June 18, 1957 K. M. ELLIOTT 2,796,390

PROCESS OF RETORTING OF OIL SHALE

Filed Jan. 31, 1952

Fig. 1

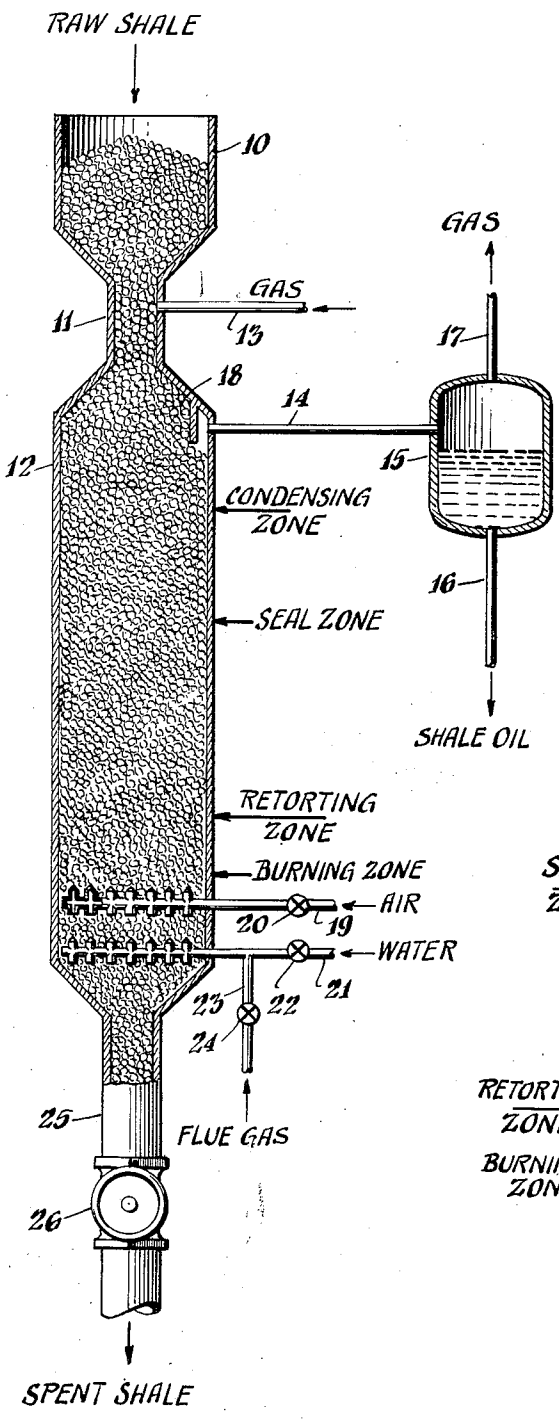


Fig. 2

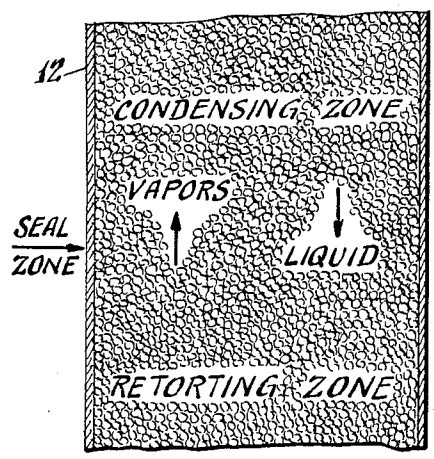
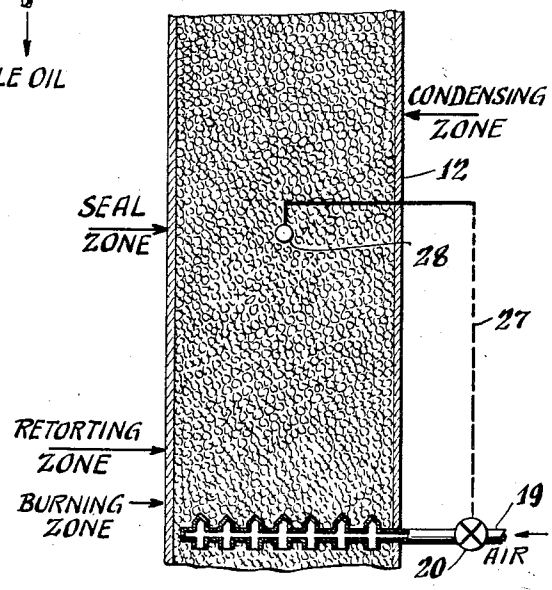


