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DESTRUCTIVE DISTILLATION OF HYDRO-CARBONACEOUS MATERIALS

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This invention relates to the destructive or pyrolytic distillation of hydrocarbonaceous materials, and is particularly concerned with an improved process for the destructive distillation of oil shale to produce liquid and gaseous hydrocarbons.

It is well known that processes for the destructive or pyrolytic distillation of hydrocarbonaceous materials such as oil shale require large quantities of heat to effect the distillation. It is also well known that although in many cases it is possible to supply the total amount of heat required by utilizing part of the sensible and chemical heat content of the products and by-products resulting from the distillation, the feasibility of the economic recovery of valuable products from materials such as oil shale depends largely upon the efficiency of utilization of the heat content of the products and by-products of the distillation in order to provide final products of high quality with a minimum of capital investment in heat exchange and other processing equipment.

In the case of oil shale, with which this invention is chiefly concerned, large quantities of non-condensable hydrocarbon gases, such as methane and ethane, are produced during the distillation together with the normally liquid hydrocarbon oil products. The chemical heat content of these non-condensable hydrocarbon gases is an important source for supplying the heat required in the processing of the shale. Likewise, the sensible heat of the gaseous and liquid products of the distillation and the sensible heat of the spent shale after distillation will furnish considerable heat for the process if such sensible heat can be economically utilized. Heretofore, it also has been considered desirable to make use of the residue of carbon remaining upon the spent shale particles after distillation by burning this residual carbon in the presence of air to produce a hot flue gas.

Prior processes for utilizing these various sources of heat in the distillation process suffer from a number of disadvantages. Oftentimes, large areas of indirect heat exchange surface, such as large, expensive tubular heat exchangers, are required. Some prior processes make inefficient utilization of the sensible heat of the products of distillation in that the products leave the system at elevated temperatures. Other processes require the use of large amounts of cooling water which is expensive to circulate and which results in the waste of large amounts of heat energy. A further disadvantage characteristic of a number of previously proposed processes is that they lead to the deterioration of both the gaseous and liquid distillation products as a result of the manner in which heat is transferred to the raw shale. According to some processes, for example, transfer of heat to the raw shale is accomplished by direct heat exchange contact between the raw shale and hot flue gases. This type of operation results in the dilution of the non-condensable hydrocarbon gases produced by the distillation of the raw shale with large quantities of flue gas, with the consequent lower-

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ing of the otherwise appreciable heat value of the product gases. Furthermore, the direct contact of the hot flue gases with the raw shale results in oxidative deterioration of the liquid distillation products due to the oxidizing effect of carbon dioxide and residual oxygen contained in the hot flue gases.

As previously mentioned, in a large number of prior processes, the fixed carbon residue on the spent shale is burned to supply heat for the process. It has now been found that the combustion of the spent shale to recover its fuel value is subject to a number of disadvantages which often outweigh any advantage to be gained. This is particularly true in the case of domestic shales such as are found in Colorado, Utah, and Wyoming which contain large quantities of mineral carbonates such as magnesium and calcium carbonates that decompose endothermically upon heating. The spent shale furnace itself together with the necessary air blowers and other equipment represents a large capital investment. In addition, the rate of burning must be carefully controlled to prevent clinkering and excessive mineral carbonate decomposition. Even at relatively low combustion temperatures such as 1000° F. the heat loss due to carbonate decomposition is serious and at practical combustion temperatures such as 1500° F., a major portion of the heat liberated by burning the shale is absorbed to supply heat for the endothermic carbonate decomposition.

It is an object of the present invention to provide a process for the destructive distillation of hydrocarbonaceous materials and in particular oil shale which eliminates the necessity for the use of large areas of indirect heat exchange surface by utilizing direct heat exchange between gases and granular solids in all the major heat exchange steps.

It is a further object of the invention to provide a process which makes efficient use of the sensible heat content of the distillation products in that the products are rejected from the system at a relatively low temperature with use of little or no cooling water.

A further object of the invention is to provide a process which eliminates the deterioration of the liquid and gaseous products of the distillation either by oxidation of the liquid products or dilution of the normally gaseous products with flue gases.

A still further object of the invention is to provide a process in which close control in all the major heat exchange steps may be easily maintained.

