

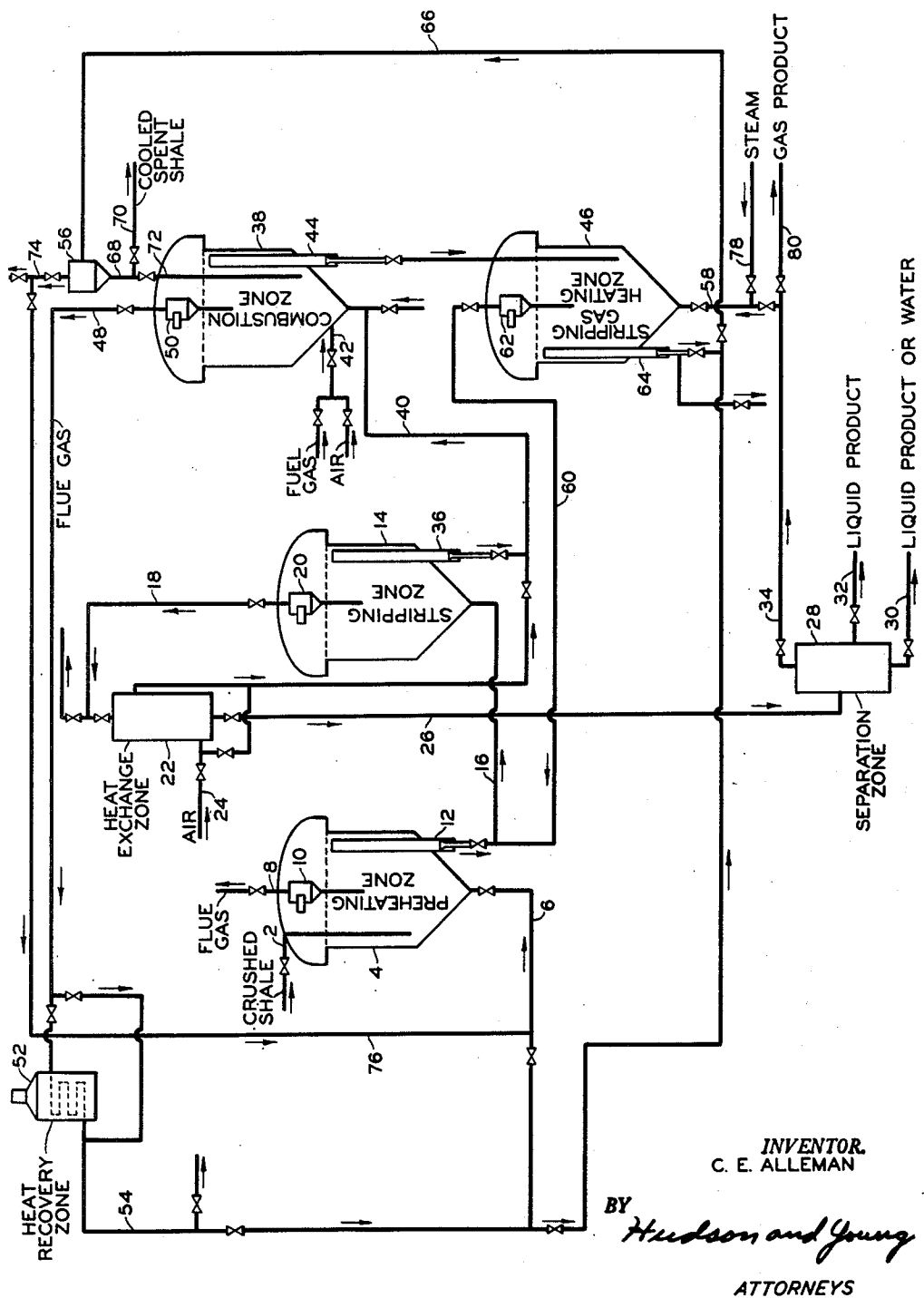
July 28, 1953

C. E. ALLEMAN

2,647,077

PROCESS FOR DESTRUCTIVE DISTILLATION

Filed June 13, 1949



UNITED STATES PATENT OFFICE

2,647,077

PROCESS FOR DESTRUCTIVE DISTILLATION

Carl E. Alleman, Bartlesville, Okla., assignor to
Phillips Petroleum Company, a corporation of
Delaware

Application June 13, 1949, Serial No. 98,807

10 Claims. (Cl. 202—16)

1

This invention relates to destructive distillation. In one of its more specific aspects, it relates to destructive distillation of carbonaceous material which is characterized by containing carbon available for producing heat by burning said carbon in the presence of an oxygen-containing gas subsequent to destructive distillation and containing material available for carrying heat subsequent to said burning. In still another of its more specific aspects, it relates to the destructive distillation of carbonaceous material which contains carbon available for producing heat by burning in the presence of an oxygen-containing gas subsequent to destructive distillation, but which does not contain an appreciable quantity of inert heat-carrying material subsequent to said burning. In yet another of its more specific aspects it relates to the recovery of shale oil from oil shale.