Fig. 3



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PROCESS OF RETORTING OF OIL SHALE

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Application January 31, 1952, Serial No. 269,180

1 Claim. (Cl. 202—6)

This invention relates to a method and apparatus for obtaining valuable hydrocarbons from shale and the like. More particularly, the present invention is concerned with an improved process and apparatus in which shale is retorted in an efficient manner utilizing the cold shale feed as a medium for effecting condensation of oil vapors emitted upon roasting the shale.

It is common practice in the art to recover oils from solid oil-bearing or oil-producing materials and particularly to recover shale oil from oil shale. As is well recognized, ordinarily oil shale does not contain oil as such but a solid bitumen type material known as "kerogen" which, when heated, breaks down into gases, petroleum-like liquids, and carbon.

The manufacture of oil from oil shale has heretofore been accomplished by heating the shale at elevated temperatures sufficient to educt the oil and separate it from residual mineral matter. However, commercial shale retorting operations previously employed have been generally cumbersome and expensive, involving large equipment and operating costs per unit of shale throughput. Important factors contributing to these economic burdens have been poor heat recovery in the retort systems and the expense, equipment, and time consumed in subsequently recovering the products of retortation.

A major object of this invention, accordingly, is the provision of a method and apparatus in which oil shale and the like may be efficiently retorted without the excessive heat loss which has been generally prevalent in the processes and the equipment heretofore used. A further object is to provide a method and apparatus for retorting oil shale wherein intimate contact between vaporous shale oil products and condensed liquid shale oil is obtained. A still further object is the provision of a compact apparatus for retorting oil shale affording convenient means for subsequent recovery of the liquid shale oil. A specific object is the provision of an internal gas seal zone in the retorting system. These and other objects which will be apparent to those skilled in the art are accomplished in accordance with the present invention.

In my copending application Serial No. 246,462, filed September 13, 1951, now Patent No. 2,723,225, there is described a process and apparatus involving the continuous passage of crushed shale downwardly as a solid moving bed through an elongated vertical vessel having a condensing zone wherein gaseous products rising from a lower retorting zone of said vessel undergo condensation while flowing counter-currently to the solid moving bed. As set forth in the above-identified application, the crushed shale and gaseous products pass through a zone in the vessel intermediate the condensing and retorting zones wherein a gas seal is maintained by the introduction of an external stream of an inert gas in an amount sufficient to prevent the downward flow of condensed liquid shale oil without substantially inhibiting the downward passage of crushed shale.

In accordance with the present invention, it has now

been found that the maintenance of a gas seal within the retort intermediate the condensing and retorting zones thereof may be accomplished without the introduction of an external stream of gas. Operation of the process and apparatus described herein involves the initiation and maintenance of an internal gas seal intermediate the aforesaid condensing and retorting zones and at a fixed position relative to the walls of the retort by control of the amount of combustion-supporting gas introduced into the retorting system. More particularly, the operation of the instant process and apparatus comprises the continuous passage of crushed shale downwardly as a solid moving bed through an elongated vertical retort having a condensing zone wherein gaseous products rising from a lower retorting zone of said vessel undergo condensation while flowing counter-currently to said solid moving bed. An internal gas seal intermediate the condensing and retorting zones and at a fixed position relative to the walls of the retort is maintained by control of the air or other combustion-supporting gas introduced into the burning zone of the retorting system. It has been found that by proper control of the amount of combustion-supporting gas into the retorting system, an internal gas seal between the retorting and condensing zones is formed at a fixed position relative to the walls of the retorting vessel, thus preventing downward flow by gravity of the condensed liquid shale oil into the retorting zone of the retorting vessel.

The invention may be further understood by reference to the attached drawings wherein:

Figure 1 represents a schematic arrangement of apparatus for carrying out the process of the invention;

Figure 2 illustrates a detailed section of the apparatus of Figure 1, and

Figure 3 shows in schematic form a preferred embodiment of the invention.