Another object of the invention is to provide a process which avoids burning the residue carbon on the spent shale and which instead utilizes the hot spent shale to provide an excellent preheating and reduction zone for the gases that are utilized as a carrier medium to transmit heat to the raw shale and to effect distillation thereof as will be apparent from the description which follows.

The process of the invention, which accomplishes these objects and other objects which will be apparent from the detailed description below, involves the use of a hot stream of gases obtained as non-condensable product gases from a previous shale distillation to transfer heat to the hydrocarbonaceous material in order to bring it to distillation temperatures. The hot stream of non-condensable product gases are passed countercurrently through a moving column of particulate hydrocarbonaceous material such as oil shale to bring about distillation. These gases, together with the condensable and non-condensable products of distillation are withdrawn in a relatively cool condition and the condensable products of distillation are separated from the ordinarily non-condensable products. A portion of these non-condensable product gases are burned to produce a hot flue gas which is passed in direct heat exchange contact with a bed of granular heat ex-

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change solids to store heat in the bed. Another portion of the non-condensable product gases are passed through hot spent hydrocarbonaceous material resulting from a prior distillation to simultaneously preheat these gases and at the same time, effect reduction of oxidizing gases such as carbon dioxide present in the non-condensable circulating product gases through the reducing action of the hot carbon residue in the spent shale. This preheated and reduced stream of non-condensable product gases is then passed through a regenerative heat exchanger consisting of a bed of hot heat exchange solids which have been previously heated by contact with hot flue gases produced by burning a separate portion of the non-condensable product gases. In this way there is produced a hot stream of non-oxidizing product gases at a suitable temperature which may be utilized for the distillation of additional quantities of raw hydrocarbonaceous material. While the invention broadly comprises the steps as outlined above, other features of the invention and preferred methods of operation will become apparent from the detailed description which follows.

In order that the invention might be better understood, reference is now made to the accompanying drawing which is a semi-diagrammatic illustration of a plant layout suitable for carrying out the process of the invention. The retorting vessel illustrated in the drawing is similar to that described and claimed in application Ser. No. 117,246, filed Sept. 22, 1949, for Apparatus for the Retorting of Oil Shale and Similar Materials, by John G. Tripp et al. Crushed, raw oil shale at atmospheric temperature is introduced into line 1 by means not shown and is then transferred by feeder mechanism 2 at a controlled rate into the feed hopper 3 above the retorting zone. Cool flue gas or other inert gas may be admitted to line 1 by means not shown to purge the crushed shale of entrained air before it is transferred to feed hopper 3. The feeder mechanism 2 acts as a positive seal to prevent the escape of gases from the retorting system which is under a pressure of, for example, 2 to 3 pounds gage.

In the retorting chamber, where the raw shale or other material is destructively distilled, there is provided an inclined endless chain conveyor 4 moving in a direction indicated by the arrow 5. A louvered supporting wall 6 is likewise provided in the retort chamber extending from the lower portion of the feed hopper 3 to a point just above the chain conveyor 4. Raw crushed shale moving downwardly from feed hopper 3 comes to rest on endless chain conveyor 4 and is continuously moved upwardly and forwardly toward the forward portion of the retorting zone. The inclined moving bed of shale fills the space between the chain conveyor 4 and the roof of the retorting chamber 7. Retarding chains 8 suspended across the forward face of the moving body of shale help to prevent any void spaces from forming adjacent to the roof of the retorting chamber. Spent shale, after retorting, is discharged off the forward end of the conveyor belt 4 and drops downwardly into line 15.

A stream of hot non-condensable hydrocarbon product gases, heated in a manner to be subsequently described, are admitted by line 9 into the retorting chamber, flow counter-currently through the moving body of shale, pass through the openings in the louvered wall 6 and then together with the condensable and non-condensable products of distillation are withdrawn from the back end of the retort by line 10.

