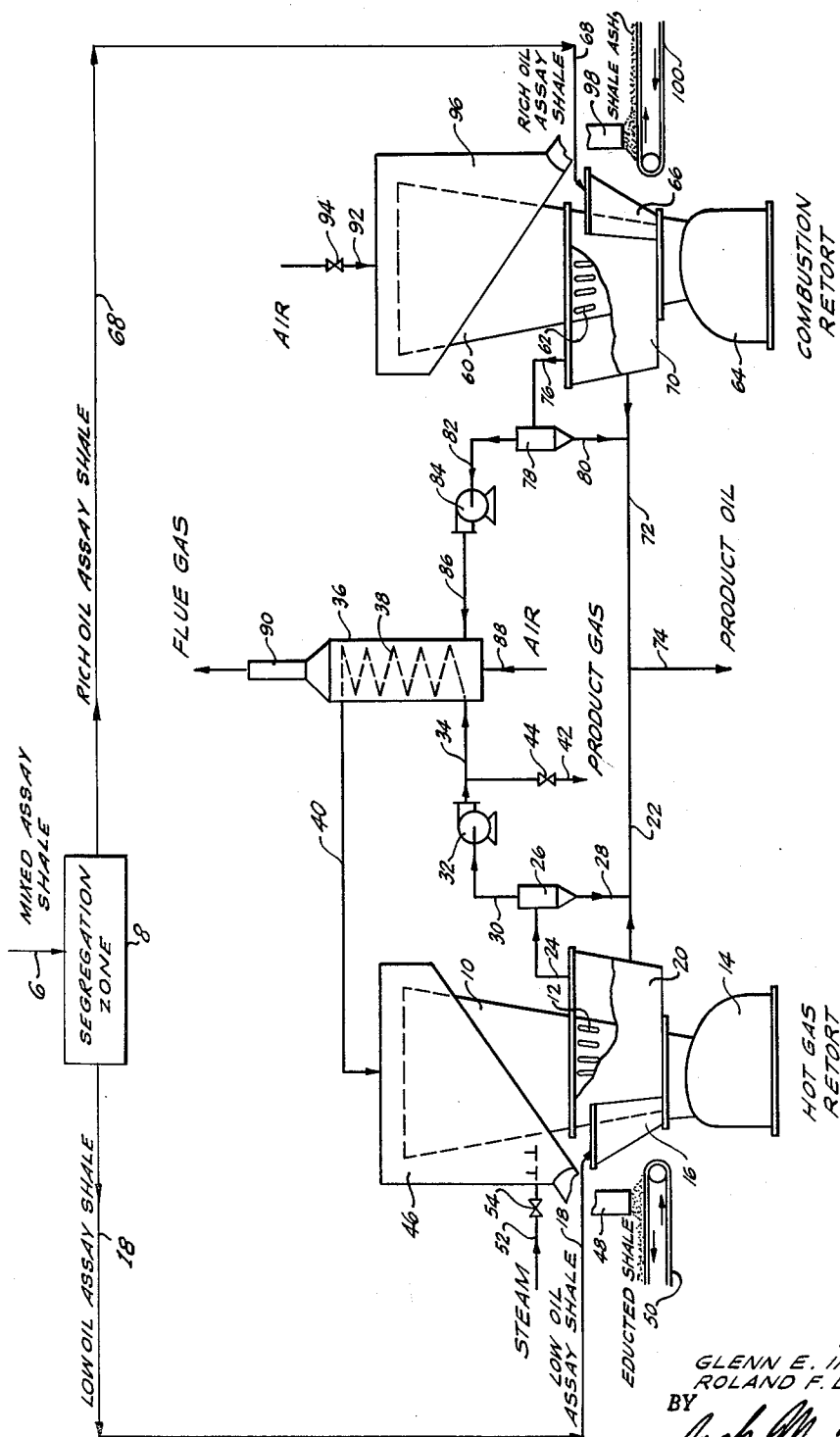


FIG-1

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2 Sheets-Sheet 2

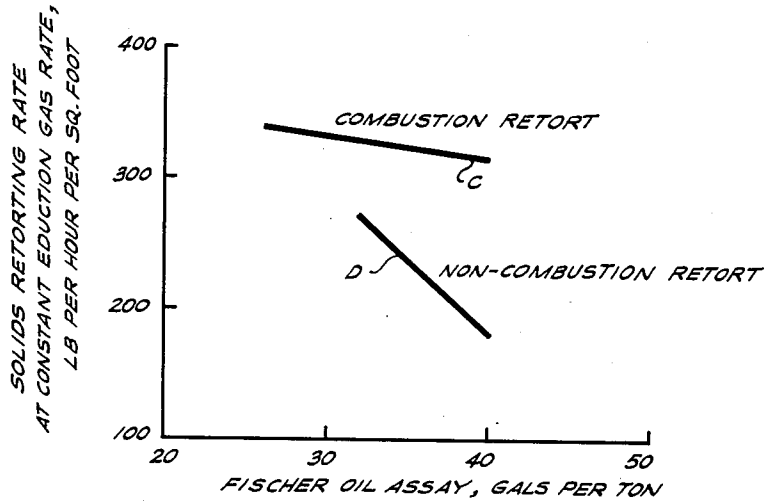


FIG 3

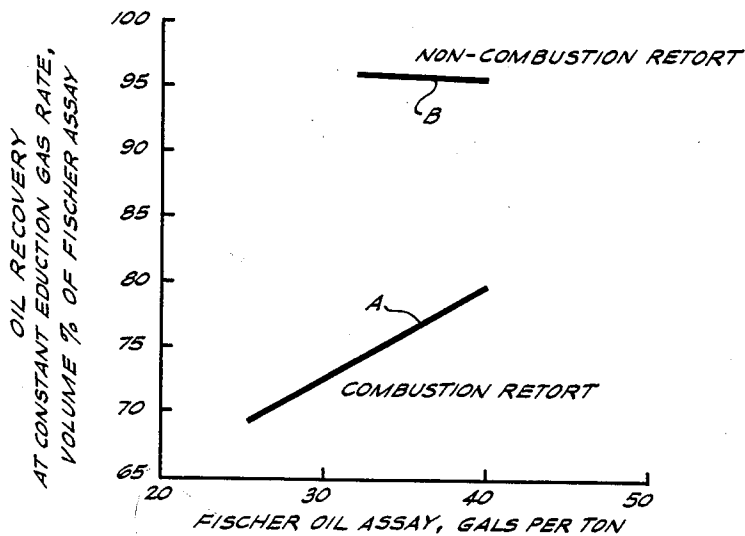


FIG 2

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3,133,010

FEED SEGREGATION IN OIL SHALE RETORTING

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Filed Nov. 17, 1960, Ser. No. 69,858
19 Claims. (Cl. 208-11)

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 new and improved methods of retorting a wide assay range of oil shale to recover optimum hydrocarbon oil and gas values therefrom.

In commercial oil shale operations, the shale as mined is not of uniform oil assay since the assay value differs appreciably from one level to another in the mine. The oil assay of these commercial shales can vary from 5 gallons per ton and lower to 100 gallons per ton and higher as conventionally determined by the Fischer Assay method (see Bureau of Mines, Report of Investigations 4477, Method of Assaying Oil Shale by a Modified Fischer Retort, Stanfield and Frost, June, 1949). In normal mining techniques, run of the mine shale is crushed and fed directly to the retorting plant. Thus, shale solids available from conventional mining and feed preparation have an oil assay which is average or typical of that mined from a single level, or from several levels, but does not normally have an oil assay value optimum for the type of retorting being utilized.

It is an object of this invention to provide an improved oil shale retorting process which achieves total optimum utilization of mined shale having a varying oil assay range and which further achieves high oil recovery, 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 with reduced sludge and gum-forming tendencies.

A more particular object is to provide an integrated retorting process in which the highly efficient combustion retorting extraction of fuel values from high oil assay shale is combined with the non-combustive eduction of high quality shale oil and product gas from low oil assay shale to yield substantially more liquid shale oil than can be realized in present retorting processes.

A further object of this invention is to improve the solids retorting rate of non-combustive hot recycle gas retort with no sacrifice in oil yield.

A still further object of this invention is to improve the oil extraction efficiency of a combustion retort with no sacrifice in solids retorting rate.

Other objects and advantages of this invention will become apparent to those skilled in the art as the description and illustration thereof proceed.

We have now found that the foregoing objects and their attendant advantages can be realized by assay segregation of the oil shale feed to retorting processes. In combustive retorting, we have found that when an oil shale feed mixture is separated into a high oil assay portion and a low oil assay portion, the high oil assay portion can be advantageously educted with substantial increased oil recovery (as a percent of Fischer Assay) as compared to an unsegregated feed mixture, and with comparatively little change in solids retorting rate. Furthermore, we have discovered that in non-combustive hot gas circulation retorting, the low oil assay portion of a feed, segregated as previously described, can advantageously be educted at substantially increased solids retorting rates with essentially no sacrifice in percentage oil recovery. Finally, we have found that the above discoveries can be advantageously combined in an integrated oil shale retorting

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process wherein the raw shale feed from the mine is separated into a high oil assay solids consist, which is fed to a combustive retort, and a low oil assay solids consist, which is fed to a non-combustive hot recycle gas retort. Thus, in this integrated oil shale retorting process, every particle of shale fed to the system is retorted under conditions best suited to obtain the highest possible yield of liquid shale oil in the most efficient manner.