Destructive distillation of carbonaceous materials, such as coal, wood, oat hulls, oil shale, etc., to recover useful valuable products of such distillation has been long known in the art. Generally, destructive distillation has been carried out by heating carbonaceous material to drive off vaporous products which are condensed to be used as desired, such as separation and recovery of individual chemicals contained therein. Since oil shale is a typical example of a carbonaceous material which may be destructively distilled to convert the kerogen contained in the oil shale into recoverable liquids and vapors, and since the process of my invention can be readily applied to the destructive distillation of oil shale, in this disclosure I will discuss the prior art relating to the destructive distillation of oil shale, usually referred to as retorting or stripping the oil shale, and the advantages over the prior art processes which the process of my invention offers. However, as will be evident to one skilled in the art, the process of my invention is applicable to the destructive distillation of any carbonaceous material and most of the advantages which the process of my invention has over prior art oil shale retorting processes can be realized in applying the process of my invention to the destructive distillation of any carbonaceous material.

In prior art practices oil shale has been stripped or retorted in batch fixed bed processes using steam or flue gas, produced in the stripping chamber or produced outside and passed into the stripping chamber, as the stripping gas. Oil shale has been stripped in contiguous moving bed processes using steam or internally produced flue gas as the stripping gas. Some processors have stripped oil shale using hot spent shale, that is, shale heated

2

by burning residual carbon remaining after stripping, to furnish the heat to convert the kerogen contained in the oil shale into shale oil. Also, it has been shown that heat-carrying materials, such as refractory pebbles, may be used to furnish stripping heat. Peck, Patent No. 2,449,615, issued September 21, 1948, teaches a cyclic fluidized process wherein hot spent shale furnishes the heat to strip shale oil from the oil shale in fluidized form. All of the processes of the prior art have disadvantages which I believe I have overcome by the process of my invention. These advantages which my process has over those processes of the prior art will appear to one skilled in the art hereinafter.

I have invented a process for destructively distilling carbonaceous materials which are characterized by containing carbon available for producing heat by burning carbon in the presence of an oxygen-containing gas subsequent to destructive distillation and preferably containing material available for carrying heat subsequent to said burning. The carbonaceous material in finely divided form is introduced into a destructive distillation zone and therein a fluidized bed of said carbonaceous material is formed and the carbonaceous material is destructively distilled by passing heated destructive distillation gas into said destructive distillation zone. The resulting products of destructive distillation and destructive distillation gas are withdrawn from the destructive distillation zone. These products of destructive distillation can be treated as desired. Residual solid material from the fluidized bed of carbonaceous material in the destructive distillation zone is withdrawn and passed into a combustion zone and therein a fluidized bed of such solid material is formed and carbon is burned from this solid material by passing an oxygen-containing gas into the combustion zone. Resulting heated material, heated as a result of the burning of carbon, is withdrawn from the fluidized bed of destructively distilled material and passed into a destructive distillation gas-heating zone, and therein a fluidized bed of resulting heated material is formed and destructive distillation gas is heated by directly contacting the heated material with the destructive distillation gas used. Heated destructive distillation gas is withdrawn from the destructive distillation gas-heating zone and is passed into the destructive distillation zone in order to destructively distill fresh carbonaceous material. Resulting cool material is withdrawn from the destructive distillation gas-heating zone, and flue gas resulting from

3

burning carbon from the destructively distilled carbonaceous material is withdrawn from the combustion zone. In what I speak of as modifications of the process of my invention which greatly enhance the efficiency and economics of the process of my invention, I recover heat from flue gas exiting from the combustion zone and employ the resulting cooled flue gas to pass cooled material from the distillation gas-heating zone back into the combustion zone. As will be seen hereinafter this gives me close temperature control. Also, in a modification of the process of my invention, I preheat the oxygen-containing gas used to burn carbon from the destructively distilled material by recovering heat from the products of destructive distillation. In addition, in another modification of the process of my invention I preheat the carbonaceous material by direct heat exchange between the carbonaceous material and flue gas just prior to the exit of flue gas from my system. In a preferred method of operating the process of my invention, I use destructive distillation gas to pass fresh preheated carbonaceous material into the destructive distillation zone, and I use heated oxygen-containing gas to pass residual solid material from the destructive distillation zone into the combustion zone. Some carbonaceous materials which can be destructively distilled do not contain sufficient heat-carrying material, subsequent to the burning of carbon which remains after destructive distillation, to be used in heating the destructive distillation gas. I overcome this difficulty by adding an extraneous heat carrying material in finely divided form into the combustion zone employed in the process of my invention in order to convey heat from the combustion zone to the distillation gas-heating zone. Of course, this extraneous heat carrying material may be added to the system at any suitable point. As will be seen hereinafter, in the discussion of the process of my invention as applied to a preferred specific embodiment of the process of my invention, that is, to the recovery of shale oil from oil shale, I prefer to use steam or product gas recovered from the products of destructive distillation as the destructive distillation heating gas.

It is an object of this invention to provide a process for carrying on destructive distillation of solid materials.

It is another object of this invention to provide a process for destructively distilling carbonaceous material which is characterized by containing carbon available for producing heat by burning said carbon in the presence of an oxygen-containing gas subsequent to destructive distillation and containing material available for carrying heat subsequent to said burning.

Still another object of this invention is to provide a process for destructively distilling carbonaceous material characterized by containing carbon available for producing heat by burning said carbon in the presence of an oxygen-containing gas subsequent to destructive distillation but which does not contain an appreciable amount of inert heat carrying material available for carrying heat subsequent to said burning of carbon.

Yet another object of this invention is to provide a process for recovering shale oil from oil shale.

Other objects and advantages of this invention will become apparent, to one skilled in the art, upon reading this discussion and disclosure.

The drawing, which accompanies and is a part of this disclosure, is a diagrammatic flow sheet

4

setting forth an arrangement of apparatus for practicing a preferred specific embodiment of the process of my invention in which the process of my invention is used to recover shale oil from oil shale. However, as will be apparent to one skilled in the art, the system which the diagrammatic flow sheet sets forth is applicable to the destructive distillation of any solid carbonaceous material.

The process of my invention can be applied to destructive distillation of carbonaceous materials, such as coal, wood, oat hulls, oil shale, etc. In applying the process of my invention to the destructive distillation of carbonaceous materials such as coal, wood, oat hulls, etc., which usually do not contain an appreciable quantity of inert material which may be used to carry heat subsequent to the burning of carbon which remains after destructive distillation, I find that the process of my invention can be advantageously carried out by only partially burning the coke or charcoal resulting from destructive distillation and using the unburned charcoal or coke to carry heat from the combustion zone to the distillation gas-heating zone. By this method, coke or charcoal may be taken as one of the products of the process. If desired, the coke or charcoal remaining after destructive distillation can be substantially completely burned and heat can be carried from the combustion zone to the destructive distillation gas-heating zone by using an extraneous inert heat carrying material. Or if desired, such materials as coke, charcoal, etc., can be added, not burned and used to carry heat. The process of my invention is particularly adaptable to the destructive distillation of materials such as oil shale because the oil shale, after stripping or retorting, contains residual carbon which can be burned in the combustion zone to heat inert heat-carrying material contained in the oil shale and remaining after combustion of the residual carbon. This heated heat-carrying residue solid material is then used to transfer heat from the combustion zone to the stripping or retorting-gas heating zone.

Referring now to the drawing which diagrammatically sets forth the process of my invention as applied to the recovery of shale oil from oil shale, I will discuss a preferred specific embodiment of the process of my invention. The following discussion is not to be deemed to unduly limit the scope of my invention. Crushed and/or ground oil shale in finely divided form is passed via line 2 into a preheating zone 4 wherein the fresh oil shale is preheated by directly contacting the fresh shale with flue gas introduced into preheating zone 4 via line 6. The contacting is preferably carried out by fluidizing the shale by the well-known methods of fluidization. The flue gas used to preheat the shale is produced in a subsequent step of the process of my invention, as will hereinafter be set forth. The flue gas used to preheat the oil shale is withdrawn from preheating zone 4 via line 8 after finely divided shale is separated from the flue gas in separation means 10 which can conveniently be a cyclone separator, a Cottrell precipitator or a supersonic separator, the shale removed by separation means 10 being passed back into the fluidized bed. Preheated shale is withdrawn from preheating zone 4 via stand pipe 12 and is passed in direct and concurrent contact with hot stripping gas to stripping zone 14 via line 16. The hot stripping gas is produced in a subsequent step of the process of my invention as will hereinafter be set

forth. I find it desirable to withdraw the preheated shale from the upper portion of the fluidized bed of fresh shale contained in preheating zone 4, and I find it desirable to introduce fresh shale into the lower portion of the fluidized bed contained in preheating zone 4. Also, I find it desirable to provide an adjustable stand pipe 12 so that the level of the fluidized bed and the rate of draw-off of preheated shale can be closely controlled. Introduction of the fresh shale into the lower portion of the fluidized bed contained within preheating zone 4 and withdrawal of preheated shale from the top or upper portion of the fluidized bed allows maximum contact time and efficient recovery of heat from the preheating flue gas. Some retorting or stripping of the fresh shale which is advantageous occurs during the passage of the fresh shale from preheating zone 4 into the lower portion of stripping zone 14. However, the stripping substantially completely takes place in a fluidized bed which is formed in stripping zone 14. Stripping gas and products resulting from stripping the oil shale are withdrawn from stripping zone 14 via line 18 after removal of stripped oil shale by separation means 20 which can conveniently be a cyclone separator, Cottrell precipitator, or supersonic separator, and are passed into indirect heat exchange zone 22. The stripped oil shale removed by separation means 20 is passed back into the fluidized bed. I prefer to introduce the preheated shale into the lower portion of stripping zone 14 and to withdraw the stripped shale from the upper portion of the fluidized bed contained within stripping zone 14. In operating in this manner, I find that the oil shale remains in the stripping zone a maximum length of time thus minimizing the amount of fresh shale which is withdrawn via stand pipe 36. The characteristic top to bottom mixing realized in fluidized beds tends to allow some unstripped shale to be withdrawn. Stand pipe 36 is preferably an adjustable stand pipe so that the rate of withdrawal and the height of the fluidized bed may be closely controlled. Heat exchange zone 22 is employed to preheat air and/or other oxygen-containing gas passed into indirect heat exchange zone 22 via line 24. The air and/or other oxygen-containing gas is used to burn carbon from stripped oil shale in a subsequent step of the process of my invention as will hereinafter be set forth. Stripping gas and resulting cooled products of stripping are withdrawn from heat exchange zone 22 via line 26 and are passed into a separation zone 28 wherein they are separated into a gaseous product resulting from stripping and a liquid shale oil product. I prefer to use gas product resulting from stripping and/or steam as my stripping gas. If steam is used as a stripping gas, it can be removed from the products resulting from stripping by condensation of the steam. Also, shale oil may be separated from the vaporous products resulting from stripping by condensing the shale oil vapors. Of course, any suitable separation means may be used. If steam or a combination of steam and product gas is used as the stripping medium, condensed water can be withdrawn from separation zone 28 via line 30, shale oil can be withdrawn from separation zone 28 via line 32 and the gas product can be withdrawn from separation zone 28 via line 34. If gas product alone is used as a stripping medium, shale oil can be withdrawn from separation zone 28 via line 30, and gas product can be withdrawn overhead via line 34. Stripped oil shale is withdrawn from the fluidized bed con-

tained in stripping zone 14 via stand pipe 36 and is passed in direct concurrent contact with air and/or other oxygen-containing gas into a combustion zone 38 via line 40. Combustion zone 38 is provided in order to burn residual carbon from the stripped oil shale. Some combustion which is very advantageous occurs in line 40 prior to introduction of the stripped shale into combustion zone 38. However, the major portion of the combustion occurs within a fluidized bed formed in combustion zone 38. Fuel gas and/or air may be supplied to combustion zone 38 via line 42 if it is necessary to ignite the residual carbon. I find that once my process is in operation usually no further ignition is necessary. After operation has begun, line 42 may be used to introduce air, steam, flue gas or mixtures thereof, into zone 38 for the proper control of the combustion reaction. Heated spent shale resulting from burning carbon is withdrawn from combustion zone 38, and preferably from the upper portion of the fluidized bed contained within combustion zone 38, via stand pipe 44. The heated spent shale is passed into stripping gas-heating zone 46 which is preferably located below combustion zone 38 so that the heated spent shale may flow by the force of gravity into the stripping gas heating zone. This eliminates the necessity of using gas-transport of heated spent shale, or other transporting means, in transferring the heated spent shale to the stripping gas-heating zone. Mechanical transfer of the heated spent shale is usually undesirable because of the high temperatures involved. Gas-transport would greatly reduce the flexibility of the system. I prefer to admit only stripping gas into the stripping gas-heating zone, and therefore, I prefer that stripping gas be used to transport the heated shale to the stripping gas-heating zone if gas-transport is employed. Flue gas resulting from the burning of residual carbon in combustion zone 38 is withdrawn via line 48 after removal of heated spent shale by separation means 50, which can conveniently be a cyclone separator, a Cottrell precipitator or a supersonic separator, and is passed into an indirect heat recovery zone 52. The heated spent shale removed by separation means 50 is passed back into the fluidized bed. Heat recovery zone 52 can conveniently be a boiler for producing steam to be used as desired, such as in the production of electricity. Resulting cooled flue gas is withdrawn from heat recovery zone 52 via line 54 and is used to pass spent shale from stripping gas-heating zone 46 into a separation zone 56, as hereinafter set forth, or else is sent to a stack for discarding. Stripping gas, preferably steam and/or product gas, is passed into the lower portion of stripping gas-heating zone 46 via line 58. A fluidized bed of heated spent shale is formed in stripping gas-heating zone 46. Resulting heated stripping gas is withdrawn from stripping gas heating zone 46 via line 60 and is used to transport preheated fresh oil shale from preheating zone 4 into stripping zone 14 and to strip oil shale as hereinbefore set forth. Spent shale is separated from the heated stripping gas by separation means 62 which can conveniently be a cyclone separator, a Cottrell precipitator or a supersonic separator, the separated spent shale being passed back into the fluidized bed contained within stripping gas-heating zone 46. The heated spent shale from combustion zone 38 is preferably passed into the lower portion of the fluidized bed contained within stripping gas-heating zone 46, and the result-

ing spent shale at reduced temperature is withdrawn from the upper portion of the fluidized bed via stand pipe 64. This method of operation gives maximum residence time and gives high heat recovery from the heated spent shale. If steam is used as the stripping gas it is passed into stripping gas-heating zone 46 via lines 78 and 58, and if product gas is used as the stripping gas it is passed into stripping gas-heating zone 46 via lines 34 and 58. Gaseous product produced by the process of my invention is withdrawn from the system via line 80. Spent shale from stripping gas-heating zone 46 is passed in concurrent flow and direct contact with relatively cool flue gas supplied via line 54 into separation zone 56 via line 66. Separation zone 56 can conveniently be a cyclone separator, a Cottrell precipitator or a supersonic separator. The spent shale is separated from the flue gas in separation zone 56. Resulting spent shale is withdrawn from separation zone 56 via line 68 and a portion of same is withdrawn from the system as cooled spent shale via line 70. The remainder is passed via line 72 into the lower portion of the fluidized bed contained within combustion zone 38. Flue gas, carrying heat picked up from the spent shale, is withdrawn from separation zone 56 via line 74 and is passed via lines 76 and 6 into the lower portion of preheating zone 4 to preheat fresh oil shale as hereinbefore set forth. By this preferred method of cooling the spent shale, part of the heat which would otherwise be lost with discarded spent shale is salvaged and returned to the system.

In recovering shale oil from oil shale by the process of my invention, I find that I can use crushed and/or ground shale having a particle size up to one-eighth inch. However, I prefer to use a crushed and/or ground shale having particles no larger than 40 mesh. The fresh oil shale can contain from 15 to 90 gallons of shale oil per ton, or even richer, without encountering any difficulty in treating by the process of my invention. I prefer to preheat the shale to a temperature no higher than 450° F. so that no distillation will occur in the preheating zone. Different oil shales require different residence times in the stripping zone, richer oil shale usually requiring a longer retorting or stripping time. I prefer to use stripping temperatures in the range from 825 to 1050° F. in the stripping zone, and I find that the temperature may be varied as well as the through-put of oil shale so as to obtain substantially complete stripping of the shale oil from the oil shale. Air and/or other oxygen-containing gas is supplied to combustion zone 38 in sufficient amount to burn the residual carbon from the stripped shale to recover available heat. Excess air can be used as desired. I prefer to use steam and/or recycled product gases as the stripping or retorting gas in the practice of the process of my invention. Steam is a very good stripping gas for oil shale because it is a relatively simple operation, requiring little separation equipment to condense the steam and separate the condensed water from the desired products. Also, the use of steam minimizes evaporation losses of shale oil in product gases leaving the separation equipment used to separate and recover the shale oil, and the hydrogen and B. t. u. content of the residual gas after removal of CO₂ is usually higher than when stripping media other than steam or recycled product gas are used.

Retorting or stripping with recycled product

gas or steam is better than using a flue gas from a separate chamber because: relatively small volumes of gas have to be handled in recovering the product resulting from stripping; a relatively high B. t. u. residue gas is produced; and much greater flexibility is realized in operating the combustion zone relative to operation of the stripping zone. Retorting or stripping with recycled product gas or steam is better than using flue gas produced by combustion within the stripping chamber for these additional reasons: troublesome oil-water emulsions (from moisture in the shale) are avoided; no oil or gas product is consumed merely to produce heat for the process; all the residual carbon may be burned and the excess heat produced may be used constructively instead of wasting residual carbon in order to prevent overheating in the stripping zone; and clinker troubles are minimized. Because of the problem of forming clinkers, contiguous moving bed processes usually cannot efficiently handle oil shale of a richness greater than 50 gallons of shale oil per ton. Retorting or stripping with recycled product gas or steam is better than utilizing heated spent shale or refractory pebbles because: there is better heat transfer, giving better efficiency and lessening retorting or stripping time; there is less handling of solids; retorting with a gas gives a lower partial pressure of shale oil, and thus lower distillation temperatures are required and heat is saved; less destructive cracking of shale oil occurs as a result of the oil vapors contacting the high temperature surfaces of the hot pebbles; and there is a less chance of losing either unstripped shale or residual carbon. I find that employing the oil shale in a fluidized state instead of in a contiguous bed makes the handling of the oil shale much simpler and permits much better temperature control.

I find that the preheating of the oil shale and partial stripping of the oil shale prior to its introduction into the stripping zone gives greater through-puts, reduces the loss of fresh or partly-stripped shale and salvages heat from the flue gas. I find that preheating air and/or other oxygen-containing gas gives greater through-puts for the combustion zone, reduces loss of partly-burned shale by providing more rapid combustion and salvages sensible heat from the products resulting from stripping. Partial burning of stripped shale prior to introduction into the combustion zone also gives greater through-puts and reduces the losses of partly-burned shale. I find that the recycling of the solids through the combustion and stripping gas-heating zones salvages sensible heat from the spent shale to be discarded (this usually is upwards of about 10 per cent of the total heat available from combustion of the coked shale), and makes the operation of the combustion zone flexible and relatively independent of the operation of the stripping zone. I find that with the stripping temperature constant, the amount of heat supplied to the stripping zone can be varied by keeping the ratio of recycled stripping gas to recycled solids constant but varying the quantity of each; or, in other words, varying quantities of stripping gas may be supplied and still keep the temperature constant by correspondingly varying the quantity of solids recycled. With the heat load in the stripping zone otherwise constant, the stripping temperature may be varied by varying the ratio of recycled gas to recycled solids, provided the temperature in the combus-

tion zone is sufficiently high. The recycling of solids through the combustion zone and the stripping gas-heating zone makes the operation of a heat recovery zone, to recover heat from the flue gases from the combustion zone, flexible and relatively independent of the stripping zone operation. This feature of the process of my invention is important because the value of the waste heat recovered in the heat recovery zone may equal or exceed the value of shale oil recovered, providing, of course, that such heat can profitably be used, for instance, by conversion to electricity, etc. The process of my invention offers efficient continuous oil shale stripping with full utilization of the heat available in the oil shale.

In practicing the process of my invention, I find that it is particularly important to allow sufficient residence time in the stripping zone so that the oil shale is stripped substantially completely. The normal travel pattern of the solids in a fluidized bed is a general upward movement at the center of the bed and a general downward movement at the periphery of the bed. The stripping zone arrangement which I prefer to use, as shown in the drawing, is with bottom inlet at the center and with the outlet from the upper periphery of the bed.

The process of my invention provides flexible operation. Carbon residue on stripped shale will provide about twice as much heat as is required for stripping even with relatively poor shales. The heat recovery zone to remove heat from the flue gases from the combustion zone, for instance a boiler, is provided to utilize this excess heat. The amount of heat going to the stripping gas-heating zone, and thus available for stripping, can be varied by varying the rate of solids recycled through the combustion zone and the stripping gas-heating zone. The temperature of the solids to the stripping gas-heating zone, and thus the temperature level available to the stripping zone, can be varied by varying the amount of air and/or other oxygen-containing gas to the combustion zone. Excess air and/or other oxygen-containing gas can be used to lower the temperature of the solids. If desired, the temperature variation can be accomplished by mixing steam and/or flue gas with the air and/or other oxygen-containing gas and limiting the quantity of air supplied for combustion. If such limited combustion methods are used, further combustion of the partly oxidized combustion products can be employed within the flue gas-heat recovery zone. I prefer to obtain temperature variations by the excess air method from a heat conversion standpoint, since limited combustion causes circulation of unburned particles and some of these will be ultimately discarded. However, as will be apparent to those skilled in the art, other factors may govern the operation.

In order to have the most flexible operation, the stripping gas-heating zone should be located at a lower level than the combustion zone so that the solids may flow by gravity from the combustion zone to the stripping gas-heating zone. This makes the rate of circulation of solids independent of the amount of recycle product gas employed, and any ratio of solids to recycle stripping gas and/or steam may be used in the stripping gas-heating zone. In addition, by the above mentioned relative locations of the combustion zone and the stripping gas-heating zone, additional temperature flexibility is obtained in the flue gas heat recovery zone without disturbing the temperature in the stripping gas-heating

zone. By using smaller amounts of solids per unit of recycled stripping gas and/or steam in the stripping gas-heating zone, the resulting temperature of the recycled stripping gas and/or steam will be decreased without decreasing the temperature in the combustion zone. Thus, the combustion zone temperature may be responsive to the flue gas-heat recovery zone requirements, while the solids recycled and stripping gas temperature are responsive to the stripping zone requirements.

The discussion of the process of my invention as applied to the recovery of shale oil from oil shale as set forth hereinbefore is a typical example of an operation to which the process of my invention can be applied. However, the temperatures, sizes, materials, etc. recited are not to unduly limit the scope of my invention.

As will be evident to those skilled in the art, various modifications of this invention can be made, or followed, in the light of the foregoing disclosure and discussion, without departing from the spirit or scope of the disclosure or from the scope of the claims.

Having described my invention, I claim:

1. A continuous process for separating and recovering shale oil from oil shale which comprises: introducing oil shale having a particle size of 40 mesh and smaller and containing from 15 to 90 gallons of shale oil per ton into an oil shale preheating zone and therein forming a first fluidized oil shale bed and heating said oil shale to a temperature no greater than 450° F. by directly contacting said oil shale with flue gas withdrawn from a second separation zone as hereinafter set forth and passed into the lower portion of said oil shale preheating zone; withdrawing preheated oil shale from the upper portion of said first fluidized oil shale bed and passing same in direct concurrent contact with heated stripping gas produced as hereinafter set forth into the lower portion of a shale oil stripping zone and therein forming a second fluidized oil shale bed and stripping shale oil from said oil shale at a temperature of from 825 to 1050° F.; withdrawing a resulting mixture of shale oil vapors and stripping gas from the upper portion of said stripping zone and passing same into a first indirect heat exchange zone wherein said mixture is indirectly passed in heat exchange relation with air passed into said first heat exchange zone thereby heating said air and removing heat from said mixture; withdrawing said mixture from said heat exchange zone and separating same in a first separation zone into a liquid stream of shale oil and a vaporous product gas stream, each of said streams being a product of the process; withdrawing stripped oil shale from the upper portion of said second fluidized oil shale bed and passing same in concurrent direct contact with heated air withdrawn from said first indirect heat exchange zone into a combustion zone and therein forming a fluidized stripped oil shale bed and burning residual carbon from said stripped oil shale; withdrawing resulting heated spent oil shale from the upper portion of said fluidized stripped oil shale bed and passing same into a stripping gas-heating zone and therein forming a fluidized spent oil shale bed and heating said stripping gas by directly contacting said heated spent oil shale with said stripping gas which is passed into the lower portion of said stripping gas-heating zone; withdrawing resulting heated stripping gas from the upper portion of said stripping gas-

heating zone and using same to pass preheated oil shale from said oil shale preheating zone into said stripping zone as hereinbefore set forth; withdrawing resulting spent shale from the upper portion of said spent oil shale fluidized bed and passing same in concurrent direct contact with flue gas from a second indirect heat exchange zone as hereinafter set forth into a second separation zone and therein separating said flue gas from said resulting spent shale; withdrawing resulting spent shale from said second separation zone and passing a first portion of same into said combustion zone and withdrawing a second portion of same as cooled spent shale product; withdrawing a flue gas resulting from burning residual carbon from said stripped oil shale from the upper portion of said combustion zone and passing same into a second indirect heat exchange zone and therein removing heat from said flue gas; withdrawing resulting flue gas from said second indirect heat exchange zone and using at least part of same to pass spent shale from said stripping gas-heating zone into said second separation zone as hereinbefore set forth; withdrawing resulting flue gas from said second separation zone and passing same into said oil shale preheating zone as hereinbefore set forth; and withdrawing resulting flue gas from the upper portion of said oil shale preheating zone.

2. The process of claim 1 wherein said stripping gas is a portion of said vaporous product gas.

3. The process of claim 1 wherein said stripping gas is steam.

4. A process for separating and recovering shale oil from oil shale which comprises: introducing finely divided oil shale into a preheating zone and therein forming a first fluidized oil shale bed and heating said oil shale by directly contacting said oil shale with flue gas withdrawn from a second separation zone as hereinafter set forth and passed into the lower portion of said preheating zone; withdrawing preheated oil shale from the upper portion of said first fluidized oil shale bed and passing same in direct concurrent contact with heated stripping gas produced as hereinafter set forth into the lower portion of a shale oil stripping zone and therein forming a second fluidized oil shale bed and stripping shale oil from said oil shale; withdrawing a resulting mixture of shale oil vapors and stripping gas from the upper portion of said stripping zone and passing same into a first indirect heat exchange zone wherein said mixture is indirectly passed in heat exchange relation with an oxygen-containing gas passed into said first heat exchange zone thereby heating said oxygen-containing gas and removing heat from said mixture; withdrawing said mixture from said first heat exchange zone and separating same in a first separation zone into a liquid stream of shale oil and a vaporous product gas stream, each of said streams being a product of the process; withdrawing stripped oil shale from the upper portion of said second fluidized oil shale bed and passing same in concurrent direct contact with an oxygen-containing gas withdrawn from said first indirect heat exchange zone into a combustion zone and therein forming a fluidized stripped oil shale bed and burning residual carbon from said stripped oil shale; withdrawing resulting heated spent oil shale from the upper portion of said fluidized stripped oil shale bed and passing same into a stripping gas heating zone and therein forming a fluidized

spent oil shale bed and heating said stripping gas by directly contacting said heated spent oil shale with said stripping gas which is passed into the lower portion of said stripping gas heating zone; withdrawing resulting heated stripping gas from the upper portion of said stripping gas heating zone and using same to pass preheated oil shale from said oil shale preheating zone into said stripping zone as hereinbefore set forth; withdrawing resulting spent shale from the upper portion of said spent oil shale fluidized bed and passing same in concurrent direct contact with flue gas from a second indirect heat exchange zone as hereinafter set forth into a second separation zone and therein separating said flue gas from said resulting spent shale; withdrawing resulting spent shale from said second separation zone and passing a first portion of same into said combustion zone and withdrawing a second portion of same as cooled spent shale product; withdrawing flue gas resulting from burning residual carbon from said stripped oil shale from the upper portion of said combustion zone and passing same into a second indirect heat exchange zone and therein removing heat from said flue gas; withdrawing resulting flue gas from said second indirect heat exchange zone and using at least part of same to pass spent shale from said stripping gas heating zone into said second separation zone as hereinbefore set forth; withdrawing resulting flue gas from said second separation zone and passing same into said oil shale preheating zone as hereinbefore set forth; and withdrawing resulting flue gas from the upper portion of said oil shale preheating zone.

5. The process of claim 4 wherein said stripping gas is a portion of said vaporous product gas.

6. The process of claim 4 wherein said stripping gas is steam.

7. A process for destructively distilling carbonaceous material characterized by containing carbon available for producing heat by burning said carbon in the presence of an oxygen-containing gas subsequent to destructive distillation, which comprises, introducing said carbonaceous material in finely divided form into a destructive distillation zone and therein forming a fluidized bed of said carbonaceous material and destructively distilling said carbonaceous material by passing a heated destructive distillation gas into said destructive distillation zone; withdrawing resulting products of destructive distillation and said destructive distillation gas from said destructive distillation zone; withdrawing destructively distilled carbonaceous material from said fluidized bed of carbonaceous material and passing same and an inert heat carrying material into a combustion zone and therein forming a fluidized bed of said destructively distilled carbonaceous material and said inert heat carrying material and burning carbon from said destructively distilled carbonaceous material by passing an oxygen-containing gas into said combustion zone; withdrawing resulting heated inert heat carrying material from said fluidized bed of said destructively distilled carbonaceous material and said inert heat carrying material and passing same into a destructive distillation gas heating zone and therein forming a fluidized bed of said resulting heated inert heat carrying material and heating said destructive distillation gas by directly contacting said heated inert heat carrying material with said destructive distillation gas which is passed into said destructive distillation gas heating zone; withdrawing re-

13

sulting heated destructive distillation gas from said destructive distillation gas heating zone and passing same into said destructive distillation zone; withdrawing resulting cooled inert heat carrying material from said fluidized bed of inert heat carrying material within said destructive distillation gas heating zone and passing same in concurrent direct contact with flue gas into a separation zone and therein separating said flue gas from said resulting cooled inert heat carrying material; withdrawing resulting inert heat carrying material from said separation zone and returning same to said combustion zone; withdrawing flue gas resulting from said burning of carbon from said destructively distilled carbonaceous material from said combustion zone, removing heat from same and using resulting cooled flue gas to pass inert heat carrying material from said destructive distillation gas heating zone into said separation zone as hereinbefore set forth; and withdrawing resulting flue gas from said separation zone.

8. A process for destructively distilling carbonaceous material containing carbon available for producing heat by burning said carbon in the presence of an oxygen-containing gas subsequent to destructive distillation and containing material available for carrying heat subsequent to said burning, which comprises: introducing finely divided carbonaceous material into a preheating zone and therein forming a first fluidized carbonaceous material bed and heating said carbonaceous material by directly contacting said carbonaceous material with flue gas withdrawn from a second separation zone as hereinafter set forth and passed into said preheating zone; withdrawing preheated carbonaceous material from said first fluidized carbonaceous material bed and passing same in direct contact with said stripping gas produced as hereinafter set forth into a carbonaceous material stripping zone and therein forming a second fluidized carbonaceous material bed and stripping distillable material from said carbonaceous material; withdrawing a resulting mixture of distillable material vapors and stripping gas from said stripping zone and passing same into a first indirect heat exchange zone wherein said mixture is indirectly passed in heat exchange relation with an oxygen-containing gas passed into said first heat exchange zone thereby heating said oxygen-containing gas and removing heat from said mixture; withdrawing said mixture from said first heat exchange zone and separating same in a first separation zone into a liquid stream of distillable material and a vaporous product gas stream, each of said streams being a product of the process; withdrawing stripped carbonaceous material from said second fluidized carbonaceous material bed and passing same in direct contact with an oxygen-containing gas withdrawn from said first indirect heat exchange zone into a combustion zone and therein forming a fluidized stripped carbonaceous material bed and burning residual carbon from said stripped

14

carbonaceous material; withdrawing resulting heated spent carbonaceous material from said fluidized stripped carbonaceous material bed and passing same into a stripping gas heating zone and therein forming a fluidized spent carbonaceous material bed and heating said stripping gas by directly contacting said heated spent carbonaceous material with said stripping gas which is passed into said stripping gas heating zone; withdrawing resulting heated stripping gas from said stripping gas heating zone and using same to pass preheated carbonaceous material from said carbonaceous material preheating zone into said stripping zone as hereinbefore set forth; withdrawing resulting spent carbonaceous material from said spent carbonaceous material fluidized bed and passing same in direct contact with flue gas from a second indirect heat exchange zone as hereinafter set forth into a second separation zone and therein separating said flue gas from said resulting spent carbonaceous material; withdrawing resulting spent carbonaceous material from said second separation zone and passing a first portion of same into said combustion zone and withdrawing a second portion of same as cooled spent carbonaceous material product; withdrawing flue gas resulting from burning residual carbon from said stripped carbonaceous material from said combustion zone and passing same into a second indirect heat exchange zone and therein removing heat from said flue gas; withdrawing resulting flue gas from said second indirect heat exchange zone and using at least part of same to pass spent carbonaceous material from said stripping gas heating zone into said second separation zone as hereinbefore set forth; withdrawing resulting flue gas from said second separation zone and passing same into said carbonaceous material preheating zone as hereinbefore set forth; and withdrawing resulting flue gas from said carbonaceous material preheating zone.

9. The process of claim 8 wherein said stripping gas is a portion of said vaporous product gas.

10. The process of claim 8 wherein said stripping gas is steam.

CARL E. ALLEMAN.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
2,393,636	Johnson	Jan. 29, 1946
2,414,973	Nelson	Jan. 28, 1947
2,435,746	Jones	Feb. 10, 1948
2,466,593	Jones	Apr. 5, 1949
2,480,670	Peck	Aug. 30, 1949
2,544,843	Leffer	Mar. 13, 1951

FOREIGN PATENTS

Number	Country	Date
487,983	Great Britain	June 29, 1938
586,391	Great Britain	Mar. 18, 1947