In the case of oil shale distillation, the hot stream of product gases entering the forward portion of the retort through line 9 should be at a temperature of from 700 to 2000° F. and preferably from 1000 to 1300° F. The incoming stream of hot gases flowing through the moving column of shale quickly yields up its heat to the shale particles at the forward portion of the column. Due to the high rate of heat transfer between a gas stream and a bed of granular solids, the hot stream of non-condensable

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product gases will be rapidly cooled after passage through a relatively short column of crushed shale. For example, hot gases entering the retort at 1200° F. may be cooled to 200° F. by passage through a 2- or 3-foot bed of shale at atmospheric temperature when crushed to a particle size of .5 x 1 inch. By proper adjustment of the length of the raw shale column in the direction of flow of the heat carrying gases in accordance with other operating conditions such as the shale particle size, the temperature and space velocity of the hot gases flowing through the shale, and the speed of movement of the raw shale column itself, a relatively cool stream of gases and oil vapors may be withdrawn from the rear portion of the column of raw shale. In order to avoid the use of excessive amounts of cooling water, the rate of flow of the raw shale column together with other operating conditions should be adjusted so that the temperature of the gases disengaging from the rear portion of the raw shale column does not exceed 200° F. Since a large portion of the distilled oil product will be below its dew point at temperatures below 400° F., a portion of the oil will condense on the incoming cold raw shale at the rearward portion of the forwardly moving column of shale and trickle down in the bottom of the retorting chamber to form a pool 11. Additional oil agglomerating in knockout space 12 behind the louvered disengaging wall 6 will also be collected in pool 11. This pool of oil at the bottom of the retort chamber forms a liquid seal to prevent the by-passing of the hot retorting gases beneath the moving column of shale and likewise serves to cool the chain conveyor 4. Shale fines and sludge collecting in the pool may be cleaned out periodically by means of cleanout line 13, while an oil product may be removed as required through line 14.

Due to the forward movement of the column of shale, fresh raw shale particles are continuously presented at the forward portion of the shale column. With counter-current flow of hot gases entering the forward portion of the retort, a relatively narrow zone of distillation may be established at the forward portion of the moving shale column. The temperature and residence time of the shale in this distillation zone may be controlled within close limits by adjusting the rate of flow of the shale column in accordance with the mass flow and temperature of the retorting gases. The temperature of the spent shale itself discharging from the end of the conveyor belt 4 may be used to control the rate of movement of the conveying belt and thus control the residence time of shale in the distillation zone. In back of the relatively narrow distillation zone, which may be for example only 10 to 20 inches in depth, there will be a preheating zone where the retorting gases are further cooled by contact with incoming cold raw shale. In this preheating zone, any water content in the raw shale is removed before the shale reaches retorting temperatures and is carried out in the stream of carrier gases. Although in the embodiment shown, the raw shale column is moved up an incline against a countercurrently flowing stream of retorting gases, other arrangements for insuring countercurrent flow of a column of raw shale and a stream of hot retorting gases may be employed. It is essential however, that the rate of flow of the shale be capable of control to insure the proper control of the temperature and the residence time of the raw shale in the distillation zone.

The relatively cool stream of retorting gases leaving knock-out space 12 by line 10 contains additional non-condensable gases produced by the retorting, water vapors, and usually the major proportion of the normally liquid hydrocarbon products of the distillation. Although most of the oil produced by the distillation is below its dew point at temperatures below 200° F., usually only a small fraction will condense on the cold incoming shale and the major proportion will form a stable mist which is taken out of the cold end of the retort in the stream of carrier gases. As the term "oil vapors" is used

in the specification and the claims, it is intended to include both oil in the true vapor state and in the form of a stable mist which is swept along in the stream of carrier gases until some means is taken to agglomerate the mist particles.

Since a typical oil shale will contain from about 1 to 2 percent of water, the stream of oil vapors leaving the back end of the retort will be associated with an appreciable percentage of water. If the oil vapors are condensed at a temperature below the dew point of the water vapors present in the gas stream, an oil emulsion with about 10 to 15 percent of water will be obtained. According to one embodiment of the invention, the stream of carrier gases containing the oil vapors largely in the form of a relatively stable mist is withdrawn from the back end of the retort at a temperature below 200° F. but above the dew point of the water vapor present. As previously explained, the temperature of the gases disengaging from the back end of the raw shale column can be adjusted to any desired temperature merely by adjusting the rate of flow of the column of raw shale in accordance with the other operating conditions.