More specifically, in processing a sub-divided solids charge which varies in oil assay value, the solids charge is divided into two fractions which differ substantially in average oil assay value. The fraction having the higher oil assay is fed to a combustive retort while the fraction having the lower oil assay is fed to a non-combustive retort. Any difference in the oil assay value of the two portions is advantageous, and a preferred solids feed has an assay value no lower than about 15 gallons per ton at one extreme and about 60 gallons per ton at the other. In a typical commercial oil shale operation, the shale is segregated into a lean fraction having an assay in the range of 20 to 35 gallons per ton, and a rich fraction having an assay in the range of 35 to 50 gallons per ton. A convenient manner of segregating the shale is to separate the rich shale from the lean shale at the mine and to arrange the solids transportation from the mine to the retort to maintain the segregation. Since low oil assay shale has a higher specific gravity than high oil assay shale, separation according to specific gravity can provide the required oil assay segregation. Further, we have found that run of the mine shale, when crushed, usually provides an inherent segregation by size, in which case the solids fines consistently are leaner in oil assay value than the larger particles. Thus, size segregation by conventional means, i.e., screening, can sometimes provide the desired assay segregation for this invention.

The preferred combustive retorting of this invention utilizes an upflow of shale solids and a downflow of flue gas, e.g., the combustion retort of Berg (see U.S. Patents Nos. 2,501,153, 2,640,014 and 2,640,019). In this type of retort, a high oil assay shale is received from storage into a hopper where it passes by gravity into a vertically acting piston feeder located within a feeder case below the kiln proper. This solids feeder passes the high oil assay shale upwardly successively through a perforated fluid-solids disengaging zone, a shale preheating and product cooling zone, a shale oil eduction zone, a spent shale burning zone, and a shale ash cooling zone from which it is expelled for disposal. The solids pass through the eduction zone at a solids retorting rate between about 100 and about 600 pounds per hour per square foot of bed cross-section. Air or other oxygen-containing gas enters the ash zone at the top of the kiln and flows downwardly where it is first preheated in cooling the hot shale ash. The heated air, at a typical flow rate between about 8 and about 18 M s.c.f. (thousands of standard cubic feet) per ton of raw shale feed flows into the burning zone where the carbonaceous residue on the spent shale is combusted forming hot flue gas and hot shale ash. This hot flue gas then continues downwardly into the eduction zone where it heats the raw shale to eduction temperatures, usually between about 600° F. and about 1,200° F. Hydrocarbon oils and gases are evolved in the eduction zone forming spent carbonaceous shale and a mixed fluid phase comprising flue gas together with the liquid and vapor educted products. The entire fluid phase passes downwardly through the preheating and product cooling zone in direct contact with the cool raw shale and is cooled, thereby condensing shale oil and preheating the raw shale near the bottom of the kiln. The liquid and gaseous products drawn off at the perforated disengaging zone, are separated from the upwardly moving shale. The shale gas phase flows from the lower surface of the eduction zone at a

superficial mass velocity of about 60 to about 400 pounds per hour per square foot of bed cross-section.

