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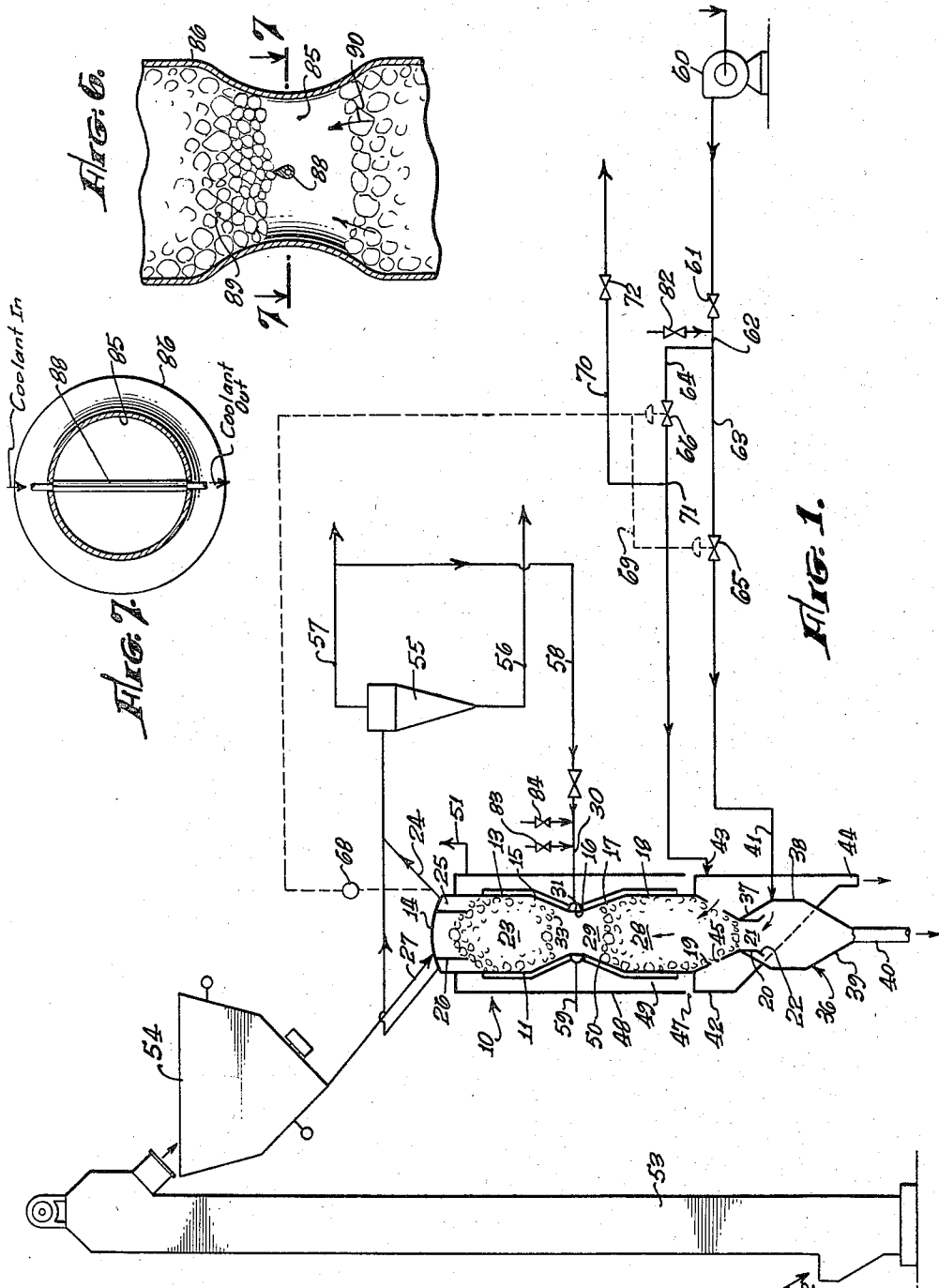
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2,879,208

