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[54] **PROCESS AND APPARATUS FOR OIL SHALE RETORTING**


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[58] **Field of Search** ..... 208/11; 202/221



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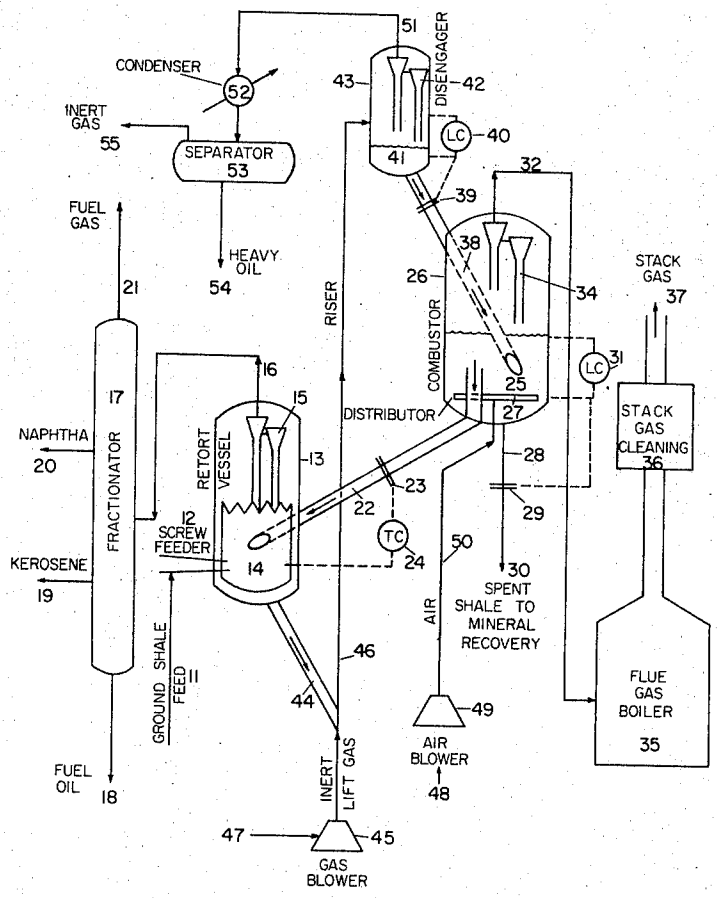
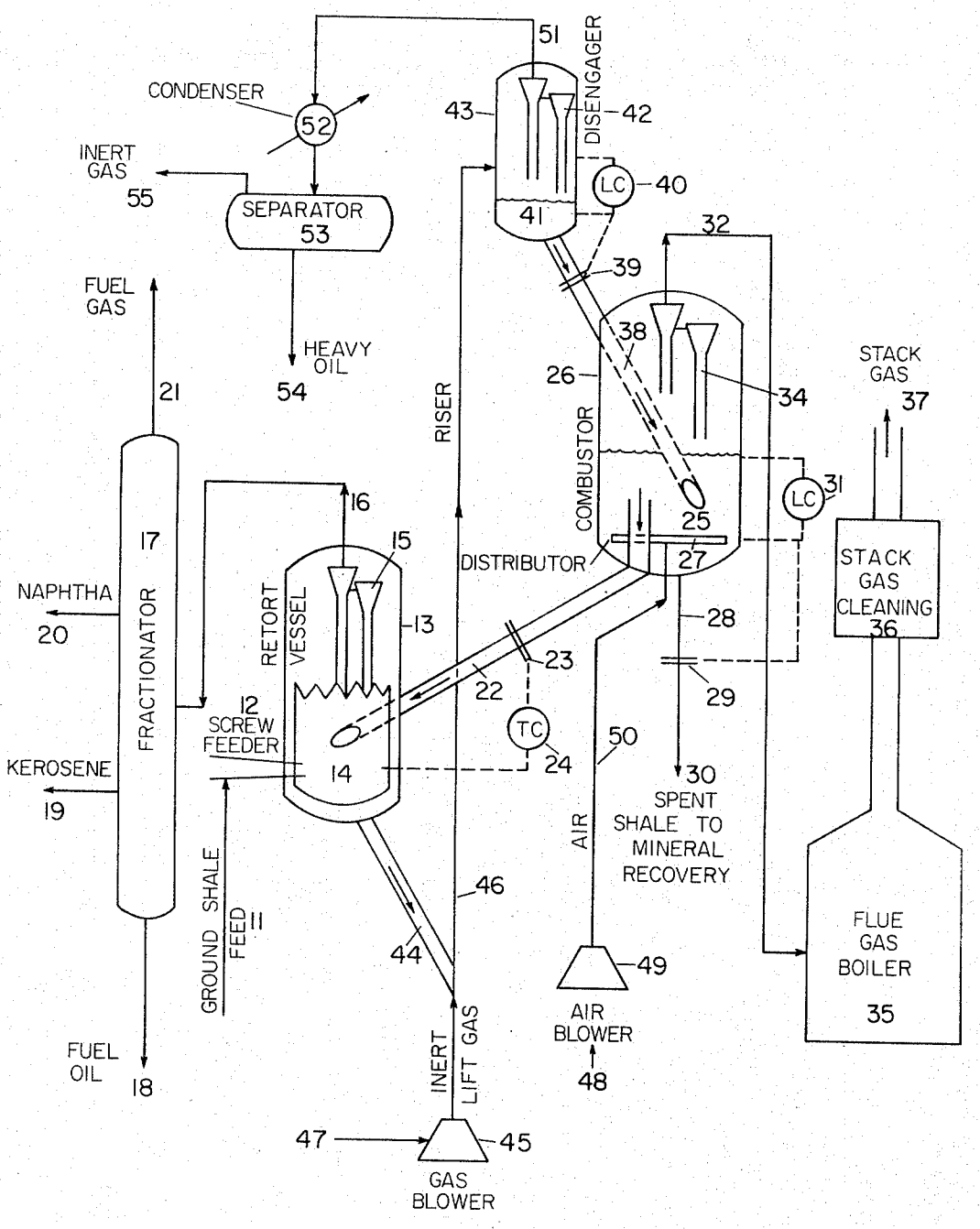
[57] **ABSTRACT**