The stream of non-condensable gases and oil vapors at a temperature below 200° F. but above the dew point of the water vapors present is conducted by line 10 through an ultrasonic mist extractor 16 or other suitable mist agglomerating device to cause agglomeration of the oil mist. Agglomerated oil mist is dropped out in knockout drum 17 and essentially water-free oil collects in pool 18 at the bottom of the knockout vessel and is withdrawn therefrom by line 19 to storage. Light oil vapors which are above their dew point, water vapor and non-condensable gases are conducted by line 20 to contact condenser 21. Here, the gas stream is cooled to a temperature just above the dew point of the water vapor by passing the gas stream through a contact condenser against a light oil reflux. A stream of reflux oil is continuously withdrawn from the bottom of contact condenser 21 by line 23 and conducted by circulating pump 24 to cooler 25 and then by line 26 to the top of the column. Oil condensed from the gas stream is removed to storage by line 27 and pump 28.

The cool gas stream leaving the top of contact condenser 21 by line 29 at a temperature from 110 to 125° F. moves to positive displacement blower 30 and by line 31 is conducted to knockout drum 32 where entrained light oil mist is removed from the stream and conducted to storage by line 33 and pump 34. The non-condensable gases leave the top of knockout drum 32 by line 35 to be utilized in a manner to be subsequently described.

In the embodiment described above, the major portion of the heavy oil leaving the retort in line 10 will be recovered substantially water free from knockout drum 17. The recovery of the heavy oil in a substantially water-free condition is an advantage since the serious problems connected with the formation of a stable emulsion of the heavy oil and water are thereby avoided. In this embodiment, some cooling of the gas stream is necessary since the gas stream from the cool end of the retort must be withdrawn at a temperature above the dew point of the water present, that is, at a temperature of the order of about 200° F. This necessitates the use of some cooling water to cool the gas stream after the removal of the heavy oil by an amount of the order of 100° F.

According to another embodiment of the invention, the gas stream is withdrawn from the back end of the retort at a temperature below the dew point of the water present, for example 100° F. This gas stream is conducted by line 10 to ultrasonic mist extractor 16 to knockout vessel 17 where the major portion of the light and heavy oil together with water vapor is dropped out of the gas stream. The overhead gas stream then passes directly from knockout vessel 17 to blower 30, by passing contact condenser 21, and then is conducted by line 31 to an additional knockout vessel 32 if desired. Operat-

ing in this manner, the gas stream leaving the retort is completely cooled by the shale and requires substantially no further cooling, thus eliminating the necessity for expensive condensing equipment and the use of cooling water.

The cool stream of non-condensable gases containing only a small percentage of water vapors is split into two streams after leaving knockout vessel 32 by line 35. One stream flows into line 36 and is conducted to gas holder 37. A net gas product having a heating value of 350 to 450 B. t. u./s. c. f. for a typical Colorado shale is withdrawn from gas holder 37 through line 22. A portion of the gas in holder 37 is conducted by line 38, and blower 39 to pressure gas burner 40, where it is burned in the presence of air supplied by line 41a, and compressor 42a, to form a hot flue gas at a temperature of from 1500° to 3000° F. The hot flue gases produced in the pressure burner are then conducted by line 41 to one of a pair of regenerative pebble heat exchangers 42 and 43. Each of the pebble heat exchangers contains a bed 44 of granular heat exchange solids which may, for example, be 1- to 2-inch selected silica stream stones or other relatively small size refractory heat exchange materials.

As shown in the drawing, the hot flue gases pass by means of line 45 controlled by valve 46 and by line 47 into the lefthand pebble heat exchanger as indicated by the arrows 50, valve 49 on line 48 being closed. The hot stream of flue gases flowing through the bed of granular solids quickly surrenders its heat to the bed and leaves at the bottom of the pebble stove 43 through line 51 controlled by valve 52 and then is discharged by line 53 to the stack, valve 54 on line 55 being closed. Due to the high rate of heat exchange between a stream of gases and granular solids, the flue gases entering at a temperature of from 1500 to 3000° F. leave the bed of granular solids at a temperature of the order of 800° F. during the entire heating cycle. Since the heat surrendered by the hot flue gas is absorbed by a few layers of pebbles, the bottom of the bed remains relatively cool until the very end of the heating cycle and the entering gases consequently leave the bed at a relatively low temperature until the end of the heating cycle at which time the bed has been heated uniformly. This will be indicated by a rather sudden rise in the temperature of the exit gases and when this happens, the flow of the hot flue gases is switched from the now hot pebble exchanger 43 to exchanger 42 by closing valves 46 and 52 and by opening valve 56 on line 57 and valve 54 on line 55.