SHALE OIL RECOVERY METHOD AND APPARATUS

Filed May 19, 1958

2 Sheets-Sheet 1



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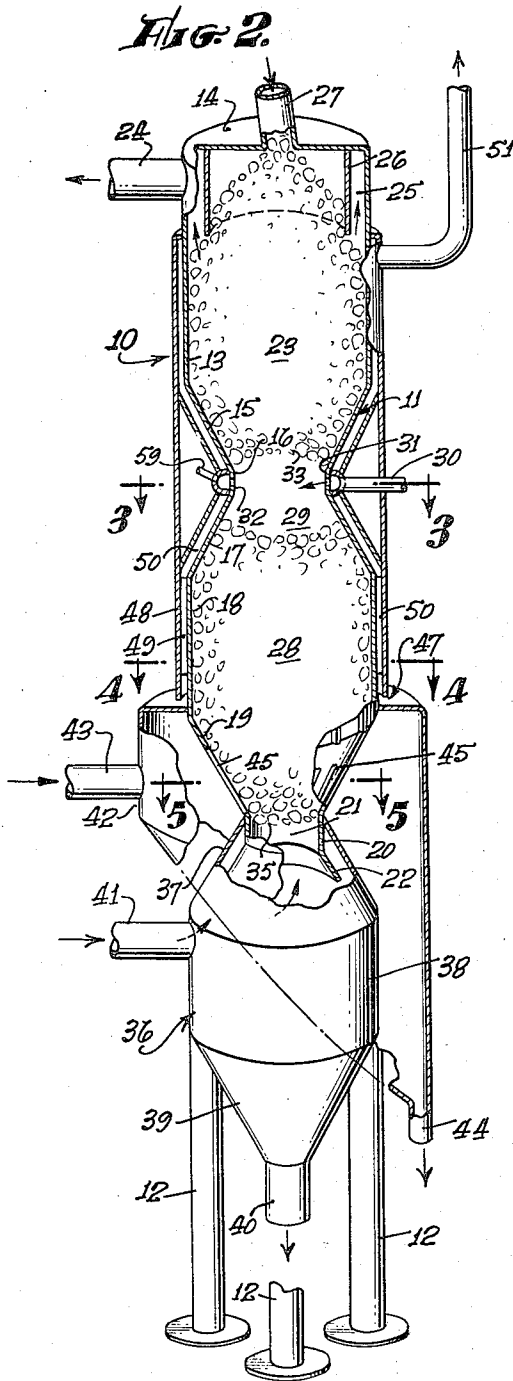
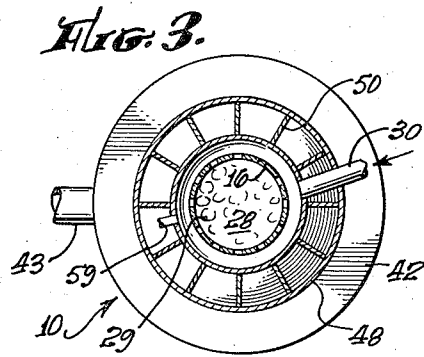
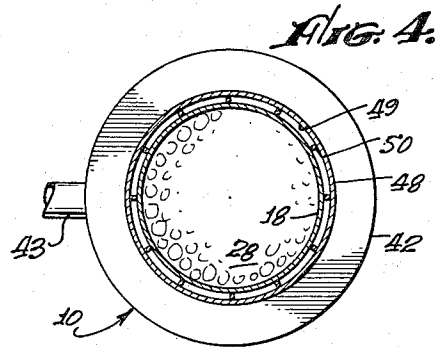
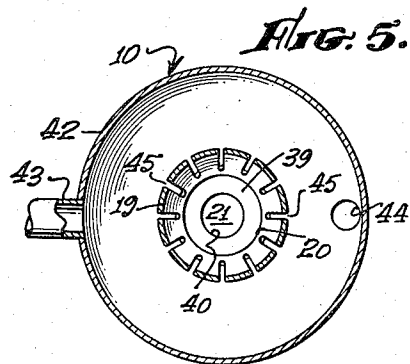
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SHALE OIL RECOVERY METHOD AND APPARATUS

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2 Sheets-Sheet 2



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2,879,208

SHALE OIL RECOVERY METHOD AND APPARATUS

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Application May 19, 1958, Serial No. 736,137

32 Claims. (Cl. 202—6)

This invention relates generally to the destructive distillation of solid hydrocarbonaceous material in retorts, and more particularly concerns an improved retorting method and apparatus for handling oil shale characterized by novel control of shale movement or gravitation in the retorting apparatus and by the substantial elimination of moving or stationary hot spot producing devices in the path of shale flow in the apparatus.

Speaking generally with regard to the prior art, certain well known methods for destructively distilling shale hydrocarbonaceous materials involve passing the particle form material downwardly in a continuous, substantially vertical column and successively through a preheating zone, a distillation zone, a combustion zone and a residue cooling zone, the column of shale being processed extending with unbroken continuity vertically through all four zones. An example of this retorting method is found in U.S. Patent No. 2,757,129 to Reeves, issued July 31, 1956, in which stationary air and fuel distributing devices are located in the shale bed for introducing an air and fuel mixture into the combustion zone, these devices being necessary for proper distribution of the products of combustion. The Reeves type retort contains stationary metallic gas and air distributors which are subject to overheating and warping due to combustion taking place in the distributors. In addition, the distributors are of necessity of rather light construction since air and gas must pass therethrough. After the hot gases flow out of the distributors, they contact the shale before the entire gas body is at thermal equilibrium, which results in local overheating and fusing of the shale. In an effort to alleviate the formation of such hot spots, it was found necessary to operate at very high dilution gas rates, causing an objectionable reduction in petroleum product yields. Therefore, as a result of uneven heating, the oil yield is reduced, and the shale agglomerates, and the distributors tend to warp, making operating conditions unstable. Also, outlet openings in the air and fuel distributors become plugged by hot shale particles.

Other known processes, all of which are objectionable, involve costly fine grinding of the shale prior to retorting thereof, the use of thermally inefficient heat transfer mechanisms such as inert steel or porcelain balls preheated in one vessel and then conveyed to the retorting apparatus for heating of the shale, and "pumping" of crushed shale upwardly in a retort requiring the use of mechanical, sodium cooled plows to break up shale agglomerates.

The above discussed problems are eliminated in the present retorting method and apparatus, in which essentially no mechanical devices project into the path of shale gravitation. Basically, the new method involves controlling the downward gravitation of shale particles from an upper or distillation zone by flowing sufficient hot gas upwardly against the exposed under side of the shale bed in the upper zone so as to restrain and preferably prevent shale gravitation into a lower zone while shale hydrocarbons are being removed in the upwardly flowing

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gas, and thereafter reducing the upward gas flow against the bed underside to allow relatively rapid gravitation of shale residue into the lower zone. Thus the process is distinguished from those in which the shale fills the retort and gravitates continuously and at the same rate, since in the present case shale gravitation is held up or retarded by the very gas which is used for distillation purposes, such gravitation being unrestrained only after the gas flow is reduced. Therefore, shale in the present process flows or gravitates downwardly in waves or batches as controlled by the upward gas flow against the exposed bed underside. One very desirable result of this method of operation consists in allowing the hot gases to mix thoroughly in the space or open zone directly below the exposed underside of the shale upper bed, the gases therefore reaching thermal equilibrium before contacting the green shale. Thus, the formation of local hot spots is prevented by inherent temperature control. Also, the open zone below the shale bed affords an adequate space for moderating the combustion gas temperature by the addition of an inert quench gas, recycle gas or steam. In addition, proper gas temperature control minimizes any tendency of the shale particles to agglomerate, and periodic gravitation thereof through the open zone keeps the shale free flowing and prevents any agglomerate from blocking the shale flow. Finally, heat transfer is at maximum efficiency as it is direct from the hot combustion gases to the shale bed, no intermediate inert carriers being required.

Referring now to the complete controlling of shale movement throughout the retorting apparatus, relatively rapid gravitation of hot shale residue from the upper zone into a lower zone is permitted by periodically reducing and increasing the upward gas flow against the upper bed underside, and gravitated shale is collected in a residue bed in the lower zone that is allowed to gravitate relatively rapidly through an outlet opening from the lower zone or the residue shale may be removed through a mechanical grate. The later bed may also have an underside exposed at said opening, and at least some of the retort gas is supplied by flowing sufficient thereof upwardly against the underside of the residue bed to control shale gravitation to the desired rate, the oxygen containing gas, most conveniently air, being preheated in its upward flow through the residue bed to the open combustion zone. Normally, more air will be required than fuel gas, and some of the air, referred to as "grate" air, is therefore preferably passed upwardly through the outlet to control residue shale gravitation, the remaining air called "plenum air" also being delivered to the residue shale bed through a plenum chamber, for preheating purposes. In addition, fuel gas, air, steam or other fluids may be introduced into the open combustion zone or fuel gas, steam or other fluids may be introduced with the air either through the grate or plenum.

One particular and advantageously simple retorting apparatus that is accommodated to the present process essentially comprises shell means forming upper, lower and intermediate zones in open vertical communication, the lower zone having a downwardly opening outlet which, together with the intermediate zone are constricted in relation to the maximum sizes of the upper and lower zones, the latter funneling downwardly toward the constrictions. The purpose for this shell construction is to cause the shale to form bridges just above the constricted areas when gas of sufficient velocity flows upwardly through the constrictions and against the shale bed undersides to interrupt gravitation thereof. Periodic collapse of the upper bed bridge is then effectuable by reducing the gas upward flow, as by reducing the "plenum air" supplied to the lower shale bed into which the upper bed then freely gravitates while the lower bed is restrained

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from freely gravitating through the downward outlet by "grate" air flow upwardly therethrough. The lower constriction or outlet is preferably, though not necessarily, of smaller size than the upper constriction, so that the residue shale will be prevented from gravitation when the shale from the upper bed drops onto the lower bed or the residue shale can be prevented from gravitation by a mechanical grate. And, the invention contemplates the use of controllable air or gas valve means to vary the flow upwardly through the residue bed to thereby control discharge of both upper and lower beds, the valve means being controllable, for example, in response to changes in the temperature of the gas stream effluent from the retort upper zone.

These and other features and objects of the invention, as well as the details of an illustrative embodiment, will be more fully understood from the following detailed description of the drawings, in which:

Fig. 1 is a flow diagram illustrating the manner in which oil shale is processed according to the invention;

Fig. 2 is a full elevation illustrating in perspective and with certain sections broken away showing the shale retorting apparatus;

Fig. 3 is a view taken on line 3—3 of Fig. 2;

Fig. 4 is a section taken on line 4—4 of Fig. 2;

Fig. 5 is a section taken on line 5—5 of Fig. 2;

Fig. 6 is a fragmentary elevation in section taken through a modified retort, and

Fig. 7 is a section taken on line 7—7 of Fig. 6.

Referring first to Figs. 1 and 2 the retorting apparatus is schematically and mechanically shown generally at 10 to include a vertically elongated inner shell generally indicated at 11 resting on three vertical column supports 12. From top to bottom the inner shell includes an upper cylindrical portion 13 the top 14 of which is closed, a converging section 15 funneling downward toward a shell constriction 16, a diverging section 17 tapering downwardly and outwardly; a second cylindrical shell section 18 joined to the diverging section, a second converging section 19 continuing downward from cylindrical section 18 and funneling toward a second constricted shell portion 20 forming an outlet 21, and finally a diverging scoop 22 below the constricted section 20. Shell sections 13 and 15 form an upper zone within which a bed of shale 23 is subjected to distillation by hot gases rising upwardly through the bed and exiting via the outlet 24, the hot gases being somewhat cooled in the upper regions of the upper zone. The gases detach themselves from the shale bed and rise upwardly and annularly into the annular chamber 25 formed between the shell section 13 and an inner cylindrical sleeve 26 arranged concentrically with respect to the shell, the sleeve confining shale particles introduced through inlet 27 into the upper zone of the retort, as indicated.

Shell sections 18 and 19 form a lower zone within which a bed of residue shale indicated at 28 is confined for preheating air or other gas flowing upwardly therethrough and within which the temperature of the preheated gases is raised from 700° F. to 2200° F. but more generally 1000° to 1800° F. primarily from burning the organic residue remaining on the shale in zone 28. This organic residue is chiefly carbon in a reactive state which will burn readily. Essentially all of the oxygen will be consumed in passing through zone 28. Additional heating can be accomplished, although it is not expected that it will normally be required, and by the introduction of fuel gas from line 30 into the annular manifold 31 and thence through the ports 32 into the combustion zone 29 for mixing with an oxygen containing gas also introduced into zone 29 and combustion therein. Quench gas can also be introduced into zone 29. Since zone 29 is open the gases mix thoroughly and reach thermal equilibrium as they flow upwardly. As mentioned in the introduction, the upward velocity of the gases and the volumetric rate of flow thereof is sufficient, considering the cross

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sectional area of the constricted zone 29, the slope of the funnel section 15, and the sizes of the shale particles in the upper bed, that the gases exert a lifting force holding or otherwise restraining the upper shale bed against freely gravitating downwardly through the combustion zone into the lower zone.

The main quantity of air flow upwardly through the lower residue shale bed 28, referred to as "grate air" is introduced upwardly through the scoop 22 and into the constricted outlet 21 at the lower end of the shell 11 so as to exert force against the exposed underside 35 of the residue shale bed, holding or otherwise restraining that bed against free gravitation downwardly through the outlet into a receiver shell 36. The latter includes an upper diverging shell section 37 annularly surrounding the scoop 22 and shell section 20, cylindrical section 38, and a converging end funneling section 39 the lower end of which connecting with an air lock outlet tube 40. The latter prevents downward escape of grate air introduced to the receiver vessel through inlet tube 41, while permitting downward escape of discharged shale residue through the outlet 40.

The remainder or minor portion volumetrically of air introduced to the residue shale bed 28 flows into a plenum chamber 42 through an inlet tube 43, chamber 42 surrounding the shell funnel section 19, the constricted shell section 20, the scoop 22 and also the receiver shell diverging section 37 which is attached to the shell constricted section 20 to prevent mixing of "grate air" with plenum air. Chamber 42 is closed except for a lower outlet 44 from which shale dust escapes through an appropriate air lock 44. Shale dust enters the plenum chamber through the slots 45 arranged circularly around the vertical axis of the main shell tapered section 19 and passing air from the plenum chamber to the shale residue bed 28. Of course, the slots have widths less than the minimum size of shale particles in the bed 28 to prevent discharge thereof into the plenum chamber. It will be seen from the above discussion that both "grate air" and "plenum air" are caused to flow upwardly throughout the residue shale bed where burning of the organic residue takes place and thence into the constricted combustion zone 29, and that only the flow of grate air controls gravitation of the shale residue bed through the outlet 21. While certain arrangements for controlling the removal of residue shale from zone 28 have been described it will be understood that any suitable mechanical grate may be used in lieu of the constricted shell section 20, so long as it accomplishes removal of residue shale necessary to the cycle of retort operation contemplated by the invention.

Cooling of the retort may for example be accomplished by flow of air at 47 into the annular bottom opening between the shell cylindrical section 18 and the cylindrical apron 48 closely spaced outwardly from the shell. Having entered the space 49 formed therebetween, the air flows upwardly in cooling relation to the retorting shell between circularly spaced fins 50 indicated in Fig. 3. Cooling air is vented at 51 after having traversed the outsides of the shell sections 18, 17, 15 and 13, in cooling relation therewith. On the other hand, the shell may be suitably insulated with a refractory lining.

Referring specifically to Fig. 1, shale to be processed is introduced at 52 to an elevator 53 which lifts the shale and discharges it to a hopper 54 from which the shale in a continuous stream is fed via the inlet tube 27 to the upper bed in the retort. The shale, typically but not necessarily of a particle size $\frac{3}{8}$ inch to 3 inches, is delivered in batches and in timed relation to batchwise downward flow in the retort, so that during gravitation of the upper shale bed 23 into the lower zone in the retort a new batch of shale from the hopper 54 will gravitate into the upper zone within shell section 13.

Hydrocarbons removed from the shale in the effluent gaseous stream are passed through the outlet 24 to an

appropriate oil recovery system indicated by a separator 55 from which separated oil is removed at 56 and gas is taken at 57. Only one stage of separation is indicated, a more detailed manner of separating the oil and gas fractions being discussed in the Reeves Patent No. 2,757,129, mentioned in the introduction. Gases removed at 57 may be recycled at 58 to supply all or a portion of the fuel that may be introduced through lines 30, 41 or 43 to the combustion zone, to improve the thermal efficiency of the process. Steam recycle gas or an inert gas may also be introduced via piping 59 to the combustion zone for controlling the temperature therein as by quenching the hotter combustion gases to the desired temperature.

Referring now to Fig. 1 and the delivery of air to the retort, 60 indicates a blower discharging through a regulator valve 61 maintaining the downstream pressure for example at 62 at a constant value. From valve 61 the air branches in two streams at 63 and 64 for flow to inlet tubes 41 and 43 respectively in separate streams as grate air and plenum air, valves 65 and 66 controlling the flow of air streams 63 and 64. Normally valve 65 will be open sufficiently to pass the main quantity of air to the retort, while valve 66 will be periodically closed and opened to shut off and reestablish supplementary air flow to the plenum chamber for introduction to the lower bed of shale at 28. For this purpose, valve 66 may be closed in response to actuation of a temperature control shown at 68 as being operative by changes in the temperatures of the effluent gas stream at 24. Valve 66 may also have a suitable timer control to maintain it shut for a short interval after which valve 66 is opened by compressed air to re-establish flow of supplementary air to the retort. In addition, a suitable ratio control indicated at 69 is adapted to control valves 65 and 66 in their open condition to maintain a preset flow ratio. Another air line 70 connecting into line 64 at 71 downstream of valve 66 is adapted to vent air from the plenum chamber when valve 66 is closed, valve 72 in line 70 at that time being at least partially open. Under these conditions a portion of the air supplied through line 41 to the retort flows upwardly through the opening 21 and then back out through the shell opening 45 into the plenum chamber 42 and exhausts through lines 43 and 70 to the exterior. While certain valve arrangements for controlling air delivery to the retort have been described it will be understood that any suitable valve arrangements may be used, so long as they accomplish air and gas delivery necessary to the cycle of retort operation contemplated by the invention.

Referring now to a typical cycle of operation of the retorting apparatus, it will first be assumed that beds of shale 23 and 28 are respectively located in the retort, the upper bed being subjected to distillation by hot gases flowing upwardly therein, and the lower bed of coking or residue shale serving to preheat the plenum air and grate air flowing upwardly therein primarily by the combustion of the carbon laid down on the residue shale. When, for example, the temperature of the effluent gas at 24 has risen to a preset value, caused by upward travel or displacement of the temperature gradient in upper zone 23, valve 66 is at least partially closed and valve 72 at least partially opened, causing a reduction in air supply through the plenum to the combustion zone 29. This reduction is sufficient to cause collapse of the bridge of shale particles in the upper bed extending as at 33 across and above the constricted zone 29, following which the upper bed of shale freely gravitates into the lower zone. At the time this bridge collapses, the grate air flow is held constant holding the shale in the lower zone. As soon as the shale in the upper zone starts to gravitate into the lower zone, additional shale from hopper 54 above the retort flows into the upper zone, keeping the latter full of shale. The amount of shale gravitation

into constricted zone 29 is that amount necessary to fill that zone.

As soon as the upper transport is completed, and zone 29 is filled with shale, the lower transport of shale from zone 28 into hopper 39 is begun by diverting part of the grate air supply through the plenum while maintaining a total gas flow constant and sufficient at zone 29 to cause bridging of the shale at 33. Such a procedure results in reduced gas flow upwardly at 21 causing the lower bridge 35 to collapse, and at the same time gas flow upwardly in zone 29 causes the bridge to reform at 33. As soon as escaping residue shale fills hopper 39, grate air flow is returned to normal, re-establishing the bridge at 35 after the residue in hopper 39 is withdrawn at 40 by any suitable means.

As pointed out in the introduction, such control of the shale flow by gas pressure alone makes possible the elimination of mechanical gas distributors within the column of shale being treated, with corresponding elimination of operating difficulties associated with such distributors.

The shale transport time represents only a small fraction of the total cycle time. All transport is as rapid as possible. The volume of hopper 39 is sized so that when shale in zone 28 drops into the hopper, it always opens up the desired volume in constricted zone 29.

The retorting zone moves up from 33 towards the top of the retort; however, it never goes over a fraction of the distance before the transport part of the cycle is repeated. In other words, the volume of the upper zone 23 is several times the volume of the normally open zone 29. The upper part of the upper zone 23 is used to quench the gas and to preheat the green shale. The lower zone 28 serves to preheat the air and, in addition, the lower part of this zone is used to cool the spent shale. Most of the heat for the retorting comes from the combustion of the carbon laid down on the shale during retorting and not from sensible heat transfer.

Also as mentioned in the introduction, fuel or recycled gas may be introduced as for example through valve 82 to line 62 for subsequent delivery to the outlet opening 21 and to the openings 45 in the shell or it may be so arrayed that recycle gas is introduced either through 41 or 43 but not both. Also, air or fuel gas may be introduced through valves 83 and 84 to line 30 for passage to the combustion zone. Thus, the air and combustion gas streams may be switched, although it is preferred to operate the retort as described at length above.

Typical operating conditions for the suspending of a bed of shale particles in a conical vessel and bridging a 10 inch discharge throat from the cone are as follows:

Mean shale diameter	0.88 inch.
Pressure drop across bed	0.43 p.s.i.
Bed depth	35 inches.
Critical air flow rate	505 c.f.m. at 85° F.
Velocity at throat	15.5 feet per second.

For larger capacity commercial retorts, a rugged solid bar or multiple bars can be firmly mounted to the shell to extend across the constricted zone 29, thereby creating multiple outlets through which the shale may flow downwardly. This arrangement will aid in supporting the bed of shale and will permit the same excellent gas distribution that is possible in the smaller throat size since for either arrangement, the transition from the constricted zone diameter to the maximum shell diameter is gradual and the rock filled chamber serves as an excellent distributing device.

Referring now to Figs. 6 and 7, a retort throat 85 or constriction is indicated within the shell 86. The constricted area is traversed by a transverse bar 88 extending across the throat area so as to form a central support for the bed of shale 89 suspended thereabove by sufficient flow of air upwardly thereagainst as indicated by the

arrows 90. Bar 88 can be hollow for passing a coolant therethrough, if required, as indicated in Fig. 7.

It will be understood that the invention may be practiced in connection with the destructive distillation of hydrocarbonaceous materials other than oil shale, such as lignite, coal, peat, etc.

I claim:

1. In the process of recovering hydrocarbons from a bed of hot flowable solid hydrocarbonaceous material in an upper zone openly exposed to a lower zone, the steps that include flowing sufficient gas upwardly against the exposed underside of the bed and upwardly within said bed so as to restrain material gravitation into said lower zone while hydrocarbons are being removed from the material in the hot upwardly flowing gas, and thereafter reducing said upward gas flow against said bed underside to allow relatively rapid gravitation of the material into said lower zone.

2. In the process of recovering hydrocarbons from a bed of hot flowable shale in an upper zone openly exposed to a lower zone, the steps that include flowing sufficient gas upwardly against the exposed underside of the shale bed and upwardly within said bed so as to restrain shale gravitation into said lower zone while shale hydrocarbons are being removed in the hot upwardly flowing gas, and thereafter reducing said upward gas flow against said bed underside to allow relatively rapid gravitation of shale into said lower zone.

3. In the process of recovering hydrocarbons from a bed of hot flowable shale in an upper zone openly exposed to a lower zone, the steps that include flowing sufficient gas upwardly against substantially the entire exposed under side of the shale bed and upwardly within said bed so as to restrain shale gravitation into said lower zone while shale hydrocarbons are being removed in the hot upwardly flowing gas, and periodically reducing said upward gas flow against said bed under side to allow periodic relatively rapid gravitation of shale into said lower zone.

4. In the process of recovering hydrocarbons from a bed of hot flowable shale in an upper zone openly exposed to a lower zone, the steps that include flowing sufficient gas upwardly against substantially the entire exposed under side of the shale bed and upwardly within said bed so as to restrain shale gravitation into said lower zone while shale hydrocarbons are being removed in the hot upwardly flowing gas, and periodically reducing and increasing said upward gas flow against said bed under side to allow periodic relatively rapid gravitation of shale into and at least partly filling said lower zone.

5. In the process of recovering hydrocarbons from a bed of hot flowable shale in an upper zone openly exposed to a lower zone, the steps that include flowing sufficient air upwardly against substantially the entire exposed under side of the shale bed and upwardly within said bed so as to restrain shale gravitation into said lower zone while shale hydrocarbons are being removed in the hot upwardly flowing air, and periodically reducing and increasing said upward air flow against said bed under side to allow periodic relatively rapid gravitation of shale into and at least partly filling said lower zone.

6. In the process of recovering hydrocarbons from a bed of hot flowable shale in an upper zone openly exposed to lower zone, the steps that include flowing sufficient gas upwardly against the exposed under side of the shale bed and then upwardly within said bed so as to prevent shale gravitation into said lower zone while shale hydrocarbons are being removed in the hot upwardly flowing gas, periodically reducing and increasing said upward gas flow against said bed underside to allow periodic relatively rapid gravitation of hot shale residue into said lower zone, supplying at least some of said gas upwardly through said lower zone, and maintaining sufficient of said hot shale residue in said lower zone to

pre-heat at least some of said gas flowing upwardly therein.

7. In the process of recovering hydrocarbons from a bed of hot flowable shale in an upper zone, openly exposed to a lower zone, the steps that include flowing sufficient gas upwardly against the exposed underside of the shale bed and then upwardly within said bed so as to prevent shale gravitation into said lower zone while shale hydrocarbons are being removed in the hot upwardly flowing gas, periodically reducing and increasing said upward gas flow against said bed underside to allow periodic relatively rapid gravitation of hot shale residue into said lower zone, supplying at least some of said gas upwardly through said lower zone so as to preheat said upwardly flowing gas, and periodically removing said hot shale residue from said lower zone.

8. In the process of recovering hydrocarbons from a bed of hot flowable shale in an upper zone openly exposed to a lower zone, the steps that include flowing sufficient gas upwardly within the exposed underside of the shale bed and then upwardly within said bed so as to restrain shale gravitation into said lower zone while shale hydrocarbons are being removed in the hot upwardly flowing gas, periodically reducing and increasing said upward gas flow against said shale bed underside to allow periodic relatively rapid gravitation of hot shale residue into said lower zone, supplying at least some of said gas upwardly through said lower zone, maintaining a bed of said hot residue shale in said lower zone in the path of said upward gas flow to preheat said flow, and periodically removing said residue bed from said lower zone.

9. In the process of recovering hydrocarbons from a bed of hot flowable shale in an upper zone openly exposed to a lower zone, the steps that include flowing sufficient gas upwardly against the exposed underside of the shale bed and then upwardly within said bed so as to restrain shale gravitation into said lower zone while shale hydrocarbons are being removed in the hot upwardly flowing gas, periodically reducing and increasing said upward gas flow, against said bed underside to allow periodic relatively rapid gravitation of hot shale residue into said lower zone, maintaining a residue shale bed in said lower zone having an exposed underside, and supplying at least some of said gas by flowing sufficient thereof upwardly against the exposed underside of said residue bed to restrain shale gravitation therefrom.

10. In the process of recovering hydrocarbons from a bed of hot flowable shale in an upper zone openly exposed to a lower zone, the steps that include flowing sufficient gas upwardly against the exposed underside of the shale bed and then upwardly within said bed so as to restrain shale gravitation into said lower zone while shale hydrocarbons are being removed in the hot upwardly flowing gas, periodically reducing and increasing said upward gas flow against said bed underside to allow periodic relatively rapid gravitation of hot shale residue into said lower zone, maintaining a residue shale bed in said lower zone having an exposed underside, and supplying at least some of said gas by flowing sufficient air upwardly against the exposed underside of said residue bed to restrain shale gravitation therefrom.

11. In the process of recovering hydrocarbons from a bed of hot flowable shale in an upper zone openly exposed to a lower zone through an intermediate combustion zone therebetween, said lower zone containing a bed of residue shale the underside of which is exposed to a downward outlet from said lower zone, the steps that include flowing sufficient gas upwardly against the exposed undersides of the shale beds and then upwardly within said beds to restrain shale gravitation from said upper and lower zones while shale hydrocarbons are being removed from the upper bed in the hot upwardly flowing gas, periodically reducing and

increasing said upward gas flow against said upper bed underside to allow periodic relatively rapid gravitation of hot shale residue into said lower zones thereby increasing the depth of said bed of residue shale, and periodically reducing and increasing said upward gas flow against said lower bed underside to allow periodic relatively rapid gravitation of hot shale residue from said lower zone through said outlet.

12. The method of claim 11 comprising flowing gas upwardly through said outlet against the exposed underside of said residue bed to restrain shale gravitation through said outlet thereby maintaining said residue bed, supplying a second stream portion of said gas to said residue shale bed at a location spaced from said outlet, and combining said first and second streams for upward flow against the exposed underside of said upper shale bed.

13. The method of claim 12 comprising periodically reducing and increasing the flow of both of said first and second gaseous streams.

14. The method of claim 13 comprising periodically reducing and increasing the flow of said gaseous streams in alternate relation.

15. The method of claim 13 comprising supplying air in both of said streams.

16. The method of claim 13 comprising supplying air in said first and second streams and combustible gas in a third stream, and introducing said third stream directly into said combustion zone.

17. The method of claim 15 including withdrawing gaseous effluent from said upper zone, treating said effluent to separate oil from the withdrawn gas, and recycling said withdrawn gas to said combustion zone.

18. The method of claim 16 comprising periodically reducing and increasing the flow of air in said first and second streams in alternate relation.

19. The method of claim 12 comprising flowing all of said gas upwardly at increased velocity through a constricted portion of said combustion zone and against the exposed underside of the upper shale bed bridging said constriction.

20. In a hydrocarbon recovery system, shell means forming upper and lower zones in open intercommunication, a flowable bed of hot hydrocarbon containing shale in said upper zone having its underside exposed to said lower zone, means flowing sufficient gas into said shell means that said gas flows upwardly against the exposed underside of the shale bed and flows upwardly within said bed restraining shale gravitation into said lower zone while shale hydrocarbons are being removed in the hot upwardly flowing gas, and means for reducing the gas flow to allow relatively rapid gravitation of shale residue into said lower zone.

21. In a hydrocarbon recovery system; shell means forming upper and lower zones in open intercommunication, said lower zone having a downward opening outlet, a flowable bed of hot hydrocarbon containing shale in said upper zone having its underside exposed to said lower zone, means flowing sufficient gas into said shell means that said gas flows upwardly against the exposed underside of said shale bed and flows upwardly therein restraining shale gravitation into said lower zone while shale hydrocarbons are being removed in the hot gas flowing upwardly in said upper zone, and means for periodically reducing and increasing the gas flow to allow periodic relatively rapid gravitation of shale into said lower zone.

22. In a hydrocarbon recovery system, shell means forming upper, lower and intermediate zones in open communication, said lower zone having a downward opening outlet, a flowable bed of hot hydrocarbon containing shale in said upper zone having its underside exposed to said intermediate and lower zones, a flowable bed of hot shale residue in said lower zone having its underside exposed to said outlet, means flowing sufficient gas upward-

ly through said outlet and into said intermediate zone that said gas flows upwardly against the exposed undersides of said shale beds and flows upwardly therein restraining shale gravitation from said zones while shale hydrocarbons are being removed in the hot gas flowing upwardly in said upper zone, and means for periodically reducing and increasing the gas flow to allow periodic relatively rapid gravitation of shale residue into said lower zone.

23. In a hydrocarbon recovery system, shell means forming upper, lower and intermediate zones in open intercommunication, said lower zone having a downward opening outlet, a flowable bed of hot hydrocarbon containing shale in said upper zone having its underside exposed to said intermediate and lower zones, a flowable bed of hot shale residue in said lower zone having its underside exposed to said outlet, means flowing sufficient gas in separate streams upwardly through said outlet, into said residue bed and into said intermediate zone that said gas streams flow upwardly against the exposed undersides of said shale beds and flow upwardly therein restraining shale gravitation from said zones while shale hydrocarbons are being removed in the hot gas flowing upwardly in said upper zone, and means for periodically reducing and increasing the gas flow to allow periodic batchwise gravitation of shale downwardly through said zones.

24. In a hydrocarbon recovery system, shell means forming upper, lower and intermediate zones in open intercommunication, said lower zone having a downward opening outlet, a flowable bed of hot hydrocarbon containing shale in said upper zone having its underside exposed to said intermediate and lower zones, said intermediate zone being constricted in relation to said upper and lower zones, a flowable bed of hot shale residue in said lower zone having its underside exposed to said outlet, means flowing sufficient gas in separate streams upwardly through said outlet, into said residue bed and into said intermediate zone that said gas streams flow upwardly against the exposed undersides of said shale beds and flow upwardly therein restraining shale gravitation from said zones while shale hydrocarbons are being removed in the hot gas flowing upwardly in said upper zone, and means for periodically reducing and increasing the gas flow to allow periodic batchwise gravitation of shale downwardly through said zones.

25. In a hydrocarbon recovery system, shell means forming upper, lower and intermediate zones in open intercommunication, said lower zone having a downward opening outlet, a flowable bed of hot hydrocarbon containing shale in said upper zone having its underside exposed to said intermediate and lower zones, means extending across said intermediate zone and supporting a portion of said bed underside, a flowable bed of hot shale residue in said lower zone having its underside exposed to said outlet, means flowing sufficient gas in separate streams upwardly through said outlet, into said residue bed and into said intermediate zone that said gas streams flow upwardly against the exposed undersides of said shale beds and flow upwardly therein restraining shale gravitation from said zones while shale hydrocarbons are being removed in the hot gas flowing upwardly in said upper zone, and means for periodically reducing and increasing the gas flow to allow periodic relatively rapid gravitation of shale from said upper and lower zones.

26. The invention as defined in claim 23 in which said gas flowing means include ducts flowing air and combustible gas in separate streams.

27. The invention as defined in claim 23 comprising ducts flowing air upwardly through said outlet and into said residue bed and flowing combustible gas ducts into said intermediate zone.

28. The invention as defined in claim 27 in which said means for reducing and increasing the gas flow includes a valve controlling the flow of air to said residue bed,

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29. The invention as defined in claim 27 including means for withdrawing gaseous effluent from said upper zone and treating said effluent to separate oil from the withdrawn gas, and means for recycling said withdrawn gas to intermediate zone.

30. Shale retorting apparatus, comprising means including a shell forming upper, intermediate and lower zones in open intercommunication and through which a bed of shale in said upper zone is freely downwardly flowable, said intermediate zone being constricted in relation to said upper zones whereby said means is adapted to partially support said shale bed, means for flowing sufficient gas into said shell means that said gas is adapted to flow upwardly through said intermediate zone against the exposed underside of the shale bed and thereafter to flow upwardly within said bed restraining shale gravitation into said lower zone while shale hydrocarbons are being removed in the hot upwardly flowing gas, and means for periodically reducing and increasing the gas flow to allow relatively rapid gravitation of shale residue into said lower zone.

31. Shale retorting apparatus, comprising means including a shell forming upper, intermediate and lower

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zones in open communication and through which beds of shale and shale residue respectively in said upper and lower zones are freely downwardly flowable, said lower zone having a downward opening outlet and said intermediate zone and outlet being constricted in relation to said upper and lower zones respectively whereby said shale and residue beds are partially supportable by said means, means for flowing sufficient gas in separate streams upwardly through said outlet, into said lower zone and into said intermediate zone that said gas streams are adapted to flow upwardly against the exposed undersides of said shale beds and upwardly within said beds restraining shale gravitation from said zones while shale hydrocarbons are being removed in the hot gas flowing upwardly in said upper zone, and means for periodically reducing and increasing the gas flow to allow relatively rapid gravitation of shale residue into said lower zone.

32. The invention as defined in claim 31, including an elongated support extending transversely within said intermediate zone.

No references cited.