A process and apparatus are disclosed for the continuous steady state retorting of ground oil shale in the absence of air. Retorting is accomplished by countercurrently contacting heated spent oil shale with fresh ground oil shale in a vessel from which air is excluded. The spent oil shale is heated by combustion of its carbonaceous residue to form a hot heat transfer medium which, when contacted with fresh oil shale in the retorting process, provides the energy for the recovery of hydrocarbons.


**10 Claims, 1 Drawing Figure**



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# PROCESS AND APPARATUS FOR OIL SHALE RETORTING

## BACKGROUND OF THE INVENTION

This invention relates to a process and apparatus for the recovery of hydrocarbons from oil shale. More particularly, the present invention is directed toward the retorting of oil shale through use of spent oil shale as a heat exchange medium.

Vast deposits of oil shale are located within the United States and are generally disposed beneath the earth's surface in underground formations. These oil shale deposits contain hydrocarbons known as kerogen which are valuable for their hydrocarbon content. Normally, the hydrocarbons cannot be recovered from the mined oil shale by conventional hydrocarbon processes. Oil shale containing kerogen must be subjected to retorting or destructive distillation to provide shale oil, which is a hydrocarbon product much like crude oil or petroleum and which may be processed to provide fuels and other useful products. Generally, a ton of oil shale can provide 1 to 50 gallons of shale oil. Therefore, these vast deposits of oil shale provide a significant reserve of hydrocarbon materials from which energy may be derived. Economical production of hydrocarbons from the oil shale deposits could provide a tremendous contribution to this country's national wealth and a great supply of hydrocarbon materials and energy.

Conventionally utilized and presently known oil shale retorting processes suffer from one or more disadvantages:

a. The retorting process is a non-steady state process with altering conditions which lead to control difficulties and high labor costs.

b. The retorting is accomplished in the presence of air which degrades the oil product by producing oxygenated compounds which are not as useful as the hydrocarbon materials from which they were produced.

c. The disposal of spent oil shale remaining after the retorting process. Residual carbonaceous material (coke) in the spent shale leads to disposal problems and represents wasted potential energy.

d. Recovery of valuable minerals, such as sodium and aluminum, from spent oil shale with the high coke residue content is troublesome.

A problem which is particular to the retorting process is the tremendous amount of heat required in order to retort or destructively distill the shale oil from the minerals. In conventional processing, heat is often supplied by a medium such as hot gas or ceramic balls. This mode of heat addition increases investment and operating expenses in the process. Conventional processes are also sensitive to oil shale particle size distribution and require expensive classification equipment to provide shale feedstock with a proper consistency. What is required is a method of optimumly heating and destructively distilling the oil shale for the economic recovery of hydrocarbons therefrom and for the optimum utilization of the heat expended in the retorting process.