In combustive retorting we have found that higher assay shales yield a higher percentage recovery of the Fischer Assay oil than low assay shales. In a solids-upflow, gas-downflow combustive retort, a number of different assay oil shales, having a particle size range between $\frac{1}{2}$ and 1-inch in diameter, were educted with an eduction zone temperature of about 850–950° F., an air flow rate of about 13.5 M s.c.f. per ton of shale feed, and a superficial mass velocity of gas in the eduction zone of about 220 pounds per hour per square foot. The solids flow rate was determined by maintaining a fixed location of the eduction zone in the retort. The results, shown in FIGURES 2 and 3, illustrate that there is an increased oil recovery obtainable with increased oil assay feed (curve A, FIGURE 2), and that there is comparatively little change in retorting rate with a change in the Fischer Assay of the feed (curve C, FIGURE 3). Thus, assay segregation of the shale feed to a combustion retort provides a means of substantially increasing the oil recovery with essentially no sacrifice in solids retorting rate. Combustive retorting of hydrocarbonaceous solids encompasses any retorting process where there is fuel combustion within the retort. In contrast, non-combustive retorting includes any retorting process wherein hydrocarbonaceous solids are educted by contact in a retort with a substantially oxygen-free hot gas, i.e., no combustion taking place within the retort.

The preferred hot recycle gas eduction method, i.e., non-combustive retorting process, of this invention comprises a substantially continuous upward feed of low oil assay shale particles 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. 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. The solids feeder passes lean shale upwardly successively through a perforated solids-fluid disengaging zone, a shale preheating zone, and a shale oil eduction zone. These spent shale particles are found to be substantially unchanged in exterior physical size and configuration throughout this hot recycle gas retorting. Product gases, vapors, and liquids, along with eduction fluid, are removed just above the bottom entry location of the fresh shale feed, and an indirectly heated recycle stream of hot shale product gas is continuously supplied to the top of the enclosed eduction zone.

The hot product recycle eduction gas, preferably at about 1,000° F. to 1,300° F., and usually at less than about 1,500° F. maximum temperature, pass downwardly into and through the upward flow of lean shale. This hot eduction gas is normally supplied at a superficial mass velocity of from about 60 to about 400 pounds per hour per square foot of bed cross-section at the surface of the eduction zone. These gas flow rates are particularly applicable to oil shale having a Fischer Assay range from about 80 gallons per ton to as low as 10 gallons per ton or lower. The eduction zone temperature required for the proper eduction of shale in our hot recycle gas retort 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 zone. Shale particles in the eduction zone need not, and preferably do 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 atmos-

pheric, the pressures 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 eduction gas, being a recycled shale product gas, contains essentially no free oxygen with which educted oil can combine chemically, nor does it contain many of the conventional diluents found in flue gases such as nitrogen, argon, etc. This product gas, collected with the liquid shale oil product in an accumulation reservoir, is usually withdrawn at a temperature of 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. A particular feature of this recycled product eduction gas is embodied in its substantially uniform composition, preferably embracing an optimum carbon dioxide concentration. In a preferred embodiment, this recycle gas is maintained high in carbon dioxide content since this apparently has a substantial retarding effect on mineral carbonate decomposition. The carbon dioxide partial pressure of this preferred eduction gas is not allowed to drop below about 10 percent by volume, and preferably is maintained at a level in the order of 15 to 30 percent by volume which results in easier retorting control, more uniform oil and gas products, and, as a result of reduced heat loss from carbonate decomposition, the use of either a lower temperature eduction fluid or a reduced quantity of recycled eduction gas. Carbon dioxide makeup, if required, can be obtained by treatment of a portion of the shale product gas stream, or of other carbon dioxide-containing streams by conventional means such as diethanolamine absorption, hot carbonate absorption, or other conventional carbon dioxide separation processes. A particularly preferred source of carbon dioxide in this invention is the low B.t.u. waste product gas stream resulting from combustion retorting.

In interrelating the retorting variables of the hot recycle gas eduction as above described, the shale particles in the eduction zone are usually maintained at a temperature below that at which mineral carbonates, in a carbon dioxide-free atmosphere, undergo substantial decomposition, i.e., less than about forty percent decomposition. This temperature effect is then correlated, in a preferred embodiment, with the carbon dioxide concentration in the eduction gas, which is maintained at a level sufficient to essentially eliminate mineral carbonate decomposition at the particular temperatures, i.e., less than about 10 percent decomposition. Thus, at higher eduction zone temperatures, the carbon dioxide concentration is maintained at a relatively high level, while at lower eduction zone temperatures, the carbon dioxide concentration required to suppress decomposition is lower.

