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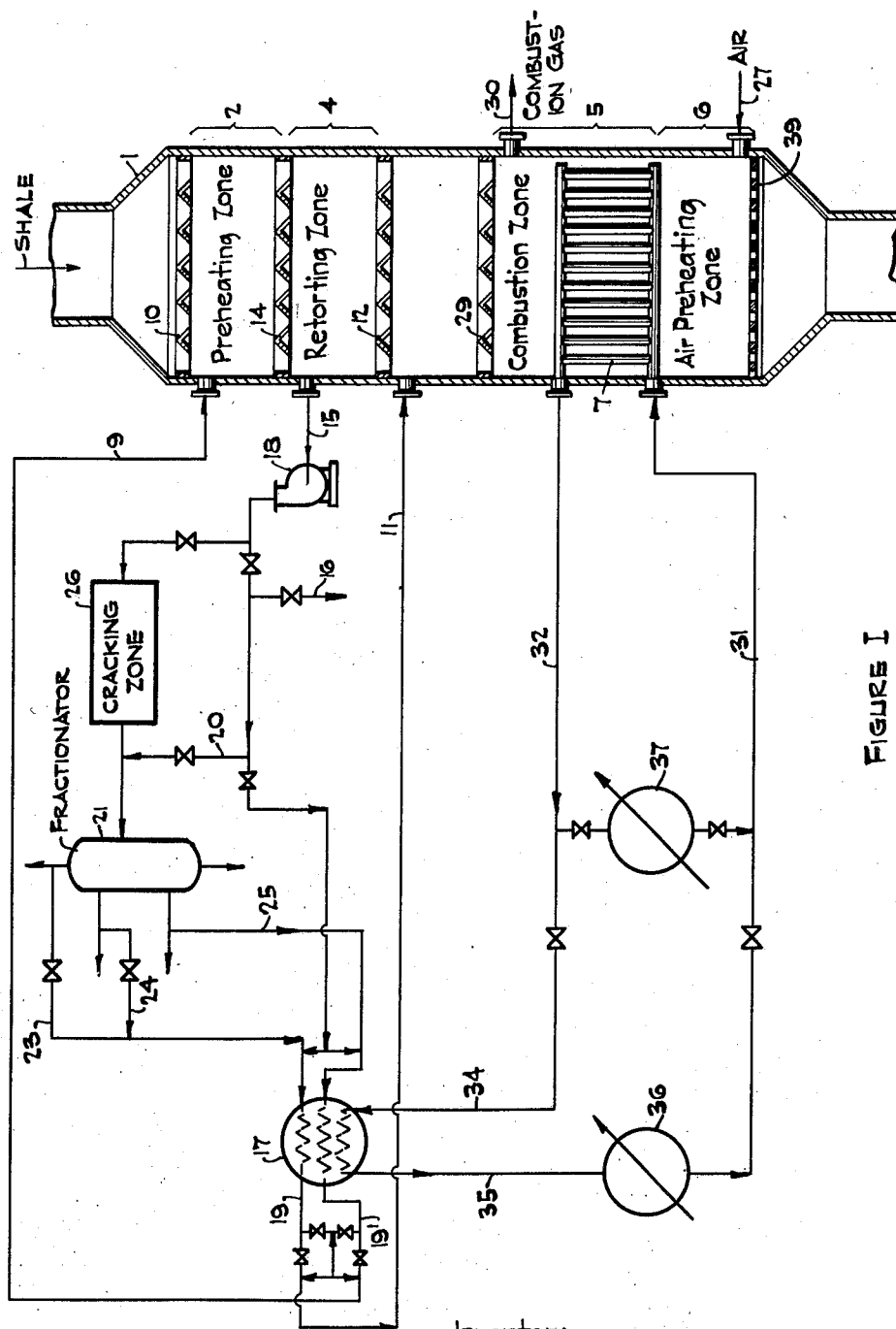
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METHOD AND APPARATUS FOR RECOVERING SHALE OIL FROM OIL SHALE