As explained previously, the non-condensable product gases flowing from final knock-out vessel 32 out through line 35 are split into two streams, one of which flows into line 36 to be partially utilized to produce hot flue gases for heating the pebble heat exchangers. The other stream flows into line 59 as a recycled gas stream to be used as a heat carrier medium for retorting raw shale. The recycled gas stream flows into heat recovery vessel 58 and contacts hot spent shale fed into the vessel by feeder mechanism 60 in line 61. Valves 62 and 63 control the relative amount of gas conducted to heat recovery vessel 58 and gas holder 37, respectively.

The column of spent shale 64 moving downwardly in vessel 58 is discharged by way of line 55 and discharge mechanism 66 which also acts as a seal for preventing the escape of gases out or the entry of air into the system. The cool recycled non-condensable product gases are passed countercurrently to the moving body of hot spent shale and flow out of preheating vessel 58 by line 67. Through the countercurrent flow of the hot spent shale and the cool stream of gases, heat is withdrawn from the solid stream and the spent shale is removed from the vessel 58 by discharge mechanism 66 at a low temperature of the order of 250° F. for example. The rate of flow of the spent shale is adjusted in accordance with other operating conditions so that in any event the

temperature of the shale leaving the vessel 58 does not exceed 300° F.

Since the shale from the retorting zone enters the vessel 53 at a temperature preferably from 900 to 1200° F., the gas stream passing through the hot spent shale is preheated to a temperature of from 700 to 800° F. At the same time, by contact with the hot residual carbon present on the spent shale, oxidizing gases present in the stream of recycled non-condensable product gases such as water vapor and carbon dioxide tend to be reduced. Thus, carbon dioxide is reduced to carbon monoxide and water vapor converted to a mixture of carbon monoxide and hydrogen.

The stream of preheated and reduced product gases is conducted by line 67 to cyclone separator 68 for dust removal and then by line 69 to one of the regenerative pebble heat exchangers 42 or 43. As shown in the drawing, the preheated stream is conducted by branch line 70 controlled by valve 71 to the right hand heat exchange vessel 42 where it passes upwardly through the bed of hot heat exchange solids, heated by contact with hot flue gases as previously described. At this time, of course, valve 73 controlling branch line 72 is closed.

The stream of product gases now heated to a temperature preferably between 1000 and 1300° F. pass out of the top of pebble heat exchanger 42 by line 74 controlled by valve 75 and are conducted by line 9 into the forward portion of the retort. When the supply of heat in vessel 42 is exhausted, the flow of preheated gases from preheater 58 is switched to vessel 43 by closing valves 71 and 75 and by opening valves 73 and 49. Thus, by the alternate operation of heat exchange vessels 42 and 43 a continuous supply of hot retorting gases may be supplied in an extremely efficient manner.

If desired, in order to moderate the temperature of the gases in line 9 a portion of the preheated gases from cyclone separator 68 may be by-passed to line 76 controlled by valve 77 into the stream of hot gases from the pebble heat exchanger. By the dilution of the hot gases from the pebble stove with the proper amount of preheated gases at a lower temperature, close control of the temperature of the gas stream admitted to the retort may be had.

In accordance with the process of the invention, an economical and efficient recovery of the sensible heat of the products and by-products of the shale distillation is effected, an efficient utilization is made of the non-condensable product gases, and a high quality liquid and gaseous product is obtained. By utilization of highly efficient gas-to-solids heat exchange in every major heat exchange step, and by use of the countercurrent flow principle in the retorting step and in the recovery of the sensible heat of the shale, the products and by-products, including liquid hydrocarbons, non-condensable hydrocarbon gases, spent shale, and flue gases, leave the system at relatively low temperatures with the use of substantially no cooling water, thus indicating a high over-all thermal efficiency.

The retorting of the raw shale occurs in the presence of a relatively non-oxidizing gas medium thus yielding a high quality hydrocarbon product. By avoiding the troublesome rate controlling step of burning the residual carbon on the spent shale, the spent shale may be used economically as a preheating and reduction zone for preheating the recycled product gases and for improving the non-oxidizing quality of the product gases before they are contacted with raw shale.

The net non-condensable product gases which are in excess of the amount required to furnish heat to the pebble heat exchangers have a high heating value since they are undiluted with air or flue gases, the flue gas system and the product gas system being kept entirely separate. Upgrading the gas product is of major importance, as the gas generated during retorting accounts for roughly 15 percent of the organic matter in a typical Colorado shale having, for example, a Fischer assay of about 30 gallons per ton.