Turning now to the drawings, and particularly to Figure 1, cold, crushed, raw oil shale is introduced into hopper **10**. The shale moves by gravity from hopper **10** through feed leg **11** provided with a suitable flow control means not shown and passes into the upper portion of retorting vessel **12**. A gas, such as flue gas or steam, is desirably introduced into feed leg **11** through conduit **13** to forestall the upward flow of gaseous retort products therethrough. As the shale descends through the retorting vessel, it passes first through a condensing zone where liquid shale oil condensed from gases generated during retorting is collected in the form of a pool. The liquid product, together with non-condensable gases, is withdrawn through outlet pipe **14** leading to a liquid gas separator **15**. Liquid shale oil collects in the bottom of separator **15** and is withdrawn therefrom through draw-off pipe **16**. Non-condensable gases are removed from separator **15** through pipe **17**. A baffle **18** is affixed to the interior wall of retorting vessel **12** overlying the outlet connection of pipe **14** to prevent entrainment of granular solid shale particles in the product oil.

The descending shale, now wet with shale oil, passes from the condensing zone of retorting vessel **12** through a gas seal zone wherein the upward flow of shale oil vapors, together with other gas present, is such as to permit sufficient condensed shale oil to flow downward which, in turn, is revaporized and flows upward to the condensing zone. Such internal gas seal zone is maintained by control of the amount of oxygen-containing gas introduced into the burning zone underlying the retorting zone. The oxygen-containing gas is suitably introduced into the burning zone of the retorting system through conduit **19** furnished with control valve **20**.

The downwardly moving shale in the retort vessel is further heated in the gas seal zone by counter-current heat exchange with the hot vapors rising from the retorting

zone immediately below. As the rising hot vapors give up their heat to the descending shale passing through the gas seal zone, the condensable portion of the vapors is liquefied. It is for the purpose of minimizing the natural downward flow of this condensate and of preventing the pool of liquid in the overlying condensing zone from flowing down into the retorting zone that the above-mentioned seal zone is maintained at a point intermediate the condensing zone and the retorting zone.

Upon emerging from the seal zone, the preheated shale continues its downward passage through a retorting zone and a burning zone wherein it is contacted with an oxygen-containing gas such as air introduced through conduit **19**. Upon contact of the oxygen-containing gas with hot shale, residual combustible matter is burned from the shale, thereby providing the heat required for retorting. The combustion products flow upward in admixture with the vapors resulting from decomposition of the kerogen content of the shale, and said combustion products ultimately leave the top of retorting vessel **12** along with non-condensable retorting gas and liquid shale oil through outlet pipe **14**. In accordance with the instant invention, the amount of oxygen-containing gas introduced into the burning zone is such as to provide sufficient gaseous products and a sufficient temperature to initiate and maintain a seal zone intermediate the condensing and retorting zone, as described above.

The hot shale flows downwardly from the burning zone and is further cooled by the introduction of a cooling medium such as water, steam, or the like, suitably introduced through conduit **21** provided with control valve **22**. For initially heating the shale, hot flue gas is introduced through conduit **23**, valve **22** being closed and valve **24** being open. After operation of the retort is begun, valve **24** is closed and valve **22** is opened as the introduction of cooling medium is desired. Spent shale flows out of the bottom of retorting vessel **12** through outlet pipe **25**, the rate of flow being conveniently controlled by valve **26**. The introduction of a cooling medium is not considered essential to successful operation of the instant retort but is advantageous in that it assists in upward transfer of heat to the retorting zone and further provides a seal by some downward leakage on outlet pipe **25**, thereby serving to facilitate the desired upward movement of gaseous retort products.