In non-combustive hot recycle gas retorting we have found that low oil assay shales allow much higher solids retorting rates than high oil assay shales under the same retorting conditions. In a non-combustive hot gas circulation retort having solids-upflow and gas-downflow, a number of different oil assay shales were retorted with an eduction zone temperature of about 950° F., and an eduction gas flow rate of about 220 pounds per hour of recycled product gas per square foot of bed cross-section. The solids flow rate was determined by maintaining a fixed vertical location of the eduction zone in the retort. The results, shown in FIGURES 2 and 3, illustrate the substantially increased non-combustive retorting rate obtainable with decreased Fischer Assay of the shale feed (curve D, FIGURE 3), and the essentially constant percentage oil recovery with different oil assay shales (curve B, FIGURE 2). Thus, assay segregation of the feed to non-combustive hot recycle gas retorting provides a means of substantially increasing the solids retorting rate with essentially no sacrifice in oil recovery.

The contact time required for substantially complete eduction in either the hot recycle gas retort or the com-

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bustion retort can be as low as 10 minutes or less, and generally does not exceed 6 hours. Contact times of from about ½-hour to about 3 hours are normal. The longer contact times are required where the eduction temperatures are in the lower part of the preferred range and the shale particles are relatively large. In the practice of the invention as described above, the shale is usually crushed to particles between about 0 and about 6 inches, preferably of a size which passes a 2-inch mesh sieve and is retained on a ¼-inch mesh sieve. However, either larger or smaller sizes can be used.

A particular preferred embodiment of our invention utilizes the advantageous features of both combustive and non-combustive retorting and entails an integrated retorting process comprising the combining of upflow-solids, downflow-gas combustion retorting of a high oil assay shale with upflow-solids, downflow-hot recycle product gas retorting of a low oil assay shale. That portion of the rich high B.t.u. product gas recycled as the hot eduction fluid for recycle gas retorting is preferably heated by indirect heat exchange with hot flue gases resulting from the burning of the low B.t.u. waste product gas from combustion retorting. Thus, our integrated retorting process yields a combined fuel product which comprises an increased net production of valuable high B.t.u. product gas, none of which is consumed in the process; a minimum production of the low B.t.u. waste gas typical of the combustion retort; and a high yield of a quality shale oil. A further development of this preferred embodiment of the invention entails combustion retorting of a portion of the total shale feed just sufficient to produce enough low B.t.u. waste product gas which, when burned, provides the heat required for educting the remaining feed by hot gas circulation retorting. Our integrated eduction process with assay segregation then effectively utilizes the individual advantages of both combustion retorting and hot recycle gas retorting. The low assay shale, representing a substantial portion of the available oil shale natural resource, is most readily and efficiently retorted in the hot recycle gas retort while the combustion retort most efficiently retorts the high assay shale solids, thus advantageously utilizing the high fuel value extraction characteristic of combustion retorting. Furthermore, the greater yield of high quality oil from recycle gas retorting, with its concomitant high B.t.u. product gas, supplements the high overall fuel value extraction found in conventional combustion retorting to yield a significantly increased and improved overall fuel oil equivalent. Consequently, vital shale oil fuel resources are conserved by the most efficient production of a maximum of marketable, transportable fuel products from each ton of raw shale.

The improved process of our invention can best be understood with reference to the accompanying drawing FIGURE 1, which forms a part of this application, and the subsequent description thereof. The illustration is a schematic process flow diagram of one example of our shale oil eduction process in which high oil assay shale and low oil assay shale from the mine are separated from one another and are separately and simultaneously treated to most efficiently obtain the maximum possible production of the desired products. 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 which forms no part of the invention.

Referring now more particularly to FIG. 1 of the drawing, the process of the present invention is described in terms of a specific example as applied to the retorting of Colorado oil shale of 0 to 6 inches in average size at a total rate of about 2,872 tons per day to produce a high quality shale oil and a high B.t.u. shale gas. The shale,

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entering segregation zone 8 by means of line 6 and averaging 34.9 gallons per ton by Fischer Assay, is segregated in segregation zone 8 at the mine into a rich portion having an assay of about 40 gallons per ton withdrawn from segregation zone 8 via line 68, and a lean portion having an assay of about 32 gallons per ton withdrawn from segregation zone 8 via line 18. The major apparatus consists essentially of two parallel recycle gas retorts (one shown), a combustion retort, and a fired heater. All of these retorts have substantially the same physical dimensions and structure.

Each recycle gas retort has essentially three parts; namely, an upper heat treating or eduction kiln 10, an intermediate perforate disengaging 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 the 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 spent shale from the top. In this way the shale is passed upwardly through the retort countercurrently to the hot eduction gases subsequently described.

The low oil assay raw shale feed portion, having a Fischer Assay of about 32 gallons per ton, is introduced at a rate of about 907 tons per day to each of the two hot recycle gas retorts (one shown), constituting about 63 percent by weight of the total shale feed, through line 18 into shale hopper 16 from which it is fed, as previously described, upwardly through the retort. The lean shale moves successively upwardly through a solids-fluid disengaging zone, a raw shale preheating and product cooling 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 the retorting in kiln 10 the shale is gradually heated to retorting temperatures. The organic matter, commonly termed kerogen, decomposes at these temperatures to produce shale oil gases and vapors. These educted hydrocarbons move downwardly in the eduction gas 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 fills feeder case 14 which prevents air from entering the retort through shale feed hopper 16.

The liquid portion of the educted product is removed from manifold 20 through line 22 at a temperature of about 120° F. and at a rate of about 664 barrels per day per recycle gas retort. The rich shale gas product of the retorting operation is removed from manifold 20 through line 24 at a temperature of about 120° 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 liquid oil product and the oil is withdrawn from cyclone 26 through line 28 and combined with the larger portion of oil product flowing 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 precipitator, or any other suitable separator or

combinations thereof for removing finely divided liquid particles from a gas stream.