In the operation of the process of the invention, using a shale of this type, non-condensable hydrocarbon gases may be recovered having a net heating value of from 350 to 450 B. t. u. per standard cubic foot. The heating content of this residual hydrocarbon gas is enhanced considerably by the reduction of water vapor and carbon dioxide by contact with hot carbon in vessel 58.

The foregoing process has application for the retorting of hydrocarbonaceous materials of various type such as torbonites, oil sands, lignite, coals, and other solid organic hydrocarbonaceous materials which can be destructively distilled to produce liquid and gaseous products. The process of the invention, however, is particularly applicable to the destructive distillation of oil shale, and particularly the type of oil shale found in this country in Colorado, Utah, and Wyoming which contain from 20 to 30 percent mineral carbonates as calcium and magnesium carbonates which tend to decompose endothermically upon heating. The relatively low temperature and the close control of the temperature in the retorting zone, and the relatively short residence time of the shale particles at retorting temperatures result in a relatively low percentage of decomposition of the mineral carbonates thus avoiding dilution of the product gases with carbon dioxide from the decomposition. Likewise, by avoiding combustion of the spent shale, mineral carbonate decomposition is likewise prevented, and the hot spent shale is more efficiently utilized as a reducing and preheating zone for the product gases used as a heat carrier for the distillation of raw shale.

As used in the specification and claims the term "non-condensable product gases" refers to those gases such as members of the methane, ethane, propane, and butane series and the unsaturated hydrocarbons of these compounds which fail to condense to liquids at atmospheric temperatures and under ordinary pressure, including, of course, carbon dioxide, nitrogen, and other non-condensable diluents that may be present.

It is to be understood that the above description and drawing are merely for the purpose of illustrating the invention, that the invention is not to be limited thereto, nor in any way except by the scope of the appended claims.

We claim:

1. In a process for the destructive distillation of oil shale wherein (1) the raw shale is brought to distillation temperature by contact with a hot counter-flowing gas stream, (2) the gaseous effluent from the distillation reaction is removed from the distillation chamber and treated to remove condensable constituents and (3) the non-condensable gas so produced is reheated and introduced into the distillation zone to sustain the process, the steps comprising: (a) providing a relatively short oil shale distilling zone having a shale supporting bottom surface, forming a solid bed of particulate oil shale in said zone on said surface, moving said bed forwardly through said zone and continuously supplying fresh, raw, particulate oil shale to the rear of said zone to maintain said bed, (b) discharging the hot spent shale from the forward end of said bed, (c) passing a first portion of the non-condensable gases resulting from the distillation of said shale in direct heat exchange relationship with the hot spent shale discharged from said bed to preheat said gases and chemically convert the water vapor and carbon dioxide present into carbon monoxide and hydrogen to produce a non-oxidizing preheated effluent gas, (d) raising said non-oxidizing effluent gas to a temperature of 700° F. to 2000° F., (e) passing the hot non-oxidizing gas so produced through said moving solid bed of particulate oil shale counter-currently to the direction of movement of said bed and regulating the speed of said bed and the rate of flow of said gases such that the temperature of said gases discharged from the rear of said bed does not exceed 200° F., a narrow forward zone only of said bed being raised to the shale distillation temperature, at least a portion of the liquid materials resulting from the distillation of said shale in said forward zone condensing in a rear-

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ward preheating zone of said bed containing relatively cold particulate oil shale, and (f) recovering liquid distillation products at the rear end of said bed.

2. The process of claim 1, wherein a minor portion of the non-oxidizing preheated effluent gas produced in step (c) of said claim is passed directly to the oil shale distilling zone to moderate the temperature therein.

3. The process of claim 1 wherein, in step (c) of said claim, the hot spent shale is cooled to a temperature not exceeding 300° F. by direct heat exchange contact with a first portion of the non-condensable gases resulting from the shale distillation.

4. The process of claim 1 wherein, in step (d) of said claim, the non-oxidizing effluent gas is raised to a temperature of 700° F. to 2000° F. by passing said non-oxidizing effluent gas through a bed of heat exchange solids previously heated by passage therethrough of hot combustion products formed by burning a second portion of the non-condensable gases resulting from the shale distillation.

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