It is an object of the present invention to provide a process and apparatus for the retorting of oil shale.

It is a further object of the present invention to provide a means for supplying heat through the utilization of spent oil shale.



It is still a further object of the present invention to optimumly utilize the heat generated during the retorting process, while simultaneously providing an easily disposable spent oil shale product and a waste flue gas free of polluting contaminants.

With these and other objects in mind, the present invention may be more fully understood through the following drawing and description:

## SUMMARY OF THE INVENTION

The objects of the present invention are accomplished through use of a process of retorting hydrocarbons from oil shale in a retorting vessel in which the oil shale is subjected to destructive distillation by the addition of heat in the substantial absence of oxygen. The improvement in the retorting process comprises the heat for the process being added through the continuous introduction of heated spent oil shale as the heating medium. Generally, the spent oil shale is heated by combustion of its carbonaceous residue. Retorting is then accomplished by comingling with fresh oil shale in a retorting vessel. It is preferred that the comingling be accomplished through the counter-current introduction of fresh oil shale into the retorting vessel. The combustion of the spent oil shale may be achieved by contacting the spent oil shale with air to form hot flue gases and heated spent oil shale. The heat content of the hot flue gases produced may be recovered for further economic benefit.

The objects of the present invention may also be accomplished through apparatus for the retorting of oil shale comprising a retorting vessel having a hydrocarbon discharge and spent oil shale discharge. A hydrocarbon fractionator is connected to the hydrocarbon discharge of the retorting vessel for recovery of the hydrocarbon materials therefrom and means for introducing hot spent oil shale into the retorting vessel are provided. The means for introducing heated spent oil shale may comprise removing the spent oil shale from the discharge of the retorting vessel and passing it through a combustor, coupled with means responsive to the temperature of the retorting vessel for introducing heated spent oil shale from the combustor into the retorting vessel.

The means for introducing spent oil shale into the combustor may comprise an inert gas lifter connected to the spent oil shale discharge of the retorting vessel and a spent oil shale disengager, fed spent oil shale by the gas lifter, connected to the combustor. Various mechanical means of lifting spent shale may also be employed. It is also preferred that a vapor condenser be connected to the disengager to receive the inert lift gas and any condensable, normally liquid compounds contained therein. These liquids are further separated in a gas-liquid separator connected to the condenser to recover the normally liquid compounds from the inert lift gas. In conjunction with the combustor may be means for purging heated spent oil shale from the combustor and means for reclaiming heat from the hot flue gases produced within the combustor.

## BRIEF DESCRIPTION OF THE DRAWING

The process and apparatus of the present invention may be more fully understood by referral to the accompanying FIGURE in which is depicted one embodiment of the oil shale retorting apparatus of the present invention.

## DETAILED DESCRIPTION OF THE INVENTION

The present invention is a method and apparatus which has been devised for the continuous-steady state retorting of ground oil shale in the substantial absence of air. Through the judicious selection of processing equipment, the retorting system is capable of producing clean, high quality oil products, clean flue gas and spent oil shale completely free of carbonaceous materials. Through the oil shale retorting process of the present invention, steady state conditions are maintained in applying retorting heat by means of a circulating stream of heated spent oil shale. Retorting is accomplished through the intimate contacting of heated spent oil shale and fresh ground oil shale in a retorting vessel from which air is excluded. Spent oil shale is heated by combustion of its carbonaceous residue in a reaction vessel called a combustor. It is generally found that spent oil shale contains a high content of residue or coke which is an unavoidable consequence of air-free retorting required for destructive distillation of the hydrocarbons from the oil shale. This residue is utilized to heat the spent oil shale into a heated or hot spent oil shale which may be utilized to supply the heating medium for the processing of the fresh oil shale supplied to the retorting vessel. Therefore, through use of the present invention, one avoids the environmental hazards of expending an effluent from the retorting vessel containing a coke residue which is undesirable and not easily disposed of through the consumption and utilization of the energy content of the carbonaceous residue. Spent oil shale is continually withdrawn from the combustor in order to maintain a constant circulating inventory of spent oil shale in the system such that only a partial recycle of the spent oil shale occurs with constant purging of spent oil shale from the combustor in a clean, discardable or readily usable form for extraction of minerals therefrom for use in other processes.