The oil-free retort gas is withdrawn from separator 26 via line 30 by means of blower 32. This maintains the downward flow of eduction gases through kiln 10 and disengaging zone 12 and maintains the lower portion of the retort under a slightly subatmospheric pressure. A net production of about 771 M s.c.f./d. (thousands of standard cubic feet per day) of dry shale product gas from each of the two recycle gas retorts is removed via the blower discharge through line 42 at a rate controlled by valve 44. This high B.t.u. (986 B.t.u. per cubic foot) shale product gas stream from line 42 has the following approximate composition:

TABLE 1
Rich Shale Gas Product

Component:	Mol percent (dry basis)
H ₂ -----	18
C ₁ -----	32
C ₂ -----	14
C ₃ -----	7
C ₄ -----	3
C ₅ -----	2
CO ₂ -----	16
CO -----	7
H ₂ S -----	1
	100

The recycled portion of the rich shale product gas (about 18,450 M s.c.f. per day for each of the two recycle gas retorts) is passed from the blower discharge via line 34 into fired heater 36 for heating to eduction temperatures. The recycle gas introduced through line 34 passes through recycle gas heating coil 38 and is thence passed through hot recycle gas line 40 into the top of the recycle gas retort at substantially atmospheric pressure. The preheating temperatures and gas quantities are controlled so that the recycled eduction gas from fired heater 36 is at a temperature of about 1,150° F. as it enters the recycle gas retort.

Alternatively, when required, the carbon dioxide partial pressure of the recycle gas entering fired heater 36 can be maintained at a level of at least about 10 percent by volume, preferably not above about 30 percent by volume, by the introduction, of a carbon dioxide rich stream into line 34. Carbon dioxide can also be introduced to the recycle gas system, if desirable, after the recycle gas has been heated by injecting a carbon dioxide rich makeup stream into line 40.

This hot recycle gas entering the retort via line 40 flows downwardly through kiln 10 countercurrently to the upwardly moving shale. Here the shale is heated to a retorting temperature of about 950° F., and hydrocarbon gases and vapors are retorted from the shale solids. This retorting normally occurs in the upper half of kiln 10. The educted oils and gases continue downwardly through the eduction zone and then through the shale preheating zone countercurrent to the rising lean fresh shale, thus heating the shale solids, cooling the eduction gas, 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 a temperature of about 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 46 by means of rotating or reciprocating scrapers or plows, not shown,

mounted in the top of hopper 46. The educted shale discharges at a temperature of about 950° F. from spent shale hopper 46 through line 48 and is removed to suitable disposal facilities by means of spent shale conveyor 50 at the rate of about 748 tons per day for each recycle gas retort. To prevent the entrance of air into the enclosed hot recycle gas retort system, steam or other seal gas is introduced through line 52 at a rate controlled by valve 54 into the lower portion of spent shale hopper 46. A rotary airlock or an equivalent device can also be used at the ash outlet to prevent air introduction.

Simultaneous retorting of the high oil assay portion of the raw shale feed is carried out in an upflow solids, downflow-gas combustion retort. The combustion retort, similar structurally to the aforementioned recycle gas retort, also comprises essentially three main parts; namely, an upper heat treating or eduction kiln 60, an intermediate solids-fluid disengaging section 62 and a lower reciprocating piston shale feeder, not shown, contained within feeder housing 64. Shale feeder housing 64 contains a vertically reciprocating feeder piston which is contained within an oscillating feeder cylinder. The feeder oscillates in a vertical plane between a vertical feeding position, in which it is aligned with the vertical axis of kiln 60 and disengaging section 62, 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 66. The feeder piston and the feeder cylinder are separately oscillated hydraulically so that raw shale is drawn into feed hopper 66, the feeder cylinder oscillates into the vertical position, the feeder piston forces the charge of fresh shale upwardly into disengaging section 62 and kiln 60, displacing solids above it upwardly and displacing shale ash from the top, and then the feeder cylinder oscillates into the inclined position to accept a new shale charge completing the feeder cycle. In this way the fresh shale is passed upwardly through the combustion retort. Surrounding the perforated disengaging zone 62 is a jacket 70 which constitutes a collection manifold for the shale oils and gases produced during retorting.

The rich shale feed portion, having a Fischer Assay of about 40 gallons per ton, is introduced via line 68 to the combustion retort at a rate of about 1,058 tons per day, which constitutes about 37 percent by weight of the total shale feed. This rich shale is then passed, as described above, upwardly through gas and liquid disengaging section 62 in which the cooled flue and shale gases and the condensed shale oil are disengaged from the upwardly moving mass of shale in kiln 60. The upwardly moving rich shale passes successively through a fresh shale preheating and product cooling and condensing zone, a shale eduction zone, a spent shale combustion zone, and a shale ash cooling and gas preheating zone. The shale ash is displaced from the top of kiln 60 and inside housing 96. This ash falls by gravity into line 98 at the bottom of housing 96 and discharges at a temperature of about 1,200° F. onto shale ash disposal conveyor 100 from whence it is carried to suitable shale ash disposal facilities. The shale ash is conventionally displaced from the top of the combustion retort by means of scrapers or plows, not shown, mounted in the top of housing 96.

In order to support the carbonaceous spent shale combustion, an oxygen-containing gas, in this case air, is introduced through line 92 at a rate, controlled by valve 94, of about 13 M s.c.f. per ton of raw shale feed. Air can also enter housing 96 via line 98, thus being preheated by the hot ash therein. Alternatively, this oxygen-containing gas can be mixed with steam or water, flue gas, fuel gas, or a portion of the mixture of shale gas and flue gas produced from separator 78, hereinafter described. The air passes downwardly through the aforementioned zones where, in the uppermost or shale ash cooling zone, the air is preheated by direct contact with the shale ash thereby cooling the ash to a convenient handling temperature.

The preheated air then moves downwardly into the spent shale combustion zone where hot flue gases are generated and the carbonaceous shale is burned forming shale ash. In the next lower or eduction zone the hot flue gases educt shale oil and gases from preheated fresh shale, forming spent carbonaceous shale and a vapor mixture of shale oil and gas together with the flue gas. In the next lower or shale preheating zone the fresh shale is preheated by direct contact with the vapor mixture from the eduction zone thereby cooling and partially condensing it and forming a liquid oil phase, a cooled gas phase, and preheated fresh shale. The cooled gas phase continues downwardly with the gravity flow of liquid product. This liquid product fills feeder case 64 thus sealing shale feeder hopper 66 against entry of air.