Filed Jan. 25, 1954

2 Sheets-Sheet 1



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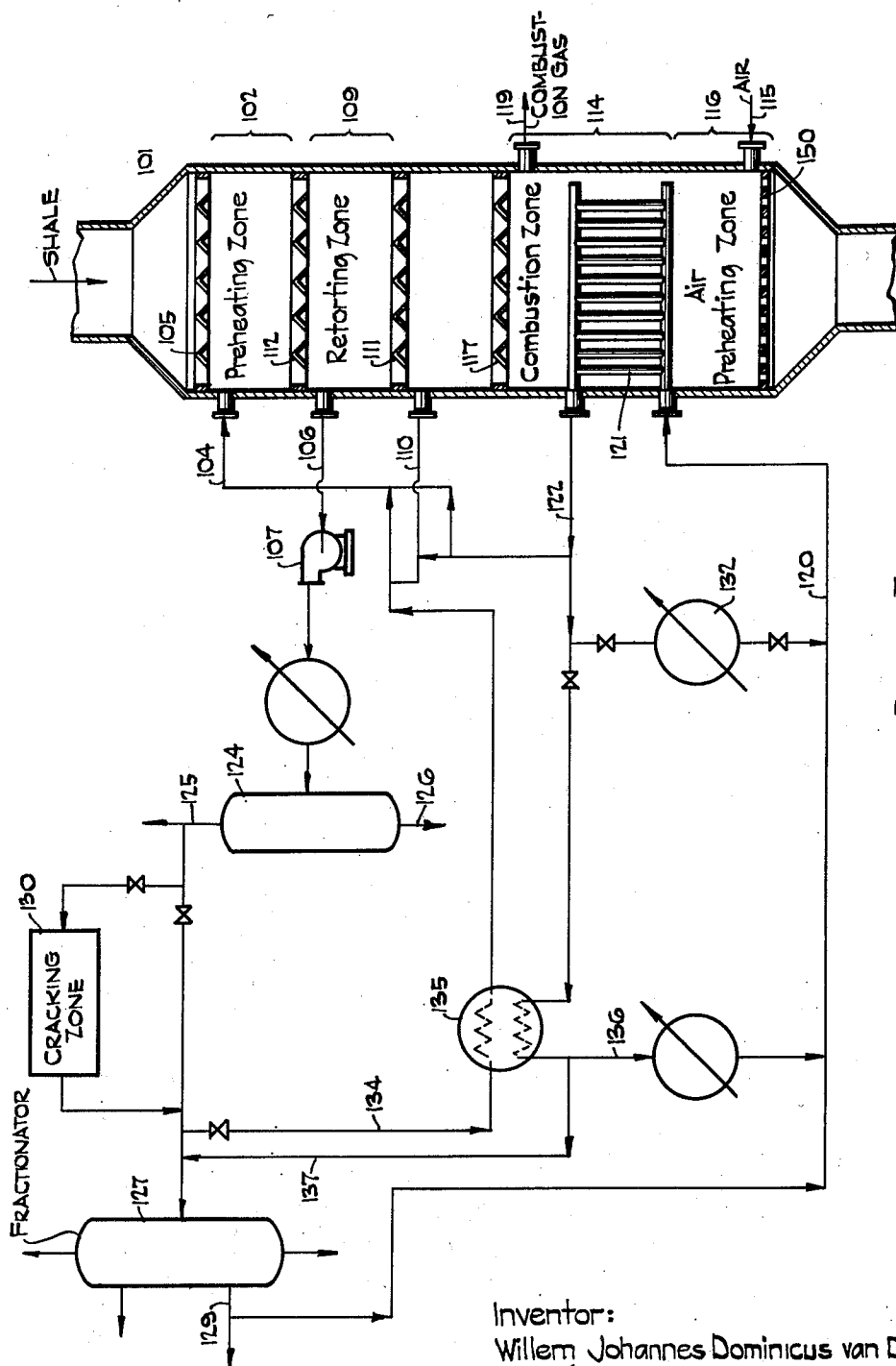


FIGURE II

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2,814,587

METHOD AND APPARATUS FOR RECOVERING SHALE OIL FROM OIL SHALE

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6 Claims. (Cl. 202—3)

This invention relates to a method and apparatus for the recovery of oil from oil-bearing carbonaceous materials, particularly from oil shales.

It is well known to recover shale oil from oil shale by the application of sufficient heat to convert the organic matter (kerogen) of the shale to organic liquids and gases. In general, the retorting processes proposed for the recovery of shale oil from oil shale can be grouped into the following four major classes:

I. Those in which heat is transferred indirectly to the shale as through the wall of a retorting furnace;

II. Those in which heat is transferred directly to the shale from the hot combustion gases which are generated in the retort by burning the residual carbon on the retorted shale;

III. Those in which heat is transferred directly to the shale by passing previously heated gases or liquids through the shale bed; and

IV. Those in which heat is transferred directly to the shale by introduction of hot refractory solids into the retorting bed, as in the fluid-flow process.

None of the processes proposed have been entirely satisfactory, mainly because of poor heat economy, undesirable dilution of the product shale oil vapors with combustion gases in those processes in which the shale is heated by direct contact with combustion gases, and the expense involved in crushing oil shale to a particle size suitable for use in the fluid flow process.

It is, therefore, a principal object of the present invention to provide an improved process and apparatus for the recovery of oil from oil-bearing carbonaceous materials. A more specific object is to provide an improved process and apparatus for the recovery of oil from oil shale. Still another object is to provide a continuous method for the recovery of shale oil from oil shale and the like in a system generally operated at elevated temperatures in which a substantial portion of the heat necessary to maintain the system in operation is obtained by burning materials within the system. Other objects and advantages will become apparent from the following detailed description which will be made in part with reference to the accompanying drawings wherein:

Figure I is a schematic diagram which represents a suitable method and apparatus for recovering oil from oil-bearing carbonaceous materials according to the present invention; and

Figure II is a schematic diagram which represents a specific embodiment of the present invention.