Accordingly, with the apparatus and process of the present invention, fresh oil shale is continuously introduced into the retorting vessel. The oil shale is subjected to destructive distillation by the addition of heat in the substantial absence of oxygen, with the improvement of the present invention comprising the heating medium of the process being provided through the addition of heated spent oil shale. The spent oil shale, heated by combustion of carbonaceous residue, is comingled with the fresh oil shale introduced into the retorting vessel. Generally, the comingling is accomplished by the counter-current introduction of fresh oil shale to the introduction of heated spent oil shale so that the most concentrated heat content of the heated spent oil shale contacts the hottest portion of the fresh oil shale introduced into the retorting vessel with an economic destructive distillation process being provided.

The apparatus and process of the present invention may be more fully understood by referral to the accompanying FIGURE. Fresh ground oil shale **11** is introduced continuously into an insert vessel **14** contained within a retorting vessel **13** by means of a screw feeder **12**, although other possibilities for fresh oil shale introduction exist. For example, use of a lock hopper or introduction by pumping a slurry consisting of ground shale mixed with a heavy oil into the retorting vessel **13** would accomplish the same end. The retorting vessel **13** can operate at or near atmospheric pressure, thus facilitating continuous fresh oil shale input. Heated spent shale flows in through a downward tangential entry point by means of an inlet pipe **22.** Fresh oil shale is introduced into the incoming heated spent oil shale countercurrently to promote turbulent mixing and favorable heat transfer of energy from the heated spent oil shale to the fresh oil shale. The retorting bed level maintained in the insert vessel **14** by means of a notched circular overflow weir forming the top of the insert vessel **14.** Bed temperature is automatically controlled by regulation of the inlet valve **23.** Inlet valve **23** is controlled by a temperature controller **24,** temperature responsive to the temperature of the oil shale within insert vessel **14.** In general, retorting temperature will be controlled between 500° and 1,500° F., and preferably between 800° and 1,200° F., depending on yield, structure of the apparatus, and the oil products desired. Higher temperatures will promote cracking of the shale oil and increasing yields of gas and light ends, while lower temperatures will increase the fuel oil and kerosene yields. The hydrocarbon vapors leave the retorting vessel **13** through stacks **15,** having cyclone inlets to retain the oil shale fines within retorting vessel **13,** and pass through a pipe **16** to a fractionator **17.** The fractionator **17** consists of a multi-plate fractionation column which separates the retorted products into the desired boiling range materials, for example fuel oil **18,** representing the bottoms of the fractionator **17,** kerosene **19,** naphtha **20,** and fuel gas **21.**

In order to maintain smooth circulation of spent oil shale, it is desirable to lift the spent oil shale particles leaving the retorting vessel **13.** It is also economically desirable to remove as much heavy oil from the spent oil shale as possible before combusting the carbonaceous residue or hydrocarbon material remaining therein by the further heating of the spent oil shale. Both these requirements may be accomplished by blowing the spent oil shale upward with a fast moving inert lift gas, preferably heated, through a vertical pipe. This is depicted in the FIGURE by a discharge line **44,** discharging spent oil shale from retorting vessel **13** into an inert lift gas **47,** provided by a gas blower **45.** The spent oil shale and inert lift gas **47** pass through a riser pipe **46.** Preferred lift gases include flue gas and steam, but inherently an inert gas should be utilized. The riser pipe **46** terminates at a disengager vessel **43** which serves to separate the lift gas, through stacks **42,** also having cyclones therein to retain fines. The lift gas passes through line **51** and is introduced into a condenser **52,** which may be water or air cooled to condense the normally liquid components of the gas, for example, any heavy oils. The gas-liquid mixture is then passed to a separator **53** in which heavy oil **54** is separated therefrom. Spent oil shale forms a level **41** in the bottom of the disengager vessel **43.** This material is then fed to a combustor **26** to form a level of spent oil shale **25** therein. The level of spent oil shale **41** in the disengager **43** is regulated by a level controller **40** connected to a responsive valve **39** connected within the discharge tube **38,** from the disengager vessel **43,** which feeds spent oil shale to the combustor **26.**

The hot bed of shale particles is maintained in the combustor **26** by continuously buring the coke contained within the spent oil shale with air **48** blown into the bottom of the combustor **26.** The air **48** is introduced through an air blower **49** and air line **50,** and passed through a distributor plate **27** to uniformly heat

and combust the carbonaceous residue contained within the spent oil shale bed **25.** The distributor **27** may consist of a perforated grid or a network of pipes having holes at close intervals. Spent oil shale flows in from the disengager **43** through the discharge pipe **38** in a downward tangential entry which promotes turbulent mixing with air **48** introduced into the combustor **26,** resulting in complete combustion of the carbonaceous residue of the spent oil shale. Heated spent oil shale is introduced into the retorting vessel **13** through an overflow well comprising the inlet pipe **22** extending within the retorting vessel **13** and is controlled by temperature control **24** previously disclosed. In addition, excess heated spent shale oil is continually withdrawn from the combustor **26** by the use of a level control **31** having a responsive valve **29** connected to a discharge line **28** such that spent oil shale **30** is provided for mineral recovery and/or disposal as it is continually purged from the combustor **26.**

As it would be possible to produce a totally carbon free spent oil shale by contacting the excess spent oil shale withdrawal stream with oxygen, a totally clean spent oil shale may be produced from the apparatus of the present invention for total environmental control and no adverse pollution effects. The process, therefore, is not inhibited by pollution criteria.

Flue gas which is vented through stack **34** and line **32** from the combustor **26** is passed through the cyclones contained within stacks **34,** to remove fines, and through line **32** into a waste heat boiler **35.** The waste heat boiler **35** recovers combustion heat value not used in the retorting process. This further allows for minimum waste of oil shale energy potential. Cool flue gas, leaving the waste heat boiler **35,** may be subjected to various gas treating operations for removal of particulates and pollutants such as $SO_2$ by passing the flue gas through stack gas cleaning stage **36.** The clean flue gas produced is then sent through stack **37** into the atmosphere. Therefore, through the process of the present invention, production of clean flue gas and clean spent oil shale insures minimum environmental debasement. As the combustor **26** may be operated in the range of 800° to 2,000° F., , the assurance of complete combustion of carbonaceous materials and with the absence of conventionally produced carbonaceous residues normally associated with spent oil shale removed, environmental control and reclamation of any heat content or energy value contained within the oil shale is provided.

Accordingly, by use of the apparatus and process of the present invention, oil shale is heated by the combustion of its own carbonaceous residue through a process whereby steady state conditions are maintained in supplying retort heat by means of a recirculating stream of heated spent oil shale particles. Through the operating conditions and system utilized, one is capable of producing high-quality oil products with the production of clean flue gas and oil shale completely free of carbonaceous materials such that environmental control and pollution inhibition are afforded conjunctively with an economically desirable process for oil shale recovery.

While the present invention is described with reference to particular embodiments thereof, it will be appreciated by those in the art that various changes and modifications can be made therein without departing from the scope of the invention as set forth.

Therefore, I claim:

**1.** In a process for the retorting of hydrocarbons from oil shale in a retorting vessel in which the oil shale is subjected to destructive distillation by the addition of heat in the substantial absence of oxygen, the improvement which comprises the heat for the process being added through the introduction of heated spent oil shale.

**2.** The process of claim **1** in which:

a. the spent oil shale is heated by combustion of its carbonaceous residue, and

b. the heated spent oil shale is comingled with fresh oil shale in the retorting vessel.

**3.** The process of claim **2** in which the comingling is accomplished through introduction of the heated spent oil shale countercurrent to the introduction of fresh oil shale.

**4.** The process of claim **3** in which the combustion of the spent oil shale is achieved by contacting the spent oil shale with air to form hot flue gases and heated spent oil shale.

**5.** The process of claim **4** further comprising recovering the heat content of the hot flue gases.

**6.** Apparatus for the retorting of oil shale comprising:

a. a retorting vessel having a hydrocarbon discharge and spent oil shale discharge;

b. a hydrocarbon fractionator connected to the hydrocarbon discharge of the retorting vessel; and

c. means for introducing heated spent oil shale into the retorting vessel.

**7.** The apparatus of claim **6** wherein the means for introducing hot spent oil shale comprise:

a. a spent oil shale combustor;

b. means for introducing spent oil shale from the spent oil shale discharge of the retorting vessel into the combustor; and

c. means responsive to the temperature of the retorting vessel for introducing heated spent oil shale into the retorting vessel.

**8.** The apparatus of claim **7** in which the means for introducing spent oil shale into the combustor comprise:

a. an inert gas lifter connected to the spent oil shale discharge of the retorting vessel; and

b. a spent oil shale disengager, connected to the combustor, fed spent oil shale by the inert gas lifter.

**9.** The apparatus of claim **8** further comprising:

a. a vapor condenser connected to the disengager to receive the inert lift gas and condense normally liquid compounds contained therein; and

b. a gas-liquid separator connected to the condenser to separate the normally liquid compounds from the inert gas.

**10.** The apparatus of claim **7** further comprising:

a. means for purging hot spent oil shale from the combustor; and

b. means for reclaiming heat from the hot flue gases produced in the combustor.

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