By means of suction from blower 84, the cooled eduction products separate from the shale solids and pass through the slots in disengaging section 62 into effluent manifold 70 surrounding disengaging section 62. The gas phase flows from manifold 70 into centrifugal separator 78 via line 76. It is to be understood that separator 78 can alternatively comprise an oil wash such as in an absorber, an electrostatic or ultrasonic treatment, any liquid scrubber used to clean up residual dust and oil mists, or other suitable separators. From separator 78 the agglomerated oil phase is removed through line 80 and combined with the liquid product produced from product manifold 70 through line 72 at a temperature of about 125° F. The liquid phase from the combustion retort, withdrawn via line 72 at a rate of 806 barrels per day, is combined with the liquid phase in line 22 from the recycle gas retorts and the mixture passed to suitable storage via the common product oil line 74. Therefore, for the shale feed rate of 2,872 tons per day of Colorado oil shale, whose average Fischer Assay is 34.9 gallons per ton, the liquid product flow rate through line 74 is approximately 2,133 barrels per day of 19.2 API gravity oil.

The gas phase from separator 78, at a temperature of about 125° F., flows through line 82, blower 84 and line 86 into the combustion chamber of fired heater 36. This product gas from the combustion retorts has the approximate composition shown in Table 2 and a net heating value of about 117 B.t.u. per cubic foot on a dry basis.

TABLE 2

Combustion Retort Shale Gas

Component:	Mol percent (dry basis)
O ₂ -----	0.4
N ₂ -----	57.2
A -----	0.7
CO ₂ -----	24.0
CO -----	9.2
H ₂ -----	4.4
C ₁ -----	1.5
C ₂ -----	0.9
C ₃ -----	1.4
H ₂ S -----	1.3
	100.0

This low B.t.u. product gas from the combustion retort, produced at a total rate of about 17,960 M s.c.f. per day, is burned in sufficient air entering fired heater 36 via line 88 to produce a substantially inert flue gas which is vented to the atmosphere via stack 90 after heat exchanging with heater tubes 38. A portion of the gas product from separator 78 can also be recirculated in part to kiln 60 as previously described. This combustion of the waste shale product gas provides all of the heat required to heat the recycled eduction gas for the recycle gas retorts which is flowing through fired heater coil 38. Of course, the low B.t.u. product gas in line 86 can alternatively be produced as a product gas and some other fuel gas introduced into fired gas heater 36 to provide sufficient heat for bringing

the recycle gas in heater tubes 38 to eduction temperature.

The significant advantages of assay segregation of the shale feed in our integrated retorting process is best illustrated by comparing the integrated combustion-recycle retorting process of the previous specific example with the retorting of the same oil shale quantity in the same retorting equipment and by the same processing conditions and sequence as previously described except that unsegregated raw shale, having the same assay value (34.9 gallons per ton) as the average assay value of the segregated feeds of our example, is fed directly to combustion retort 60 and hot recycle gas retort 10.

Table 3, outlining the important differences in these retorting approaches, particularly emphasizes the increased retorting rate and increased oil yield obtained with this preferred embodiment of our invention.

TABLE 3

Retorting Comparison

Retort Type	Integrated Combustion-Recycle	
	Without feed assay segregation	With feed assay segregation
Number of retorts (structurally identical).	1 combustion.	1 combustion.
Net shale feed to retorts, tons/stream day.	2 recycle.----- 2,691	2 recycle. 2,872.
Feed shale quality, gallons/ton.	34.9	34.9 (average).
Oil yield, barrels/stream day.	1,968	2,133.
Net low B.t.u. gas yield, M s.c.f./s.d. (136 B.t.u./cu. ft.).	0	0.
Net high B.t.u. gas yield, M s.c.f./s.d. (986 B.t.u./cu. ft.).	1,600	1,542.

Thus, by segregating the feed according to oil assay, it is possible to retort 6.7 percent by weight more shale per day, and to produce 8.4 percent by volume more oil without any change in retorting equipment.

We have also found that a hot recycle gas retort, not having a combustion zone with its attendant sintering and gas flow problems, is able to more conveniently and effectively educt a finer solids consist than a combustion retort. Thus, a further preferred embodiment comprises segregating a raw shale feed into a fines consist portion and a coarse consist portion and feeding the fines consist to a hot recycle gas retort and feeding the coarse consist to a combustion retort. Thus, for example, the portion fed to line 18 might have a consist of from 0 to 6-inch particles while line 68 would introduce a consist of 2 to 6-inch particles. A further example might feed a consist of 0 to 3-inch particles to line 18, while line 68 would carry a consist of 3 to 6-inch particles.

It should be emphasized that although the foregoing detailed description has been conducted 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 having a varying oil assay value. 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.

We claim:

1. A method of improving the solids retorting rate of a process for educting oil-producing hydrocarbonaceous particulate solids of varying oil assays which comprises: segregating said solids into a lean oil assay portion and a rich oil assay portion; passing said lean oil assay portion

through a non-combustive retort; educting hydrocarbons from said lean oil assay portion by contacting said lean oil assay portion with an essentially oxygen-free hot eduction gas in said non-combustive retort; collecting oil and gas from said non-combustive retort; and subjecting said rich oil assay portion to eduction in an eduction combustible retorting zone by passing said rich oil assay portion through said eduction combustible retorting zone to extract hydrocarbon fuel values therefrom.