According to the present invention, oil is recovered from an oil-bearing carbonaceous material by concurrently contacting the oil-bearing material with hot end-products of the process in a preheating zone to preheat the oil-bearing material, countercurrently contacting the thus preheated oil-bearing material with hot vaporized end-products of the process in a retorting zone so as to convert kerogen thereof to organic liquids, passing the resulting hot spent shale through a zone of combustion to burn residual carbon from the spent shale, and providing

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the combustion zone with indirect heat exchange means in order to control the temperature within the combustion zone and to recover the heat of combustion.

Described in greater detail with respect to the recovery of oil from oil shales, the present process comprises permitting crushed particulate oil shale, previously dried, if necessary, e. g., by direct contact with combustion products, to gravitate successively through (1) a preheating zone, (2) a retorting zone, (3) a combustion zone, and (4) a combustion-supporting gas (e. g., air or oxygen) preheating zone; concurrently contacting the shale in the preheating zone with hot product shale oil vapors to heat the shale to temperatures of the order of from about 300° F. to about 600° F.; countercurrently contacting the oil shale in the retorting zone with hot product shale oil vapors to further heat the shale to temperatures of from about 800° F. to about 1200° F., at which temperature oil is driven from the oil shale; withdrawing shale oil vapors from the upper portion of the retorting zone; separating a portion of the withdrawn shale oil vapors as product; heating the remaining portion of the withdrawn shale oil vapors and employing separate portions of the heated vapors as heat transfer media in the aforementioned preheating and retorting zones; burning the hot spent shale from the retorting zone with a preheated oxygen-containing gas in the combustion zone; circulating a fluid heat transfer medium through the combustion zone in indirect heat exchange relationship with the spent shale to recover the heat of combustion; withdrawing combustion gases from the upper part of the combustion zone; introducing a combustion-supporting gas, such as a free oxygen-containing gas, into the hot shale ash from the combustion zone to provide the preheated oxygen-containing gas for the combustion operation; and removing shale ash from said combustion-supporting preheating zone. According to a specific feature of the present invention, the heat of combustion of the hot spent shale is utilized indirectly to supply at least a portion of the heat necessary to separate oil from the oil shale by contacting the heated fluid heat transfer medium removed from the combustion zone in indirect heat exchange relationship with that portion of the product shale oil vapors which is utilized for heating the oil shale in the preheating zone and the retorting zone.

The preferred apparatus for carrying out the present process comprises a unitary vertical retort having, in vertical alignment, (1) a preheating zone, (2) a retorting zone, (3) a combustion zone, and (4) a zone for preheating a combustion supporting gas, whereby a bed of crushed oil shale or other oil-bearing solid carbonaceous material, can move continuously from top to bottom by gravity through the various contact zones, with spent shale ash being removed from the bottom of the retort. The spent shale combustion zone is provided with means for circulating a fluid heat transfer medium therethrough in indirect heat exchange relationship with the hot spent shale in order to recover at least a portion of the heat of combustion. The retort is provided with various gas and vapor outlet and inlet means so arranged that the raw oil shale is directly contacted with a vaporous heating medium and that the combustion gases from the spent shale combustion zone are withdrawn therefrom without coming in contact with the shale in the preheating and retorting zones.

The invention will be further understood by the following detailed description made with reference to the retorting of oil shale, and with reference to Figure 1 which is a diagrammatic representation of suitable apparatus for carrying out the process of the present invention.

Referring to the drawing, a vertical rectangular retort housing 1 is shown in cross-sectional elevation. The housing is preferably made of steel or alloy construction and

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is lined with refractory to withstand the temperature conditions prevailing throughout the height of the retort. A plurality of contact zones are disposed vertically within the housing 1 such that crushed oil shale gravitates successively through the various zones. The various contact chambers or zones within the retort, from top to bottom, can be identified as follows: a preheating zone 2, a retorting or distillation zone 4, a spent shale combustion zone 5, and a gas preheating zone 6. The spent shale combustion zone 5 is provided with heat exchange means 7 for circulating a heat transfer fluid through the combustion zone in indirect heat exchange relationship. It will be understood that there is no sharp distinction between the preheating zone 2 and the retorting or distillation zone 4, some retorting or distillation already occurring in zone 2.

Oil shale, which has been crushed to an average particle size of from about $\frac{1}{2}$ inch to about 2 inches, and preferably an average particle size of about 1 inch, is fed to the top of the retort 1 by any suitable means, such as a conveyor or elevator, not shown. The shale moves downwardly by gravity through the preheating zone 2 in concurrent contact with heated product shale oil vapors introduced into preheating zone 2 by means of line 9 and gas distributing devices 10. The gas distributing means also serve to maintain an even distribution of the descending oil shale. The gas distributing means can be of any conventional design, for example, they can be angle-shaped, as shown, or gable-shaped. In order to avoid loss of product vapors through and introduction of air from the top of the retort, the pressure differential across the point of introduction of the vaporous heating medium should be zero. The pressure can be suitably controlled by any conventional means. For example, concurrent flow of the heating medium can be accomplished by suitably creating a suction in the product shale oil-withdrawal line 15 as by means of a suitable pump 18. By the arrangement shown loss of shale oil vapors from the top of the retort at the point of introduction of fresh oil shale is substantially prevented without having to provide expensive equipment, such as gas seal devices.