It is essential, in accordance with the present method of operation, that the amount of oxygen-containing gas introduced into the burning zone of the retort system be controlled in amount such that a seal zone is maintained between the condensing zone and the retorting zone of the retort system. The manner in which such seal zone is effected may be readily understood from an inspection of Figure 2. By careful control of the amount of oxygen-containing gas introduced into the burning zone, it is possible in accordance with the instant invention to operate the retorting system without providing a high velocity gas seal from an external source. Referring to Figure 2, which illustrates a portion of the retort containing the condensing and retorting zones, hot gases and shale oil vapors from the retorting zone pass upwardly and the shale oil vapors condense upon contact with the cold shale. The upward gas velocity is too low in and of itself to prevent the condensed shale oil from flowing back to the retorting zone. The condensed shale oil, upon contacting the hot shale in the retorting zone, then revaporizes and passes upwardly to the condensing zone wherein it re-condenses. This cycle repeats itself until the upward flow of shale oil vapors, together with non-condensable gases present in the retorting system, is just the rate required to permit sufficient oil to flow downward to vaporize and to flow back up the retort. After this internal recycle is established, it is maintained by control of the amount of oxygen-containing gas introduced into the burning zone of the retorting system so that the net amount of shale oil produced in the retorting zone would be condensed and removed as product from the retort. As will be realized, it is essential, in accordance with the above-described operation that the downflowing shale carry as much heat down through the retort as the shale oil vapors carry upwardly. If such were not the case, the retorting zone would gradually rise in the retorting vessel until it would be at the shale feed hopper and no cold shale would be available for condensing the shale oil and cooling the gases. One purpose in accurately controlling the amount of oxygen-containing gas fed to the bottom of the retort, is to control the location of the gas seal zone at a predetermined fixed position relative to the walls of the retort. A suitable automatic control means for such purpose is shown in Figure 3.

Referring to Figure 3, a preferred embodiment of the invention is depicted wherein the amount of air or other oxygen-containing gas introduced through conduit **19** is responsive to a variable condition such as temperature or pressure maintained in the seal zone of the retorting system. Thus, responsive device **27** extends from control point **28** to throttle valve **20** so that the quantity of air passing through said valve is directly responsive to a variable condition at said control point. It is contemplated that any of the commercially available temperature or pressure responsive devices may be employed for the above purpose. With the installation of such responsive device, the retorting system becomes substantially automatic since the amount of oxygen-containing gas introduced through conduit **19** to the burning zone is responsive to a variable within the seal zone. For example, the responsive device may be regulated by the temperature at some predetermined point in the seal zone. If, during operation of the retort, the temperature at the control point starts to increase, this means that the rising shale oil vapors and non-condensable gases are carrying more heat up through the retort than the shale is carrying down. Consequently, the retorting zone begins to move up the retort, which movement is detected by the increase in temperature at the control point. The temperature responsive device, actuated by the increase in temperature, effects an increase in the amount of oxygen-containing gas being introduced through conduit **19** to the burning zone. This increase in supply of oxygen-containing gas effects an increase in the amount of non-condensable gases in the rising gaseous stream coming into contact with the temperature control point and thereby lowers the heat capacity per cubic foot of rising gas. Since the volume of seal gas required for maintenance of the seal zone is constant, the amount of shale oil liquid reflux required is lowered and the rate of said reflux is automatically reduced by the increase in rate of feed of the oxygen-containing gas being conducted to the retort. Consequently, the amount of latent heat of vaporization transferred from the retorting zone up through the seal zone to the condensing zone is also lowered. The over-all effect of increasing the oxygen-containing gas rate to the retort accordingly is a decrease in the amount of heat carried up by the rising vapors from the retorting zone through the seal zone to the condensing zone and a stopping of the upward movement of the retorting zone initially caused by a minor upset in the retorting system.

It is particularly to be noted in conventional shale retorting operation, as heretofore practiced, in which shale oil reflux was not used to aid in maintenance of a seal zone between retorting and condensing zones that the rate of oxygen-containing gas conducted to the retort would be decreased under the above circumstances instead of being increased as described to lower the heat carrying capacity of the upward flowing vapors through the seal zone. Operation in accordance with the instant retorting process is accordingly quite different from prior practice.

If, on the other hand, the temperature at the control point begins to decrease during operation of the retort, this means that the descending shale is carrying more heat down through the retort than the oil vapors and non-condensable gases are carrying up. Accordingly, the retorting zone begins to move down the retort. Such downward movement is detected by the decrease in temperature at the control point. The temperature responsive device thereupon effects a decrease in the amount of oxygen-containing gas being introduced to the burning zone of the retort. The resulting decrease in supply of oxygen-containing gas decreases the amount of non-condensable gases in the rising gaseous stream and consequently increases the heat capacity of said gaseous stream. The amount of shale oil liquid reflux is increased, the rate of reflux being increased by the decrease in the rate of feed of the oxygen-containing gas being conducted to the retort. The latent heat of vaporization being transferred from the retorting zone up through the seal zone to the condensing zone is also increased. The net result of decreasing the oxygen-containing gas rate to the retort is an increase in the amount of heat being carried up by the vapors passing from the retorting zone to the condensing zone which, in turn, stops the downward movement of the retorting zone. In this case, also, it is to be noted that operation in accordance with the process of the invention is just the reverse of prior practices in which shale oil reflux was not used as an aid in maintaining the seal zone. Thus, operation in accordance with prior practice would have dictated that the rate of oxygen-containing gas conducted to the retort be increased under the above given conditions instead of being decreased as in the present method of retorting.