2. A method of improving the oil recovery from oil-producing hydrocarbonaceous particulate solids of varying oil assays which comprises: segregating said solids into a rich oil assay portion and a lean oil assay portion; passing said rich oil assay portion through a combustible retort; educting hydrocarbons from said rich oil assay portion by contacting said rich oil assay portion with a hot combustion gas to produce carbonaceous spent solids therefrom, said hot combustion gas being generated by the burning of said carbonaceous spent solids; collecting oil and gas from said combustible retort; and subjecting said lean oil assay portion to eduction in an eduction non-combustive retorting zone by passing said lean oil assay portion through said eduction non-combustive retorting zone to extract hydrocarbon fuel values therefrom.

3. An improved integrated retorting process for educting hydrocarbons from particulate oil-producing hydrocarbonaceous solids of varying oil assays which comprises: segregating said solids into a high oil assay portion and a low oil assay portion; contacting said low oil assay portion with a hot recycle gas in a non-combustive retorting eduction zone; collecting oil and a high B.t.u. gas from said non-combustive retorting eduction zone; contacting said high oil assay portion with hot combustion gas in a combustible retorting eduction zone to produce carbonaceous spent solids, said combustion gas being generated by the burning of said carbonaceous spent solids; collecting oil and a low B.t.u. gas from said combustible retorting eduction 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 eduction zone as said hot recycle gas.

4. A process as defined in claim 3 wherein at least a portion of said low B.t.u. gas from said combustible retorting eduction zone is burned to produce hot flue gas, and wherein said heated portion of said high B.t.u. gas is heated to eduction temperature by heat exchange with said hot flue gas.

5. A process as defined in claim 3 wherein said solids comprise oil shale particles of sizes up to about six inches in diameter.

6. A process as defined in claim 3 wherein said low oil assay portion is passed upwardly in the form of a dense bed and said hot recycle gas is passed downwardly, through said non-combustive retorting eduction zone; and wherein said high oil assay portions is passed upwardly in the form of a dense bed and said hot combustion gas is passed downwardly through said combustible retorting eduction zone.

7. A process for retorting particulate oil-producing hydrocarbonaceous solids of varying oil assays which comprises: separating a feed of said solids into a lean oil assay solids feed portion and a rich oil assay solids feed portion; passing said lean portion successively through a first fluid-solids disengaging zone, a first solids preheating and product cooling zone, and a first eduction zone; passing a hot, essentially oxygen-free first eduction fluid through said first eduction zone and thereby educting liquid and gaseous hydrocarbons from said lean portion therein; cooling said liquid and gaseous hydrocarbons in said first solids preheating and product cooling zone thereby obtaining a first gas phase and a first liquid phase; withdrawing said first liquid phase and said first gas phase from said first fluid-solids disengaging zone; separating said first liquid phase from said first gas phase; heating a portion of said first gas phase to eduction temperature; passing said heated por-

tion of said first gas phase to said first eduction zone as said hot first eduction fluid; removing spent solids from said first eduction zone; passing said rich portion successively through a second fluid-solids disengaging zone, a second solids preheating and product cooling zone, a second eduction zone, a combustion zone, and an ash cooling zone; passing an oxygen-containing gas through said ash cooling zone; contacting carbonaceous spent solids in said combustion zone with said oxygen-containing gas from said ash cooling zone thereby burning the carbonaceous residue from said spent solids to produce a hot second eduction fluid and ash solids; contacting said rich portion in said second eduction zone with said hot second eduction fluid thereby educting liquid and gaseous hydrocarbons therefrom; cooling said liquid and gaseous hydrocarbons from said second eduction zone in said second solids preheating and product cooling zone thereby obtaining a second gas phase and a second liquid phase; withdrawing said second gas phase and said second liquid phase from said second fluid-solids disengaging zone; and removing said ash solids from said ash cooling zone.

8. A process as defined in claim 7 wherein the heating of said portion of said first gas phase to eduction temperature is accomplished by heat exchange with hot flue gases, wherein said second liquid phase is separated from said second gas phase, and wherein at least a portion of said second gas phase is burned to produce said hot flue gases.

9. A process as defined in claim 7 wherein said solids comprise oil shale particles of sizes up to about six inches in diameter, and wherein said oxygen-containing gas is air.

10. A process as defined in claim 8 wherein said rich oil assay solids feed portion is that part of the total feed sufficient to provide a sufficient amount of said hot flue gas to raise the heat content of said first eduction fluid to a value just sufficient to educt said lean oil assay solids feed portion.

11. A retorting process for efficiency obtaining maximum fuel values from oil shale which comprises: separating a raw oil shale feed comprising shale particles having an oil assay value between about 5 gallons per ton and about 100 gallons per ton into a lean oil assay feed portion and a rich oil assay feed portion; passing said lean oil assay feed portion upwardly in the form of a dense bed from a first solids feeder zone successively through a first fluid-solids disengaging zone, a first solids preheating and product cooling zone, and a first eduction zone; passing an essentially oxygen-free hot first eduction fluid downwardly through said first eduction zone at a temperature sufficient to educt oil and gas from said lean oil assay feed portion; cooling and partially condensing said oil and said gas in said first solids preheating and product cooling zone thereby obtaining a first gas phase and a first liquid oil phase; removing said first gas phase and said first liquid oil phase from said first disengaging zone; separating said first liquid oil phase from said first gas phase; heating a portion of said first gas phase to eduction temperature; recycling said heated portion of said first gas phase to said first eduction zone as said hot first eduction fluid; removing spent shale from the top of said first eduction zone; passing said rich oil assay feed portion upwardly in the form of a dense bed from a second solids feeder zone successively through a second fluid-solids disengaging zone, a second solids preheating and product cooling zone, a second eduction zone, a burning zone, and an ash cooling zone; passing an oxygen-containing gas downwardly through said ash cooling zone; contacting spent shale in said combustion zone with said oxygen-containing gas from said ash cooling zone thereby burning the carbonaceous residue on said spent shale to produce shale ash and a hot second eduction fluid; passing said second eduction fluid downwardly through said second eduction zone at a temperature sufficient to educt oil and gas from said rich oil assay feed

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portion; cooling and partially condensing said oil and said gas in said second solids preheating and product cooling zone thereby obtaining a second gas phase and a second liquid oil phase; removing said second gas phase and said second liquid oil phase from said second disengaging zone; and removing said shale ash from the top of said ash cooling zone.