In connection with the distribution and control of pressure within the column the following is to be considered.

When gas is to be introduced at a certain point of the column and to be withdrawn at another point thereof there necessarily should exist a pressure gradient in the gas in the direction of flow. If at the two levels of the column substantially the same pressure exists, it will then be impossible to cause a substantial unidirectional flow of gas between these two levels. The method to cause notwithstanding a flow of gases through the zone between the two levels is to arrange a symmetrical flow by either introducing the gas about midway between the two levels and withdrawing the gas at the said levels or introducing the gas at the said levels and to effect the withdrawal thereof somewhat midway between.

Which of these two arrangements is to be chosen in connection with the treatment of oil shale by hot gases depends for a large part on the products it is desired to obtain. Now it is usually desirable to get a maximum of intermediate distillates.

If the hot gas for contacting the shale should be introduced at 15 and withdrawal take place through 9 and 11 such intermediate distillates which might be formed near 15 would, in moving upwardly to the colder zone at the top of the column, be condensed on the fresh shale and only the light vapors would be removed at the top. Further with such an arrangement the vapors withdrawn at 11 would be rather heavy and not be subjected to further cracking after their generation. Therefore such an arrangement would not be very suitable for attaining the desired results and the other arrangement is chosen, viz. that in which the hot gases are introduced at 9 and 11 and the withdrawal takes place through 15.

With the latter arrangement as shown on the drawing, gaseous products of intermediate volatility formed in zone

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2 are rapidly removed through 15, whereas heavier products are first subjected to cracking in the hotter zone 4 before being withdrawn through 15. The temperature of the hot gas and the vertical position of the place of withdrawal are chosen in connection with the volatility desired for the drawn-off gases.

As the oil shale descends through the preheating zone, it is heated to a temperature of the order of from about 300° F. to about 600° F., depending on the inlet temperature and the relative proportion of the vaporous shale oil preheating medium. Any shale oil vapors released from the oil shale at the preheating temperature and any condensed preheating medium commingle with the shale oil vapor preheating medium and flow downwardly therewith. The preheated shale then descends into and through the retorting zone 4 where it is countercurrently contacted with heated product shale oil vapors introduced by means of line 11 and gas distributing means 12. In the retorting zone, the shale is progressively heated to a temperature of from about 800° F. to about 1200° F., thereby converting kerogen in the oil shale to shale oil products. The most suitable retorting temperature is determined by the source of the oil shale and its oil content as determined by the Fischer assay test. The throughput rate of the oil shale is such as to provide a residence time in the retorting zone 4 sufficient to assure complete retorting of the oil shale at the temperature of retorting. Generally, the residence time will vary from about 30 minutes to about 90 minutes. Product shale oil vapors, together with the shale oil vapors which are utilized as the heating media in the preheating zone and the retorting zone, are withdrawn from the upper portion of the retorting zone by means of gas collecting devices 14 and line 15. In order to prevent the escape of oil vapors and/or ingress of undesirable gases at the bottom of the retorting zone the pressure differential at the transition zone between the retorting zone and the combustion zone has to be zero. It is thus necessary to keep the pressure at the top of the preheating zone and at the bottom of the retorting zone under control. Such control can be effected with the aid of two variables, namely, the total amount passing per unit of time through line 15 and the ratio of the flow rates through the lines 9 and 11.

A portion of the withdrawn shale oil vapors are suitably separated as product and removed via line 16. The remaining portion of the withdrawn shale oil vapors are passed through a suitable heat exchanger 17 where they are heated to a temperature suitable for heating oil shale to retorting temperatures. Generally, the shale oil vapors are heated to a temperature of from about 1000° F. to about 1300° F. The heated shale oil vapors are removed from the heat exchanger 17 by means of line 19, a portion thereof being recycled to the preheating zone 2 by means of line 9, and a portion being recycled to the retorting zone 4 by means of line 11. The portions to be utilized in the preheating and retorting zones can as well be heated separately and to different temperatures in heat exchanger(s) represented by 17.

Preferably, the shale oil vapor heating medium is a fraction which is not too readily condensable upon contact with incoming cold oil shale, and also it is resistant to thermal cracking. Therefore, it is desirable to suitably fractionate the shale oil vapors, withdrawn from the retorting zone 4 by means of line 15, into a relatively higher boiling fraction and a relatively lower boiling fraction. The relatively higher boiling fraction is then removed, as product, by means of line 16, and the relatively lower boiling fraction is introduced into the heat exchanger 17 where it is heated for recycle to the system. In some cases, however, the relatively higher boiling fraction may be preferred for use as the heat transfer medium since the higher boiling fraction has a higher specific heat per cubic foot, and thus the blower capacity and energy can be reduced.

It is also preferred practice of the invention to segregate

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the portions to be used as heating media in the preheating and retorting zones, according to molecular weight or boiling point and according to thermal refractoriness. Thus, the fraction for preheating utility does not require heating to such a high temperature as the fraction for retorting utility. Therefore, the preheating fraction may be less refractory, i. e., of higher molecular weight. Also, since it flows downwardly with the oil shale, it may be selected so that it is partially condensed in the preheating zone to give up heat of vaporization and to give solvent action on the oil shale, after which it is reevaporized in the retorting zone. On the other hand, the retorting fraction is advantageously a more refractory product. Accordingly, product shale oil vapors, withdrawn from retorting zone 4 by means of line 15, are introduced by means of line 20 into a suitable fractionator 21 wherein the product is fractionated by any suitable method, as by distillation, into desired product fractions, and utilizing a portion or all, as required, of suitable fractions, such as in lines 23, 24 and 25, as heating media for the preheating and retorting operations. The operation of the process is further improved by subjecting the shale oil product to a suitable cracking operation, such as a thermal cracking or a catalytic cracking, as by passing it through a cracking unit represented by 26, and then suitably fractionating the cracked products in fractionator 21.

Hot spent shale from the retorting zone 4 descends, by gravity, into and through combustion zone 5 where it is contacted with a suitable combustion supporting free oxygen-containing gas, such as air, which is introduced by means of line 27 into the preheating zone 6 and which is preheated by countercurrent contact with the resulting shale ash from the combustion zone. In the combustion zone, the spent shale is subjected to relatively complete oxidation in order to remove residual carbon therefrom, and the temperature of the bed is thereby increased to 1300-1600° F. The resulting hot combustion gases are withdrawn from the combustion zone by means of gas collecting devices 29 and line 30 which is provided as required with suitable suction. In order to prevent the flow of combustion gases into the retorting zone 4 with resulting dilution of product shale oil vapors, the pressure differential across the point of withdrawal of the combustion gases should be substantially zero. If desired, a steam lock as known in the art can be provided.

A suitable heat transfer fluid is introduced, via line 31, into suitable heat exchange means 7, which can be of any suitable design, a heat exchange means consisting of vertically disposed tubes being shown. Another very suitable type of heat exchange means consists of horizontally disposed tubes having either an inverted tear-shaped cross-section or a circular cross-section with small vertically disposed longitudinal fins at the upper side and, if desired, also at the lower side. The tubes should be suitably spaced and manifolded to permit ready movement of the spent shale particles downward therebetween and in contact therewith. If desired, the tubes can be vibrated to further reduce clogging possibilities. The fluid is circulated through the combustion zone in indirect heat exchange relationship with the shale bed. The resulting heated heat transfer fluid is withdrawn by means of line 32. At least a portion of the recovered heat is preferably utilized for supplying the heat necessary for retorting raw shale by passing the heated fluid, by means of line 34, into heat exchanger(s) 17, in indirect heat exchange relationship with product shale oil vapors from line 15. The resulting cooled heat transfer fluid is then withdrawn from heat exchanger 17 by means of line 35, and is returned to the combustion zone via line 31, after further removal of heat, if required, in heat exchange means 36. The heat recovered from the combustion zone can be utilized in any heating operation, such as for steam generation for power and other utilities, as indicated by heat exchange means 37, or for pre-drying of wet shale.

The shale ash from combustion zone 5 descends through

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preheating zone 6 where it is cooled by countercurrent contact with an oxygen-containing gas introduced by means of line 20, whereby the oxygen-containing gas is preheated for use in combustion zone 5 as above described. The cooled shale ash is removed from the retort by means 39, which may be any standard device, such as shaking grates. The most suitable type of grate is the type composed of rotating rollers with spikes.

Pressure control and pressure indicating devices, the proper placement of which will be evident to those skilled in the art, are not illustrated in the accompanying drawings. However, such devices are desirable and normally may be connected with each of the contact zones such that the proper operating pressures and gas flows may be maintained throughout the retort.

Spent oil shale contains about 20% mineral carbonates. If these carbonates were decomposed during spent shale combustion, the resulting endothermic reaction would consume most of the energy available from the combustible material. In order to minimize coking of shale ash, it is necessary to maintain relatively low combustion-zone temperatures. Circulation of a heat transfer fluid through the combustion zone as previously described, not only serves to recover heat of combustion, but serves also to control the temperature in the combustion zone. The combustion zone temperature is most suitably controlled by removing the excess heat as heat of vaporization of a suitable liquid heat transfer medium. This is best accomplished by introducing a liquid heat transfer medium, at about its vaporization temperature, into the combustion zone for indirect contact with the shale bed. The liquid heat transfer medium is then vaporized and the resulting vapors are withdrawn from the combustion zone. The vaporized heating medium is then suitably recondensed for recirculation through the combustion zone. By operating in this manner, the combustion zone temperature can be readily controlled to maintain a temperature sufficiently low to minimize carbonate decomposition, and yet maintain a temperature sufficiently high to support combustion of the spent shale.

Particularly suitable heat transfer media for use in the above operation are the high boiling, highly refractory, hydrocarbon oil fractions having a relatively narrow boiling range. The preferred hydrocarbon oil fractions are those boiling within the range of from about 750° to about 950° F. It is further preferred to employ a relatively narrow boiling range hydrocarbon oil fraction, that is, one having a boiling range of not greater than about 100° F., and preferably not greater than about 50° F., in order to avoid too wide a vaporization temperature range.

The hydrocarbon oil fractions which are preferred for use in the present invention can be obtained from the recycle stream from high severity thermal cracking operations, i. e., thermal cracking at temperatures of from about 950° to over about 1000° F., and particularly from thermal cracking of substantially aromatic feed stocks. Suitable feed stocks for the thermal cracking operation include distillate gas oils, gas oil fractions obtained from flash cracked or vacuum flashed residual oils, aromatic extracts, e. g., liquid sulfur dioxide extracts, of lubricating oil fractions, and the like. The highly aromatic fractions obtained from the product shale oil vapors of the present invention can also be used as feed stocks for the thermal operations.

Although the relatively higher boiling hydrocarbon oil fractions are preferred for a more accurate control of the combustion zone temperature, it is also possible to employ lower boiling materials, such as lower boiling hydrocarbon oil fractions, Dowtherm (a mixture of diphenyl and diphenyl oxide) and the like. Water or steam can be used and thus the heat of combustion can be utilized for generating and/or superheating steam.

Again referring to the drawing, a suitable hydrocarbon oil fraction is introduced in the liquid state and at about its vaporization temperature, into heat exchanger 7 in

combustion zone 5. The hydrocarbon oil fraction removes heat from the combustion zone and is thereby vaporized. The resulting vapors are withdrawn from the combustion zone by means of line 32. The heat of vaporization of the resulting vaporized hydrocarbon can then be used to supply, indirectly at least, a portion of the heat necessary for retorting fresh oil shale, by contacting the vaporized hydrocarbon with product shale oil vapors in heat exchanger(s) 17. The hydrocarbon oil heating medium is thereby condensed to the liquid state and is removed from the heat exchanger by means of line 35. The liquefied heating medium is then recycled to the combustion zone via line 31.

Since the heat available from burning the spent shale is generally greater than the retorting requirements, the vaporized hydrocarbon oil heat transfer medium can be employed for supplying heat to any other heating operation, as indicated by heat exchange means 37. The vaporized hydrocarbon oil heating medium is particularly suitable for introduction into oil shale deposits in indirect heat exchange relationship with the oil shale, whereby the heat of vaporization of the oil is utilized to convert kerogen of the shale to hydrocarbon oils in place.

In the event that the heat generated in the combustion zone is not sufficient for carrying out the present retorting process, additional heat should be supplied, e. g., by means of a furnace.

A modification of the above-described process in which a portion of the product shale oil is utilized as the heat transfer fluid in the combustion zone is represented schematically in Figure II.

Referring to Figure II, crushed oil shale is fed to the retort 101 and moves downwardly by gravity through a preheating zone 102 in concurrent contact with heated product shale oil vapors introduced into preheating zone 102 by means of line 104 and suitable gas distributing devices 105. The pressure differential across the point of introduction of the vaporous heating medium is suitably maintained at about zero, as by creating a suction in the product shale oil withdrawal line 106, e. g., by means of a suitable pump 107. The preheated shale then descends into and through the retorting zone 109 where it is countercurrently contacted with heated product shale oil vapors introduced by means of line 110 and gas distributing means 111. In the retorting zone, the shale is progressively heated to a temperature of from about 800° F. to about 1200° F., thereby converting kerogen in the oil shale to shale oil products. The throughput rate of the oil is such as to provide a residence time in the retorting zone 109 sufficient to assure complete retorting of the oil shale at the temperature of retorting. Product shale oil vapors, together with the shale oil vapors which are utilized as the heating media in the preheating zone and the retorting zone, are withdrawn from the upper portion of the retorting zone by means of gas collecting devices 112 and line 106, and are treated as hereinafter described. The pressure distribution in the preheating and the retorting zones must be kept under control to prevent the escape of oil vapors and the ingress of undesirable gases at the top of the preheating zone and the bottom of the retorting zone. Such control can be effected with the aid of two variables: the total amount passing per unit of time through line 106 and the ratio of the flow rates through the lines 104 and 110.

The hot spent shale from the retorting zone 109 descends, by gravity, into and through combustion zone 114 where it is contacted with a suitable combustion supporting free oxygen-containing gas, such as air, which is introduced by means of line 115 into the gas preheating zone 116 and which is preheated by countercurrent contact with the resulting shale ash from the combustion zone 114. In the combustion zone, the spent shale is subjected to relatively complete oxidation in order to remove residual carbon therefrom, and the temperature of the

bed is thereby increased to 1300°–1600° F. The resulting hot combustion gases are withdrawn from the combustion zone by means of gas collecting devices 117 and line 119 which is provided as required by suitable suction.

In order to prevent the flow of combustion gases into the retorting zone 109 with resulting dilution of product shale oil vapors, the pressure differential across the point of withdrawal of the combustion gases should be substantially zero. A suitable heat transfer fluid, obtained from a source as hereinafter described, is introduced by means of line 120 into suitable heat exchange means 121 and is circulated through the combustion zone 114 in indirect heat exchange relationship with the shale bed, thereby recovering at least a portion of the heat of combustion. The resulting heated heat transfer fluid is withdrawn by means of line 122.

The shale ash from combustion zone 114 descends through the preheating zone 116 where it is cooled by countercurrent contact with an oxygen-containing gas introduced by means of line 115, whereby the oxygen-containing gas is preheated for use in the combustion zone 114 as above described. The cooled shale ash is removed from the retort by means 150, which may be any standard device, such as shaking grates, the most suitable type of grate being the type composed of rotating rollers with spikes.

The product shale oil vapors from line 106 are introduced into a suitable fractionating zone 124, after removal or addition of heat as required, to separate relatively lower boiling products, which are withdrawn by means of line 125, from relatively higher boiling products which are withdrawn by means of line 126. A portion or all of the overhead product, as required, is introduced into a suitable fractionator represented by 127, wherein the product is fractionated by any suitable method, as by distillation, into desired product fractions, and a portion or all of a relatively higher boiling fraction, such as in line 129, is passed via line 120 into heat exchange means 121 for recovery of heat of combustion. The operation of the process can be further improved by subjecting the shale oil product to a suitable cracking operation, such as a thermal cracking or a catalytic cracking, as by passing it through a cracking unit represented by 130, and then suitably fractionating the cracked product in fractionator 127.

The relatively higher boiling shale oil fraction from line 129, which is circulated through heat exchange means 121, is heated by indirect heat exchange with the hot spent shale in the combustion zone. The thus heated shale oil fraction is removed from the heat exchange means 121 by means of line 122 and a portion or all of the heated fraction, as required, is introduced into the preheating zone 102 and the retorting zone 109 to provide the heat requirements therein.

Since the heat available from burning the spent shale is greater than the preheating and retorting requirements, the heated shale oil heat transfer medium can be employed for supplying heat to any other heating operation, as indicated by heat exchange means 132. If desired, a portion of the overhead shale oil product from separator 124 can be withdrawn by means of line 134 and passed into heat exchanger 135 wherein it is heated by indirect heat exchange relationship with a portion of the heated shale oil heat transfer fluid from line 122 and then introduced into the preheating zone 102 and the retorting zone 109, thus providing relatively lower boiling shale oil components as heat transfer media therein. Preferably, the relatively lower boiling fraction from line 134 is introduced into the retorting zone and the relatively higher boiling fraction from line 122 is introduced into the preheating zone. The resulting cooled heat transfer fluid from heat exchanger 135 is removed therefrom by means of line 136 and is returned to heat exchange means 121 after the removal or addition of heat as required. Preferably, at least a portion of the cooled shale oil fraction

from line 136 is introduced into the fractionator 127 by means of line 137.

While the invention has been described in detail with respect to the retorting of oil shale, it is to be understood that it is also applicable to the retorting of any crushed oil-bearing solid carbonaceous material.

I claim as my invention:

1. A method for recovering shale oil from oil shale which comprises permitting crushed oil shale to gravitate successively through a preheating zone, a retorting zone, a combustion zone, and an air preheating zone; contacting said oil shale in direct, concurrent heat exchange relationship with heated vaporized preheating medium comprising product shale oil vapors in the preheating zone; contacting preheated oil shale in direct, countercurrent heat exchange relationship with heated vaporized retorting medium comprising product shale oil vapors in the retorting zone, whereby shale oil vapors are released from said oil shale; withdrawing product shale oil vapors together with spent preheating medium and retorting medium from the upper portion of the retorting zone; separating the product shale oil vapors into a relatively higher boiling fraction and a relatively lower boiling fraction; removing said relatively higher boiling fraction as product; heating said relatively lower boiling fraction by indirect heat exchange as hereinafter described; recycling the heated relatively lower boiling fraction to the preheating and the retorting zones for contact with further portions of raw oil shale; contacting the hot spent shale from the retorting zone with preheated air in the combustion zone to oxidize the combustible material on the spent shale; withdrawing hot combustion gases from the upper portion of the combustion zone; introducing a liquid hydrocarbon heat transfer medium at about its vaporization temperature into the combustion zone in indirect heat exchange relationship with the spent shale therein, whereby said liquid hydrocarbon heat transfer medium is vaporized; contacting the vaporized hydrocarbon heat transfer medium in indirect heat exchange relationship with said relatively lower boiling shale oil fraction whereby said vaporized hydrocarbon heat transfer medium is condensed and said shale oil fraction is heated for recirculation to the preheating and the retorting zones; recycling the condensed hydrocarbon heat transfer medium to the combustion zone; directly contacting the hot shale ash from the combustion zone with the air in the air preheating zone, whereby the air is preheated for use in the combustion zone, and removing cooled shale ash from the air preheating zone.

2. The method according to claim 1, wherein the liquid hydrocarbon heat transfer medium is a hydrocarbon fraction boiling within the range of from about 750° F. to about 950° F., and having a boiling point range of not greater than about 100° F.

3. A method for recovering shale oil from oil shale which comprises permitting crushed oil shale to gravitate successively through a preheating zone, a retorting zone, a combustion zone, and an air preheating zone; contacting said oil shale in direct, concurrent heat exchange relationship with heated product shale oil vapors in the preheating zone; contacting preheated oil shale in direct, countercurrent heat exchange relationship with heated product shale oil vapors in the retorting zone, whereby shale oil vapors are released from said oil shale; withdrawing product shale oil vapors from the upper portion of the retorting zone; heating at least a portion of the withdrawn product shale oil vapors; recycling the heated product shale oil vapors to the preheating zone and the retorting zone for contact with further portions of raw oil shale; contacting the hot spent shale from the retorting zone with preheated air in the combustion zone to oxidize the combustible material on the spent shale; withdrawing hot combustion gases from the upper portion of the combustion zone; circulating a heat transfer fluid through the combustion zone in indirect heat

exchange relationship with the spent shale therein to remove at least a portion of the heat of combustion; and directly contacting the hot shale ash from the combustion zone with air in the air preheating zone, whereby the air is preheated for use in the combustion zone.

4. A method for recovering hydrocarbon oils from oil-bearing solid carbonaceous materials which comprises permitting a bed of solid carbonaceous material to gravitate successively through a preheating zone, a retorting zone, a combustion zone, and a combustion-supporting gas preheating zone; contacting said solid carbonaceous material in direct, concurrent heat exchange relationship with heated product hydrocarbon vapors in the preheating zone; contacting the preheated solid carbonaceous material in direct, countercurrent heat exchange relationship with heated product hydrocarbon vapors in the retorting zone, whereby hydrocarbon oil, in vaporous form, is released from said solid carbonaceous material; withdrawing product hydrocarbon vapors from the upper portion of the retorting zone; heating at least a portion of the withdrawn product hydrocarbon vapors; recycling the heated product hydrocarbon vapors to the preheating zone and the retorting zone for contact with further portions of raw solid carbonaceous material; contacting the resulting spent solid carbonaceous material in the combustion zone with a preheated combustion-supporting gas whereby oxidation of combustible materials is effected, leaving a solid residue withdrawing hot combustion gases from the upper portion of the combustion zone; circulating a heat transfer fluid through the combustion zone in indirect heat exchange relationship with the solid residue to remove at least a portion of the heat of combustion; and directly contacting the solid residue from the combustion zone with a combustion-supporting gas in the combustion-supporting gas preheating zone, whereby the combustion-supporting gas is preheated for use in the combustion zone.

5. An apparatus for recovering hydrocarbon fluids from oil-bearing solid carbonaceous materials which comprises a unitary, imperforate vertical housing having vertically aligned therein and adapted for gravitation of particulate solids therethrough, a solids preheating zone, a solids retorting zone, a combustion zone, and a gas preheating zone, said zones being arranged in the order named, the solids preheating zone being uppermost, an inlet for charging crushed solids to the upper end of said solids preheating zone, an outlet for discharging ash from the lower end of said gas preheating zone, a fluid inlet to an upper section of said solids preheating zone, a fluid inlet and a fluid outlet to lower and upper sections respectively, of said retorting zone, a fluid outlet from an upper section of said combustion zone, a fluid inlet to a lower section of said gas preheating zone, gas distributing means within said housing adapted to distribute gas entering through each of said inlets and gas collecting means within said housing adapted to collect gas for withdrawal through each of said outlets and indirect heat exchange means disposed in said combustion zone and adapted for circulating a heat transfer fluid therethrough.

6. An apparatus for recovering hydrocarbon fluids from oil-bearing solid carbonaceous materials which comprises a unitary imperforate vertical housing having vertically aligned therein and adapted for gravitation of particulate solids therethrough, a solids preheating zone, a solids retorting zone, a combustion zone, and a gas preheating zone, said zones being arranged in the order named, the solids preheating zone being uppermost, an inlet for charging crushed solids to the upper end of said solids preheating zone, an outlet for discharging ash from the lower end of said gas preheating zone, a fluid inlet to an upper section said solids preheating zone, a fluid inlet and a fluid outlet to lower and upper sections, respectively, of said retorting zone, a fluid outlet from an upper section of said combustion zone, a fluid inlet to a lower section of said gas preheating zone, conduit means con-

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necting the fluid inlet to the solids preheating zone to the fluid outlet from the retorting zone, conduit means for connecting the fluid outlet from the retorting zone to the fluid inlet to the retorting zone, gas distributing means within said housing adapted to distribute gas entering through each of said inlets and gas collecting means within said housing adapted to collect gas for withdrawal through each of said outlets, indirect heat exchange means disposed in said combustion zone and adapted for circulating a heat transfer fluid therethrough, a fluid inlet and a fluid outlet to said heat exchange means and conduit means connecting said inlet and outlet to said heat exchange means, a part of said last-mentioned conduit being in heat exchange relationship with parts of each of said previously-mentioned conduits.

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