In a less preferred embodiment, the responsive device employed may be actuated by changes in pressure at some predetermined point in the gas seal zone so that the upward pressure of non-condensable gaseous products and vaporized shale oil, including shale oil reflux, can be controlled so that it is always sufficient to support the overlying pool of condensed liquid shale oil. In this case, if the pressure at the control point should begin to decrease, the rate of introduction of oxygen-containing gas to the retort is automatically increased to compensate for such pressure drop. Conversely, should the pressure at the control point start to increase, then the rate of introducing oxygen-containing gas to the retort is decreased responsive to said pressure increase. In either case, the gas seal zone is maintained at a fixed position relative to the walls of the retort.

Modifications and refinements of the foregoing process may be made, depending largely on the nature of the shale oil product desired. Thus, where the presence of water in the retort is considered detrimental, it may be advantageous to preheat the raw shale being introduced into hopper **10** to a temperature above the dew point of the retort gas to obviate possible condensation of water in the condensing zone.

In practice of this invention, the shale is suitably crushed. The preferred size should pass a 2-inch mesh sieve and be retained on a ¼-inch mesh sieve. However, crushed shale outside of this preferred mesh size may also be used. The temperature in the retorting zone is generally between about 800 and about 1500° F., depending on the type of shale employed and the nature of the products desired.

It is to be understood that the crushed shale flows downward through the apparatus of this invention as a compact moving bed and that the unit is so designed that vapor velocities do not reach a value sufficiently high to cause the descending solids to boil to any appreciable extent. The elimination of a high velocity gaseous stream within the retorting system affords several advantages. Thus, erosion of equipment and shale is minimized by substantial elimination of high vapor velocities. Collection of the liquid shale oil in a pool inside the retorting vessel is also advantageous in that a high degree of contact between the rising vapors and the liquid oil is achieved, resulting in greater heat recovery and improved adsorption of light hydrocarbons from the retort gas. The intimate contact between liquid shale oil and retort gas is further advantageous in eliminating the tendency of the retorted shale oil to disperse itself as a finely divided mist in the retort gas such as is ordinarily the case when recovery by condensation is attempted in conventional equipment. This problem of dispersion is so troublesome in some instances that expensive electrical precipitators must be employed to resolve the shale oil mist. Operation in accordance with the present process eliminates the need for such precipitators.

While the method and apparatus described herein have been particularly directed to the recovery of shale oil from oil shale, the present invention may be adapted for the recovery of oils from any solid substance. Accordingly, it is to be understood that the above description is merely illustrative of preferred embodiments of the invention, of which many variations may be made within the scope of the following claim by those skilled in the art without departing from the spirit thereof.

I claim:

A process for the recovery of shale oil from oil shale, which comprises feeding crushed, raw oil shale to an elongated vertical retort, passing said shale downwardly through said retort, while bringing the same to ignition temperature, contacting the resulting hot shale with a stream of oxygen-containing gas to effect combustion of combustible matter present therein, flowing hot vaporous products emitted from the heated shale upwardly through a zone wherein a gas seal is maintained at a fixed position relative to the walls of the retort solely by control of the amount of said stream of oxygen-containing gas such that the upward flow of shale oil vapors and non-condensable gases passing through said gas seal zone sufficient to permit adequate liquid shale oil to flow downward to said retorting zone, vaporize, and flow back up to said condensing zone, thereby effecting an overall upward vapor flow sufficient to prevent the bulk of condensed shale oil from passing into said retorting zone but insufficient to prevent the downward passage of crushed oil shale therethrough, passing said vaporous products from said gas seal zone and immediately condensing a portion thereof to liquid shale oil by contacting with cold, crushed raw shale feed, maintaining a pool of the liquid shale oil so obtained, passing said cold, crushed raw shale, wet with oil, through the aforementioned gas seal zone, removing a stream of non-condensable gases and liquid shale oil from the upper portion of said retort and withdrawing a stream of spent shale on the lower portion of said retort.

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