12. A process as defined in claim 11 wherein the heating of said portion of said first gas phase to eduction temperature is accomplished by indirect heat exchange with hot flue gas; wherein said second liquid phase is separated from said second gas phase; and wherein at least a portion of said second gas phase is burned to produce said hot flue gas.

13. A process as defined in claim 11 wherein said oxygen-containing gas is air.

14. A process as defined in claim 11 wherein said heated portion of said first gas phase recycled to said first eduction zone is at a temperature between about 1,000° F. and about 1,300° F., and said lean oil assay feed portion in said first eduction zone is maintained at a temperature no greater than about 950° F.

15. A process as defined in claim 11 wherein said first eduction fluid is provided to said first eduction zone at a rate between about 60 and about 400 pounds per hour per square foot of eduction zone cross-sectional surface; and wherein said raw shale feed has a Fischer Assay range of between about 10 and about 80 gallons of shale oil per ton.

16. A process as defined in claim 11 wherein said rich oil assay feed portion is that portion of the total feed sufficient to provide a sufficient amount of said flue gas to raise the heat content of said first eduction fluid to a value just sufficient to educt said lean oil assay solids feed portion.

17. A process for retorting oil shale which comprises: separating a raw oil shale feed comprising shale particles of sizes up to about six inches in diameter and having an oil assay value ranging between about 15 gallons per ton and about 60 gallons per tons into a lean oil assay feed portion and a rich oil assay feed portion; passing said lean oil assay feed portion upwardly in the form of a dense bed from a first solids feeder zone successively through a first fluid-solids disengaging zone, a first solids preheating and product cooling zone, and a first eduction zone; passing an essentially oxygen-free hot first eduction fluid at an eduction temperature between about 1,000° F. and about 1,300° F. through said first eduction zone at a rate between about 60 and about 400 pounds per hour per square foot of eduction zone cross-sectional surface to educt oil and gas from said lean oil assay feed portion, said lean oil assay feed portion in said first eduction zone being maintained at a temperature no greater than about 950° F.; cooling and partially condensing said oil and said gas in said first solids preheating and product cooling zone thereby obtaining a first gas phase and a first liquid oil phase; withdrawing said first gas phase and said first liquid oil phase from said first disengaging zone, separating said first liquid oil phase from said first gas phase; heating a portion of said first gas phase to said eduction temperature by indirect heat exchange with hot flue gas; recycling said heated portion of said first gas phase to said first eduction zone as said hot first eduction fluid; removing spent shale from the top of said first eduction zone; passing said rich oil assay feed portion upwardly in the form of a dense bed from a second solids feeder zone successively through a second fluid-solids disengaging zone, a second solids preheating and product cooling zone, a second eduction zone, a burning zone, and an ash cooling zone; passing air down-

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wardly through said ash cooling zone at a rate of between about 8,000 and about 18,000 standard cubic feet per ton of said rich oil assay portion; contacting spent shale in said combustion zone with said air from said ash cooling zone thereby burning the carbonaceous residue on said spent shale to produce shale ash and a hot second eduction fluid; passing said second eduction fluid downwardly through said second eduction zone at a temperature between about 600° F. and about 1,200° F. sufficient to educt oil and gas from said rich oil assay feed portion; cooling and partially condensing said oil and said gas in said second gas preheating and product cooling zone thereby obtaining a second gas phase and a second liquid oil phase; withdrawing said second gas phase and said liquid oil phase from said second disengaging zone; separating said second liquid oil phase from said second gas phase; burning at least a portion of said second gas phase to produce said hot flue gas; and removing said shale ash from the top of said ash cooling zone.

18. An improved integrated retorting process for educting hydrocarbons from particulate oil-producing hydrocarbonaceous solids of varying oil assays and varying specific gravities which comprises: segregating said solids into a high specific gravity portion having a low oil assay and a low specific gravity portion having a high oil assay; contacting said high specific gravity portion with a hot recycled gas in a non-combustive retorting eduction zone; collecting oil and a high B.t.u. gas from said non-combustive retorting eduction zone; contacting said low specific gravity portion with hot combustion gas in a combustive retorting eduction zone to produce carbonaceous spent solids, said combustion gas being generated by the burning of said carbonaceous spent solids; collecting oil and a low B.t.u. gas from said combustive retorting eduction zone; heating a portion of said said B.t.u. gas to eduction temperature; and passing said heated portion of said high B.t.u. gas to said non-combustive retorting eduction zone as said hot recycle gas.

19. An improved integrated retorting process for educting hydrocarbons from particulate oil-producing hydrocarbonaceous solids of varying oil assays and varying particle sizes which comprises: segregating said solids into a fines consist portion having a low oil assay and a coarse consist portion having a high oil assay; contacting said fines consist portion with a hot recycle gas in a non-combustive retorting eduction zone; collecting oil and a high B.t.u. gas from said non-combustive retorting eduction zone; contacting said coarse consist portion with hot combustion gas in a combustive retorting eduction zone to produce carbonaceous spent solids, said combustion gas being generated by the burning of said carbonaceous spent solids; collecting oil and a low B.t.u. gas from said combustive retorting eduction 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 eduction zone as said hot recycle gas.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,133,010

May 12, 1964

Glenn E. Irish et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 11, line 23, for "education" read -- eduction --;
line 55, for "portions" read -- portion --; column 12, line
39, for "efficiency" read -- efficiently --; column 13, line
59, for "sparating" read -- separating --; column 14, line
35, for "said", second occurrence, read -- high --.

Signed and sealed this 22nd day of September 1964.

(SEAL)

Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents