Dec. 16, 1952 C. E. LESHER 2,622,059

LOW-TEMPERATURE CARBONIZATION OF COAL

Filed Feb. 28, 1948 2 SHEETS—SHEET 1

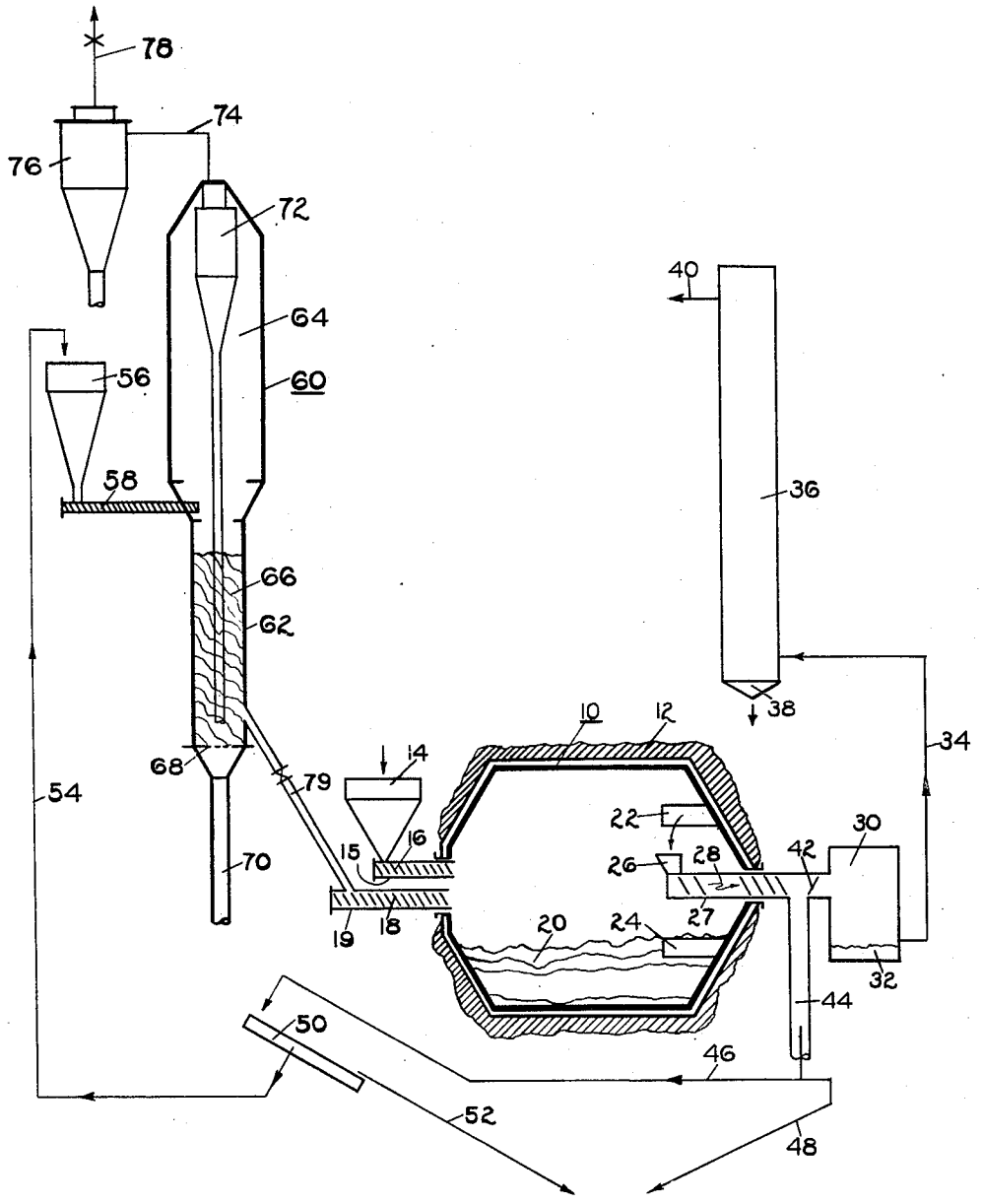


Figure 1

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LOW-TEMPERATURE CARBONIZATION OF COAL

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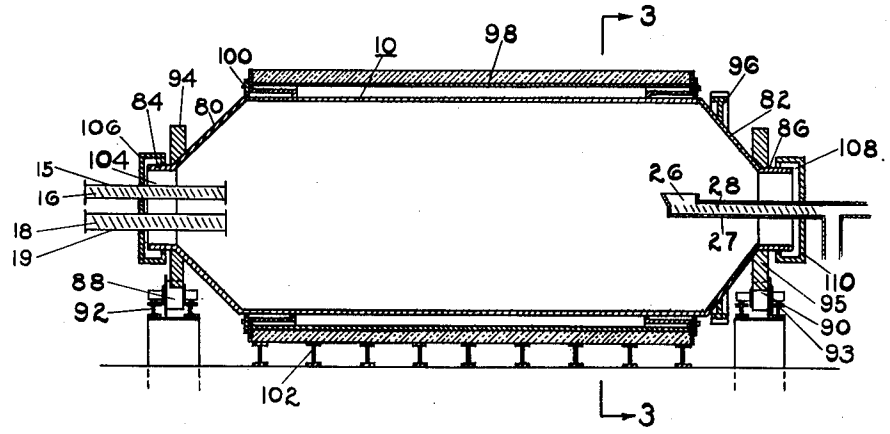


Figure 2

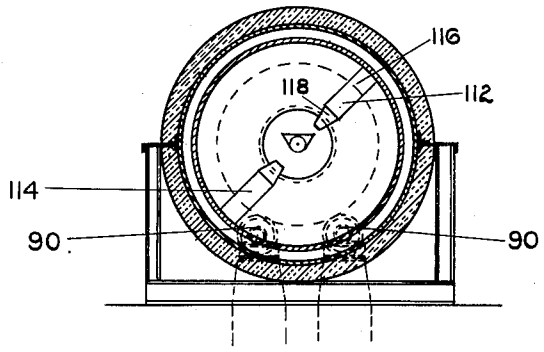


Figure 3

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Patented Dec. 16, 1952

2,622,059

UNITED STATES PATENT OFFICE

2,622,059

LOW-TEMPERATURE CARBONIZATION OF COAL

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Application February 28, 1948, Serial No. 11,964

4 Claims. (Cl. 202—9)

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This invention relates to the distillation of carbonaceous materials and, more particularly, to the distillation of distillable carbonaceous solids such as bituminous coal, lignite and oil shale.

The primary object of the present invention is to provide a process and an apparatus for continuously distilling carbonaceous solids.

Another object of the present invention is to provide a process and an apparatus for the distillation of carbonaceous solids to continuously produce a solid product and a maximum yield of volatile products at a high throughput rate of carbonaceous solids.

A further object of the present invention is to provide a process and apparatus for continuously producing from distillable bituminous coals or lignites a granular carbonaceous product within the approximate size range of the coal or lignite charge and substantially free of lumps of coke.

In accordance with my invention, the above objects are attained by the use of a two vessel system. One vessel serves as a preheating zone for raising the temperature of finely divided previously distilled carbonaceous material to a temperature sufficiently high to distill the material being treated. The second vessel is the distillation zone and comprises a substantially cylindrical horizontal retort which is mounted for rotation about its central longitudinal axis.

In operation, hot distillation residue from the heating zone and finely divided undistilled carbonaceous solids are separately charged into one end of the rotating retort in such proportions that the average temperature of the solids in the retort is within the distillation range of the carbonaceous solids. The rotation of the retort produces intimate mixing of the hot distillation residue and distillable solids whereby distillation of the latter takes place. Solid distillation residue is continuously removed from the opposite and outlet end of the retort, thereby causing progressive and continuous movement of solids through the retort. The volatile products are also continuously removed through the same outlet end of the retort. To complete the cycle a portion of the distillation residue is returned to the heating zone.

I have found that the size of the distillation residue removed from the distillation zone in the retort does not differ appreciably in size from that being charged to the retort in the hot condition. This means that the hot distillation residue from the retort can be recirculated directly to the heater without substantial loss of heat since little or nothing has to be done to it to place it in condition for continued use in the system.

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In the preferred embodiment of this invention, the preheating zone, as distinguished from the distillation zone, comprises a fluidized bed of granular distillation residue with the fluid condition being maintained by oxygen or an oxygen bearing gas. The entire bed of granular carbonaceous solids is thereby uniformly raised to the desired temperature by combustion of a part thereof. I have found that the granular distillation residue produced in the rotating retort is eminently adapted to being fluidized. The use of the fluidized bed to effect heating of the distillation residue in combination with distillation of the distillable carbonaceous solids by direct contact with the hot distillation residue results in the maximum utilization of heat in the system.

The operation of the above two vessel system on bituminous solids such as high volatile Pittsburgh seam coal which is a coking coal, produces continuously a high yield of liquid tar rich in tar acids, a substantial quantity of high B. t. u. gas, and a granular loose char which is suitable for a number of uses including that as solid boiler fuel. Furthermore, the production capacity of the system has been found to considerably exceed expectations and to be greatly superior to any heretofore proposed to the best of my knowledge.

Other details, objects and advantages of the invention will become apparent upon reference to the following description of a preferred embodiment thereof.

In the accompanying drawings I have shown apparatus by the use of which the invention may be practiced and have illustrated a present preferred method of practicing the invention, in which:

Figure 1 is a diagrammatic showing of the apparatus in which the invention may be practiced;

Figure 2 is a central longitudinal cross-sectional view of a portion of the apparatus illustrated in Figure 1;

Figure 3 is a vertical transverse cross-sectional view taken on the line 3—3 of Figure 2.

Referring to Figure 1 of the drawings, a flow sheet of a preferred embodiment of the invention is shown. Numeral 10 designates a substantially cylindrical horizontal retort which is mounted for rotation about its central longitudinal axis. This retort is provided with a layer of insulating material 12. A hopper 14 serves to hold distillable carbonaceous solids which are conveyed to the interior of the retort 10 through a conduit 15 by means of a variable screw feeder 16. Another variable screw feeder 18 located adjacent to feed-

er 16 is adapted to introduce hot carbonaceous distillation residue in granular form through a conduit 19 into the retort 10 wherein a bed 20 of solids of substantially constant level is maintained by means of lifters 22 and 24. The latter upon rotation of the retort 10 pick up solids from the bed 20 and drop them into a hopper 26 from which the solids are conveyed out of the retort through a conduit 27 by means of a screw feeder 28. A more detailed description of the retort 10 will be given later in connection with Figures 2 and 3.

The volatile products produced within the retort 10 leave the retort through the conduit 27 and are conducted to a dust chamber 30 which is provided with water 32 for the collection of dust. From this chamber the gas is carried through conduit 34 to a spray scrubber 36 where condensation of any condensable vapors takes place. Liquid condensate is removed through the bottom 38 of the scrubber while the non-condensable gas product leaves the scrubber at the top through conduit 40.

The solid products from the rotating retort 10 are prevented from entering the dust chamber 30 by means of a guard 42 and are forced to pass through discharge conduit 44. This discharge conduit is divided into two conduits 46 and 48. The latter leads to product storage while the former serves to recirculate a portion of the distillation residue in the system. In order to insure that the size of the solid distillation residue is kept below a certain size it is passed through a screen 50, the oversize particles being conducted by conduit 52 to product storage. The remaining portion of the distillation residue which passes through the screen 50 is carried by conduit 54 to a hopper 56 from which it is fed by means of a variable screw feeder 58 into a preheating vessel 60.

Vessel 60 comprises two sections 62 and 64. The former and lower section serves to hold a bed of granular solids 66 upon a grid element 68 while the latter section serves as a disengaging space. To maintain bed 66 in fluidized condition, gas containing oxygen such as air, is introduced through tube 70 at the bottom of the gas vessel 60. A cyclone 72 is provided for returning the solid fines to the bed while the gaseous product escapes from the vessel through conduit 74 to another cyclone 76 where the separation of gas from solids is substantially completed. The gas is then led to purifying apparatus through conduit 78.

Referring to Figures 2 and 3 of the drawings for detailed views of the rotary retort 10, numbers 80 and 82 designate cone-shaped end sections provided with cylindrical flanges 84 and 86, respectively. The retort is rotatably supported at each end by rollers 88 and 90 which are mounted upon pedestals 92 and 93, respectively. Heavy flanges 94 and 95 are connected to the end portions of the retort and ride upon the rollers 88 and 90, respectively. A ring gear 96 is connected to the retort and is adapted to be driven by a suitable driving pinion (not shown) to cause the retort to rotate. The retort is sealed within a stationary shell 98 which carries insulation 12 by means of packing 100. The entire shell structure is supported on pedestals 102.

The cylindrical flange 84 encloses an opening 104 through which the variable speed screws 16 and 18 extend. A sealing device 106 is provided to seal off the end of the retort. At the opposite end of the rotary retort a cylindrical flange 86 encloses an opening 108 through which the screw feeder 28 disposed in conduit 27 extends. A sealing device 110 serves to seal this end of the retort from the atmosphere.

Within the retort in line with hopper 26 and directly opposed to one another are two lifters 112 and 114 (Figure 3). Each of these comprises a rigid supporting member 116 which is sealed at one end to the inner wall of the cylindrical portion of the retort. This supporting member extends toward the central longitudinal axis of the retort and is attached at its interior end to one edge of a scoop-like member 118, the other edge of the member 118 being attached to the cone-shaped section 82. The lifters are arranged so that their scoop portions are in line with the hopper 26 and are shaped in such a manner as to release their contents into the hopper as they traverse their paths above the hopper.

In the preferred operation of my two vessel system as applied, for example, to high volatile Pittsburgh seam coal which as previously stated, is a coking coal, the raw materials are finely divided coal and air with possibly a small amount of steam. The retort 10 is first charged with finely divided previously distilled coal (preferably −0 to +4 mesh) which has been uniformly raised by suitable means to a distillation temperature for starting purposes only. The temperature is preferably in the range 800 to 1000° F. Finely divided previously distilled coal is also charged to the preheating vessel 60 and is raised to a temperature substantially above that to be maintained in the retort and in general is in the range 1000 to 1400° F. but may be less depending upon the temperature to be maintained in the retort. The heat required in the vessel 60 is preferably created by passing air or oxygen up through the bed of granular carbonaceous solids 66 whereby partial combustion takes place and heat is evolved. This heat is immediately and uniformly conducted throughout the entire bed.

The operation of the fluidization vessel to produce a fluidized condition is well known in the art. The velocity of the air, the depth of the bed, etc. are factors which can be readily determined. Because of the fluid condition of the bed, the granular solids therein contained are maintained at a uniform temperature. The gaseous products of combustion are separated from fines in the disengaging chamber 64 by means of a cyclone 72. Further separation is obtained by means of cyclone 76. The gas so produced is a low B. t. u. gas useful for certain limited purposes. If so desired, steam may be used in conjunction with the air to produce a fluidized condition in the vessel 60. The composition of the resulting gas is accordingly changed to some extent. While the use of a fluidized heating zone is preferred in practicing the present invention, other heating devices which are adapted to heat granular solids uniformly throughout may be employed, for example, rabbled hearths or rotating kilns.

Hot distillation residue from vessel 60 is conducted to the retort 10 through conduits 79 and 19 by means of the variable speed screw 18. Concurrently with the introduction of this residue a stream of finely divided coal is introduced from hopper 14. Both the coal and the distillation residue are substantially within the same size range i. e. −0 to +4 mesh. The two streams of solids are intimately mixed in the retort by

the rotation of the retort. At the inlet end of the retort the solids have their maximum difference in temperature with the result that distillation of the coal is rapid and effective and the transition of the coal through the plastic stage to a dry state is rapid. Little or no agglomeration of the coal takes place.

The vaporous products are immediately withdrawn from the upper half of the retort through the hopper **26** and out through conduit **27**. Concurrently with the removal of the vaporous products the bed of solids in the rotating retort is maintained at a substantially constant level by means of lifters **22** and **24** which pick up dry granular solids from the opposite end of the retort and drop it into the hopper **26**. This continuous withdrawal of granular solids results in a continuous and progressive movement of the solids from the inlet to the outlet end. The time within the retort is adjusted by varying the total input of solids into the retort as can be readily understood. For instance, it has been found that with the preheater at 1200° F. and a distillation temperature of 900° F. in the retort, the time required to distill Pittsburgh seam coil, less than ¼ inch size, within the retort by the present process is from fifteen to twenty minutes.

The temperature maintained in the retort is controlled by adjusting the relative proportions of coal and granular distillation residue introduced by the variable screw feeders **16** and **18** as well as by adjusting the temperature of the heated distillation residue before its introduction into the retort. If desired, the coal charge can be preheated up to a point just below that at which it begins to give off hydrocarbon vapors before being charged to the retort. The temperature differential between the distillation residue being fed to the retort and the average distillation temperature within the retort may be as low as 50° F. In adjusting the ratio of the proportion of the Pittsburgh seam coal to that of its distillation residue being charged to the retort, to avoid agglomeration I have found it neecssary to keep the ratio less than 1 to 3 by weight.

The vaporous products from the carbonizer are at least partially freed of dust in the dust chamber **30** in the conventional manner and from there are passed through a scrubber or condensing chamber **36** where the tar portion of the products is condensed out. The non-condensable portion which is high B. t. u. gas is removed from the top through conduit **40** to be further purified according to the usual practices.

The solid products from the retort are forced by screw **28** through the discharge conduit **44** where a portion thereof is conducted to product storage through conduit **46**. The size of the distillation residue leaving the retort is in general substantially the same as that of the coal introduced which in itself is a noteworthy discovery as respects strongly coking coal since this solid product can be recirculated for use without further treatment and consequent loss of heat. However, occasionally a small percentage of the char may be above the size desired. This larger size is screened out on screen **50** and conducted to the product storage through conduit **52**. That part which passes through screen **50** is carried by conduit **54** or by any suitable means such as an elevator, screw feeder, pneumatic means, etc. to the hopper **56** from which it is fed to the fluidized vessel **60** by variable screw feeder **58**. The rate of feed of the solids will depend, of course, upon the bed level desired in the lower section **62** of the vessel. The above cycle is then repeated.

The products from the retort are carbonaceous distillation residue, gas, tar, and water vapor. The product from the fluidized preheater is a vent gas.

The solid product produced as the result of the application of my process and apparatus to high volatile Pittsburgh seam coal as described above, is a loose granular solid within substantially the same size range as the coal charged to the process. It is friable, cellular and non-agglomerated in contrast to that produced by other methods from coking coals. If properly controlled, as has been described, with respect to the ratio of preheated material and coking coal charged, the product is substantially free of lumps of coke. Since a large part of this solid product has passed through the preheating zone, this part has a lower volatile content than that part which has passed only through the retort. The volatile content of the latter part is determined by the average temperature within the retort. The difference in volatile content depends on the temperature difference between the preheating zone and the distillation zone and may accordingly be varied if desired. The solid product is suitable for use as solid boiler fuel as well as for many other applications.

The tar product is a fluid and by the above process in the case of the Pittsburgh seam coal, a yield of 26 to 27 gallons per ton of coal is obtained. Its ash content is less than 1% and when distilled up to 300° C. 30% is found to pass over as distillate. Of this distillate approximately 40% represents tar acids.

The gas from the retort when separated from the condensable portion has approximately 800 B. t. u. or more per cu. ft. The yield of such gas is approximately 2000 cu. ft. per ton of coal.

The gaseous product from the fluidized preheater has a B. t. u. content of 75 to 80 and is at a temperature corresponding to that of the fluidizing vessel. About 28,000 cu. ft. of this gas is produced per ton of coal processed.

While the above example described the application of my invention to high volatile Pittsburgh seam coal, it was for purposes of illustration only. The process and apparatus hereinbefore described may be applied to any distillable carbonaceous solids including both coking and non-coking bituminous coal, lignites, oil shales, and the like. In the application to coking coals other than high volatile Pittsburgh seam coal and other than coking oil shales, the preferred proportions of coal or shale and distillation residue charged to the retort may be other than those specified in the above example depending on the particular coking qualities of the coal but these may be readily determined. In the application to non-coking coals, lignites, and non-coking oil shales greater latitude in the adjustment of the proportions of fresh charge and hot distillation residue and also in the selection of the operation temperatures is permitted, since these materials do not agglomerate. In such cases the temperature to which the charge is heated and the temperature of the preheating zone may be as high as it is practical in order to accomplish the desired distillation.

According to the provisions of the patent statutes, I have explained the principle, preferred construction, and mode of operation of my invention and have illustrated and described what I now consider to represent its best em-

bodiment. However, I desire to have it understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically illustrated and described.

I claim:

1. In the method of distilling high volatile Pittsburgh seam coal by contacting said coal directly with hot distillation residue from previously distilled coal in a closed unobstructed substantially cylindrical horizontal retort which is mounted for rotation about its longitudinal central axis, the steps comprising maintaining a granular bed consisting of said distillation residue in said retort in direct contact with the walls of said retort to serve as a barrier between fresh coal and said retort walls, rotating said retort, whereby a rotary movement is imparted to said bed, continuously and separately feeding a stream of said coal in finely divided form and a stream of hot finely divided distillation residue into one end of said retort onto the top of said bed, the mixing of said fresh coal and said hot residue being effected solely by the aforesaid rotary movement of said bed, said hot distillation residue being at a temperature between 1000° and 1400° F. and in such quantity that the average temperature of the total solids in the retort is between 800° and 1000° F., the ratio by weight of coal and distillation residue fed to said retort being less than 1 to 3, distilling the coal by heat supplied from the distillation residue, removing the volatile products from the retort, withdrawing distillation residue from the retort in excess of that required to provide the aforesaid bed of distillation residue in said retort, conducting at least a portion of said withdrawn residue to a preheating zone, circulating a gas containing oxygen gas under fluidizing conditions through said portion in said preheating zone, oxidizing a portion of the solids in the fluidized preheating zone to maintain a temperature in said zone between 1000° and 1400° F., and returning said heated residue to the retort to repeat the above cycle.

2. In the method of distilling high volatile Pittsburgh seam coal by contacting said coal directly with hot distillation residue from previously distilled coal in a closed unobstructed substantially cylindrical horizontal retort which is mounted for rotation about its longitudinal central axis, the steps comprising maintaining a granular bed consisting of said distillation residue in said retort in direct contact with the walls of said retort to serve as a barrier between fresh coal and said retort walls, rotating said retort, whereby a rotary movement is imparted to said bed, continuously and separately feeding a stream of said coal in finely divided form and hot finely divided distillation residue into one end of said retort onto the top of said bed, the mixing of said fresh coal and said hot residue being effected solely by the aforesaid rotary movement of said bed, said hot distillation residue being at a temperature between 1000° and 1400° F. and in such quantity that the average temperature of the total solids in the retort is between 800° and 1000° F., the ratio by weight of coal and distillation residue fed to said retort being less than 1 to 3, distilling the coal by heat supplied by the distillation residue, removing distillation residue from the retort in excess of that required to provide the aforesaid bed of distillation residue in said retort, removing the volatile products from the retort, and returning at least a portion of the distillation residue after heating it to the aforementioned temperature range of 1000° to 1400° F. to the retort to repeat the above cycle.

3. In the method of distilling a highly coking coal by contacting said coal directly with hot distillation residue from previously distilled coal in a closed unobstructed substantially cylindrical horizontal retort which is mounted for rotation about its longitudinal central axis, the steps comprising maintaining a granular bed consisting of said distillation residue in said retort in direct contact with the walls of said retort to serve as a barrier between fresh feed and said retort walls, rotating the retort, whereby a rotary movement is imparted to said bed, continuously and separately feeding a stream of said coal in finely divided form and a stream of hot finely divided distillation residue into one end of said retort onto the top of said bed, the mixing of said fresh coal and said hot residue being effected solely by the aforesaid rotary movement of said bed, said hot distillation residue being at such a temperature and in such quantity that the average temperature of the total solids in the retort is at a distillation temperature of said coal, the ratio by weight of coal and distillation residue fed to said retort being less than 1 to 3, distilling the coal by the sensible heat supplied by the distillation residue, continuously removing solid distillation residue from the opposite end of the retort in excess of that required to maintain the aforesaid bed of distillation residue in said retort, removing the volatile products from the retort, continuously circulating at least a portion of the distillation residue to a combustion zone, circulating a gas containing oxygen gas under fluidizing conditions through a bed of said distillation residue, oxidizing a portion of said solids in said fluidzed bed whereby the entire bed is maintained at a temperature substantialyl higher than that required to effect distillation of said fresh coal, continuously withdrawing a portion of the hot solids from the fluidized bed, and recycling it to the retort as said hot distillation residue.

4. In the method of distilling highly coking coal by contacting said coal directly with hot distillation residue from previously distilled carbonaceous solids in a closed unobstructed substantially cylindrical horizontal retort which is mounted for rotation about its longitudinal central axis, the steps comprising maintaining a granular bed consisting of said distillation residue in said retort in direct contact with the walls of said retort to serve as a barrier between fresh feed and said retort walls, rotating the retort, whereby a rotary movement is imparted to said bed, continuously and separately feeding a stream of said coal in finely divided form and a stream of hot finely divided distillation residue into one end of said retort onto the top of said bed, the mixing of said fresh coal and said hot residue being effected solely by the aforesaid rotary movement of said bed, said hot distillation residue being at such a temperature and in such quantity that the average temperature of the total solids in the retort is at a distillation temperature of said coal, the ratio by weight of coal and distillation residue fed to said retort being less than 1 to 3, distilling the coal solely by the sensible heat supplied by the distillation residue, continuously removing solid distillation residue from the opposite end of the retort in excess of that required to maintain the aforesaid bed of distillation residue in said retort, removing the volatile products from the retort, and continuously returning at least a portion of the dis-

tillation residue after heating it to an elevated temperature to the retort to repeat the above cycle.

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