This invention relates to destructive distillation and carbonization of coal, particularly suited for but not limited to the production of coke.

Coal is heated in the absence of oxygen to produce carbonized products known as coke or char, depending upon the nature of the coal taken for treatment and the temperature and time of carbonization. These products are useful as fuels and as sources of carbon for metallurgical reduction processes. Coke is produced in units called "coke ovens." Two types of ovens have been used, namely, the beehive oven and the by-product oven. Carbonization in either of these units is a relatively small-scale batch operation. Char is generally produced by low temperature carbonization from non-cooking type coals. Heating of such coal is accomplished in both ovens and in retorts or kilns and may utilize both batch and continuous processes.

Practically all of the presently used processing equipment for coal carbonization has one thing in common. That is, the heat for the carbonization process is supplied through a refractory or metal wall. This limits the practical size of the processing equipment because of heat transfer considerations. One exception to this is the beehive oven where heat is supplied by convection and radiation from gases burning in a chamber above the coal bed. Other exceptions are units in which hot inert gases are passed through a coal bed. In the latter case, such processes require superheated steam or combustion gases that have been elevated to combustion temperature in a heat exchanger or furnace located near the retort.

By far the major portion of the coal carbonized in the United States is processed in byproduct ovens for formation of metallurgical grade coke. These ovens are built in batteries each consisting of a long narrow silica brick chamber in which the coal is cooked by heat from the combustion of fuel gases in flues built into the refractory walls. The capacity of such an oven may be from four to twenty tons per charge and it may require from sixteen to twenty-four hours to complete carbonization of each batch. Because of the relatively small capacity per oven, the special materials used in the construction and the large amount of auxiliary equipment required for the byproduct coking process, such installation represents a large capital investment.

The present invention offers a simplified treatment procedure permitting continuous operation with a relatively short treatment interval or retention time required to obtain maximum extraction or conversion and which is a relatively low cost installation and operation because of the simplicity of the equipment required and the effective utilization of only a portion of the coal taken for treatment as the fuel source of the operation. One of the innovations of the present invention is the utilization of internal heating so controlled that only a relatively minor portion of the fixed carbon content of the coal is combusted as fuel, as gases produced in the early phases of the destructive distillation are the primary sources of fuel for the process, and a satisfactory grade of coke or char is produced with an efficient separation of coal tar and other liquid and gaseous components which also comprise a valuable product of the extraction or separation.

Another innovation of the present invention is the establishment of a relatively low temperature oxidation zone or combustion front of limited vertical extent in a confined treatment zone of substantial vertical extent in which the coal advancing toward said front is maintained at temperatures below its spontaneous ignition temperature until in the vicinity of the combustion front and the coal, after passing from said front, is directed through an oxygen-free atmosphere to its point of discharge with a sufficient retention time provided for such movement in conjunction with the maintenance of distillation temperatures to effectively carbonize the residual solid so as to produce a metallurgical grade of coke when cooking coals are taken for treatment and a satisfactory char residue as a fuel when non-cooking coals are treated.

It is an object of my invention to provide a simple, economical and efficient continuous process for destructive distillation and carbonization of coal to recover a residual solid product suitable as a fuel and coal tar and associated gases as another valuable product of the separation.

Another object of my invention is to provide a continuous process for destructive distillation and carbonization of coal in which retort off-gases may be recycled for heating coal under treatment and as an element of the flow control of such operation.

A further object of my invention is to provide a simple, efficient and economical continuous process for destructive distillation and carbonization of coal permitting treatment of relatively large tonnages in a short treatment interval in equipment of relatively low cost and of durable quality.

Other objects reside in novel control steps and procedures utilized in a continuous process for destructive distillation and carbonization of coal, all of which will be fully set forth in the course of the following description.

The present invention may be performed in a variety of equipment, most of which corresponds to types of equipment now in use for other processes but all of which has been modified to suit the control procedures of the present invention. All of such modified equipment has one common factor, namely, the utilization of a countercurrent combustion technique for applying direct internal combustion to the carbonization of coal, and such technique involves the progressive movement of the coal through a flame or combustion front of limited vertical extent at a rate which is calculated to allow destruction of only a minor fraction of the total fixed carbon content of such coal in its passage through the front.

The practice of my invention will be more easily understood by reference to the accompanying drawings which illustrate a typical circuit utilized in the performance of a process according to my invention and depicting modified types of retorts which are well suited to effect the destructive distillation of coal according to my invention.

In the drawings, in the several views of which like parts bear similar reference numerals:

FIG. 1 is a schematic flow sheet representation of an installation utilizing a retort of the type shown in FIG. 2 with associated equipment arranged in operative relation thereto;

FIG. 2 is a front elevation of a retort according to my invention, partially broken to show the arrangement of interior parts and material, which is particularly adapted for an all-gravity movement of coal through the retort;

FIG. 3 is a vertical section through a modified form of retort in which an elevating movement of coal is provided and which utilizes an effective type of heat insulation and material discharge; and

FIG. 4 is another front elevation of a modified form of retort combining gravity and force feeding of coal through the retort, and partially broken to show the interior arrangement.
Referring first to FIG. 1 of the drawings, sized coal such as a coking coal from Sunnyside, Utah, is first screened on a grizzly screen for removal of lumps larger than six inches and then is deposited in bins or hoppers 12 to comprise the feed to the distillation operation. A controlled amount of such coal is discharged through an outlet 13 to the feeding device 15 of a retort 14, a suitably sized coal feeder 16, shown here in the form of a star feeder (FIG. 2), moves the coal device 15 through the inlet 17 of retort 14 and is so arranged as to prevent any substantial pressure leak from the interior of retort 14.

Retort 14 comprises an elongated upright chamber, preferably coal insulated as indicated at 14a, which is dome-shaped at its upper end and widens toward the bottom. The bottom portion of the retort has a conical portion with a central outlet 15 which represents the bottom of the treatment zone, and said outlet discharges into a vacuuming device, also shown in the form of a star feeder which is capable of holding retort pressures. The discharge from valving device 19 passes to atmosphere as metallurgical grade coke.

When desired, recycle gas, preferably at high temperature, is introduced through an inlet 21 in the upper portion of retort 14 and of such gas introduction may be controlled as by a valve 22a. An oxygen-containing gas, usually compressed air, is delivered through an air inlet 22 formed as a header interiorly of retort 14 and having a series of nozzles 22a through which the gas is distributed in the descending coal stream throughout the width of the retort. This gas introduction also is suitably controlled as by a valve 22b, through a control of a blower 23 to vary the input volume of the gas.

Coal tar, coke oven gases and products of combustion discharge through an outlet 24 in the bottom portion of retort 14 and may be passed into a separating unit 25 which may be of condenser and gas-solid separator and, if desired, may also include a heat exchanger. The expression "coke oven gases" is used in this specification in the sense of its definition appearing in The Condensed Chemical Dictionary, 5th edition (1952), published by Reinhold Publishing Company. The coal tar and water of such separation are delivered into a tank 26 or other suitable receptacle permitting separation of the water from the coal tar. The separated gas passing from unit 25 may be delivered through a line 28 to storage or process (not shown) with a portion of same comprising the recycle gas introduced through inlet 21. Optionally, some of the gas passing from unit 25 may be directed through a branch 27 for mixing with the air supply introduced through inlet 22.

The foregoing circuit is intended only as representative of a complete treatment circuit and, other than the features of the retort and the distillation process performed therein, may be varied substantially in accordance with the requirements of a given operation.

Next referring to FIG. 2, a series of breakers 31 (here shown as rolls) are provided adjacent the bottom of retort 14 to reduce the enlarged masses of coke to a convenient size for discharge and metallurgical use.

In order to prevent clogging of the coal tar outlet 24, a suitable baffle 33 is provided allowing easy passage of coal tar, coke oven gases and products of combustion through the outlet 24 while obstructing passage of coke or other solids into clogging relation to said outlet.

In FIG. 2, sized coal supplied to the feeding device 15 is forced by the star feeder 16 through the inlet 17 of retort 14 and pressures established within the retort are prevented from escaping to any appreciable degree by the star feeder and the compacting of the coal in the force feeding arrangement. After entry into the top of retort 14, the entering coal piles and moves by gravity downwardly through the retort. For some purposes it will be desirable to preheat the coal before it reaches the combustion area and the setting of valve 21a will regulate the amount of gas such as recycled gas delivered into the top portion of the retort as a heating medium. Recycled gas is also beneficial in helping to establish the required gas flow which is coincident with the coal movement. While relatively high temperatures may be arrived at in such preheating, care must be exercised not to bring the temperature of coal above its spontaneous ignition temperature until it reaches the immediate vicinity of the gas distribution zone.

The oxygen-containing gas, which may be air or a mixture of air and recycled gas as previously described, is introduced through the inlet 22 at a rate or volume controlled by the setting of valve 22a and this gas discharges in the descending coal at approximately the top of the combustion front 30. This serves to maintain a head in advance of the combustion front so as to bring the descending coal immediately adjacent the combustion front above its spontaneous ignition temperature with resultant heat input, and on entering the combustion front or zone, the temperature of the coal is elevated for the following distillation action. In this operation said front is maintained at approximately the same level in the retort throughout a substantial period of continuous operation. Most of the available oxygen is consumed in the face of such front toward which the coal advances and so much oxygen-containing gas with the gas flow or coal to descend further in the retort is consumed in a short distance of travel so that the oxidation zone, otherwise termed the "combustion front," is of limited vertical extent in relation to the vertical dimension of the entire treatment zone. By consuming all the available oxygen within the combustion front, an oxygen-free atmosphere is maintained in the retort area beneath such front, and as a consequence the coal passing from the front, even though at a temperature substantially above its spontaneous ignition temperature, produces no combustion.

I have found that the aforesaid process is quite effective when the temperature range of 100° to 2000° F. is maintained in the coal or residual solid throughout the extraction stage, and at about 1500° F. high temperature cokes are formed. As the highest temperatures are attained in the upper face of the combustion front and most of the oxygen is consumed, in the high temperature area, there is a temperature drop to the rear of said front area, and a further drop as the coke passes from said front. However, the insulation of the retort prevents any substantial heat loss and the hot gases leaving the front in their passage to discharge are an effective heating medium to maintain distillation temperatures in the solid within said range throughout the travel of the solid from the front to discharge.

As shown in FIG. 2, retort 14 widens progressively toward its bottom to accommodate the expansion of the residual solid material and to break up fused coke as it passes from plastic to a more brittle condition and in which distillation continues following descent from the front. Only a small amount of the fixed carbon content of the coal is consumed as fuel in the combustion front due to the short distance of travel therein and the limited amount of oxygen to support combustion. Thus sufficient fuel is provided to maintain the temperatures for the heat requirement of said combustion front with only limited destruction or loss of the fixed carbon content. The heat insulation 14a is a valuable adjunct to this control, as heat losses are held to a minimum even though there is a substantial distance of travel beneath the combustion front and a substantial retention of heat. Adequate distillation of fused low volatile coals results in substantial expansion of the solid as it is formed into coke, and the breakers 31 will be provided adjacent the bottom of the retort whenever it is necessary to break the coke into sizes convenient for discharge and subsequent handling. The arrangement of the baffle 32 functions somewhat as a valve in addition to preventing clogging and restricts the flow of coal tar and other constitu-
ents to and through outlet 24 sufficiently to prevent any pressure loss of consequence which otherwise might produce a fluctuating level of the combustion front.

By maintaining a proper material balance in such an operation in the manner which will be described in more detail hereinafter, a continuous operation as described will permit substantially complete extraction of coal tar and coke oven gases with the residual solid which is separated from the material by the density bed when necessary, and separately discharged at the bottom of the retort as a metallurgical grade coke suitably sized for industrial usage. The modified form of retort shown in FIG. 3 provides an elevating movement to the coal charge and the gaseous flow also is directed upwardly in the retorting zone with the combustion front heating the coal advancing in proximity to the front to substantially ignition temperature before it reaches said front. Again in this form, a material balance is employed to maintain the combustion front of limited vertical extent at approximately the same elevation in the retort throughout a protracted period of operation. The retort is also arranged to accommodate the expansion of the solid resulting from the coining action by having enlarging space in the direction of solid flow. Retort insulating is provided so that temperatures in the coal passing from the combustion front are maintained high enough to continue distillate distillation.

As shown in FIG. 3, a belt feeder 33 delivers sized coal from a suitable supply source such as a bin (not shown) as the feed to a retort 34, the details of which will be set forth hereinafter. The base support of retort 34 has a feed intake 35 to receive the coal discharging from feeder 33 and coal from the intake is delivered to a charging mechanism 36 which force feeds it through the inlet 37 at the bottom of the retort which represents the bottom of the vertical treatment zone. Solid residue passes across an overflow lip 38 at the top of retort 34 and such overflow is assisted by a rotary agitator 39 which defines the upper limit of the vertical retorting zone. In addition to imparting an impelling movement to the residual solid for its discharge across the overflow 38, the agitator 39 also is effective in breaking up chunks or pieces of excessive size, as it is arranged to provide only a restricted discharge space at the overflow position.

The major portion of the retort 34 is enclosed within an exhaust chamber 40 which functions as the heat insulating medium for maintaining the required temperatures within the retort area. The solids overflow across the overflow lip 38 enters the upper portion of chamber 40 and falls by gravity to a lower point of discharge. Hot gases such as recycled gas are delivered through an inlet 41 into the lower portion of retort 34 for selective preheating of the coal charge in the manner previously described. As the coal charge to the retort is in a compacted condition and the feeding mechanism is arranged as a valve to prevent pressure leak, the gas introduced through inlet 41 flows upwardly through the combustion front 50 to finally escape from the retorting zone through the space above the overflow lip 38. An oxygen-containing gas is delivered through an inlet 42, which has a portion within retort 34 arranged as a header and provided with a series of circumferentially spaced nozzles 42a by which available oxygen is widely distributed throughout the cross sectional extent of the retort at the face of combustion front 50 toward which the coal advances. The evolved gases of the combustion entrain with the recycled gas flow when provided and otherwise pass upwardly in an induced flow.

As the solids discharge into exhaust chamber 40 produces a substantial heating effect therein, due to the high temperature of the solids entering said chamber and the high temperature of the coal tar, coke oven gases and products of combustion also flowing out at the top of retort 34, the chamber 40 is arranged as a heat exchange device by the provision of a water jacket 43 on its side walls intermediate its ends, and water is supplied to the jacket 43 from a suitable source (not shown) introduced through an inlet 45 with evolved steam exhausted through an outlet 46 at the top of the jacketed portion. The coal tar, coke oven gases and products of combustion pass from chamber 40 through an upper outlet passage 44 as a commingled stream moving in induced flow. Such flow may be provided by having an exhaust pump in the line extension of outlet 44, or such flow may be attained by establishing a high pressure condition in the lower portion of chamber 40 through prevention of pressure leak in connection with the solids discharge, which pressure will be sufficiently high to direct the outflow of coal tar and gases through the outlet 44.

While the aforesaid water jacket arrangement provides an effective heat transfer for utilization of waste heat, the atmospheric temperatures in exhaust chamber 40 are sufficiently high to prevent any substantial heat loss through the walls of retort 34 in the portion thereof above heat front 50, and as a consequence, the high temperature condition established by consumption of most of the available oxygen at the lower face of said front is only reduced to a small degree in the solids traveling from said front to the upper overflow 38. Thus, the exhaust gas from the chamber 40 in this apparatus and the low thermal conductivity of the evolved coke function as heat insulation similar to the insulation 14c of retort 14 (FIG. 2) so that the wall temperature is reduced to a safe working level. The solids discharge falling by gravity from retort 34 passes along the inclined bottom of chamber 40 to an outlet portion in which a water quench is provided by an inlet 47 to bring the temperature of the solid material below its spontaneous ignition temperature, and a valve device 48 shown as a star feeder, prevents any substantial pressure leak while moving the solids discharge onto a belt-type conveyor 49 by which it is conducted to a suitable point of storage or use (not shown).

The destructive distillation process performed in retort 34 is essentially the same as that previously described except as to the direction of flows and the fact that the movement of the coal is more in the nature of an intermittent progressive movement rather than a completely continuous movement such as is provided by the gravity flow in retort 14. The charging action in this operation involves the intermittent swinging of the charging mechanism 36 about a pivot 51 and said mechanism includes a sector-shape member having an arcuate portion of substantial width moving in engagement with an arcuate surface 52 of the base support of retort 34. The sector has a cylindrical portion 53 of essentially the same diameter as the inlet 37 of retort 34, and a ram-type device 54 which may have either a hydraulic or pneumatic drive, is movable from a lower inactive position in which it is assumed when the sector brings the cylinder 53 in register with feed intake 35 to an uppermost charging position in which the top surface of the ram substantially closes the inlet 37 defining the lower limit of the retort zone in retort 34. Movement of the sector 56 as aforesaid is directed by another ram unit 55 which also may include a hydraulic or pneumatic drive.

The aforesaid intermittent charging is performed at a rapid operating rate so that the actual effect of said charging is to keep the coal bed in almost a continuous state of movement, which movement progresses from inlet 37 to the overflow 38. The enlargement of the retort toward the top is calculated to accommodate any expansion in the solid resulting from the coining effect but does not dissipate the motive force applied to the coal charge. As a consequence, the rate of movement of the solid is substantially uniform throughout the vertical extent of the treatment zone. The oxygen-containing gas introduced through nozzles 42a may be compressed air from a blower or an air-recycle gas mixture as previously described, and is so controlled as to rate and amount of available oxygen delivered to the combustion front 30 as
to maintain said front at a substantially uniform elevation as previously described. When desired, the coal charge may be preheated by the introduction of hot gases through inlet 41, and when such heating is performed, the charge will be held below the spontaneous ignition temperature of the coal at least until it reaches the heat front immediately forward of the combustion front 59 with respect to the coal traveling area. The combustion is held within a limited vertical extent in relation to the total vertical extent of the retort treatment zone.

This arrangement provides a substantial distance of travel and a substantial retention time for the residual solids ascending from the front 50 to the overflow 38, and this distance and retention time is calculated to provide maximum conversion and extraction at the temperatures which are established and maintained.

The apparatus of FIG. 3 is well suited for treatment of both coking and non-coking coals, and in addition to obtaining the two main products of residual solid (coke or char) and the liquid-gaseous product (coal tar, coke oven gases and products of combustion), such apparatus also provides steam from waste heat as a third product of its operation.

Another retort modification is illustrated in FIG. 4 which utilizes a combined gravity and force feed of the coal charge. In this form, a belt feeder 63 discharges sized coal from a suitable source (not shown) as the feed to an upright retort 64 having insulated walls 64a. The coal discharging from feeder 63 drops into an intake 65 of retort 64 and is moved by a star feeder 68 into a charging chamber 56 at the top of retort 64. Chamber 56 is cylindrical and has a side entrance opening or intake 57 receiving the feed from star feeder 66. A spiral mechanism 58, or a ram (not shown) force feeds the entering coal through the top inlet 67 of the retort and the feeder 58 is suitably journalled to prevent pressure loss. The star feeder 66 is also arranged to prevent pressure loss through intake 65.

Retort 64 widens between inlet 67 and the combustion front 70 and its intermediate portion is substantially cylindrical with a frusto-conical bottom discharge arrangement. The lower end 68 of the frusto-conical portion comprises the bottom outlet for the residual solids and defines the lower limit of the treatment zone. A valving device 69 in the form of a star feeder is located in said outlet to prevent pressure loss and effect a positive discharge of the solids residue. A recycle gas inlet 71 is provided above the combustion zone and the air supply header 72, is provided with a series of circumferentially spaced nozzles 72a for introduction of the oxygen supply in proximity to the upper face of the combustion front 70. A series of breaker rolls 61 is disposed across the retort adjacent a gas outlet 74 located above the bottom outlet 68 and a suitable baffle 62 is arranged to prevent clogging of outlet 74 and to restrict the coal tar, coke oven gas and products of combustion discharged from the retort. The solids discharge of the valving device 69 of outlet 68 after suitable quenching when needed, is discharged onto a belt conveyor 59 by which it is conducted to a suitable location for storage or use.

The treatment performed in retort 64 is essentially the same as performed in retort 14 with the coal descending into the upper face of the front 70, and the portion of the retort below the combustion front 70, providing the required retention interval and high temperature condition required in completing the destructive distillation in an oxygen-free atmosphere. Retort 64 is intended for use in operation where substantial expansion of the solids residue does not occur, as with non-coking coals or high volatile coals, and layers of excess size or fused coke formed in the destructive distillation are broken up by the breaker 61 so that the solids passing outlet 68 to the feeding device 69 are in a suitable size for discharge and subsequent use. Again in this form, the only oxygen to sup-
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It should be noted that with respect to all of the structural embodiments illustrated in the drawings, the distillation process performed therein is essentially the same, although the apparatus of FIG. 3 causes the coal to flow upward through the distillation zone rather than downward as in the other forms. However, the gas flow is directed in a direction related to the coal flow in all such forms and the oxygen-containing gas is introduced intermediate the ends of the zone so as to establish a combustion front of limited vertical extent.

Where considerable expansion results in the destructive distillation, it will be preferable to have an expanding zone through which the solids move during such expansion and either of the embodiments of FIGS. 2 or 3 provide satisfactory arrangements for accommodating the expansion. While not illustrated in FIGS. 2 and 4, a coke quenching arrangement similar to that shown at 47 in FIG. 3 may be installed adjacent the outlets 18 or 65 to prevent ignition of hot coke after passing through the distillation zone. It should be understood that the features of feeding, discharge, quenching and material balances described herein are of general application to the various structural embodiments of my invention illustrated in FIGS. 2, 3 and 4 and similar structures adapted to perform the practice of my invention. The arrangements and embodiments of apparatus illustrated in the drawings are merely illustrative of the practice of my invention, the scope of which is set forth in the hereunto appended claims.

I claim:

1. In a process for the destructive distillation of coal wherein coal is introduced into one end of a retort, coke is formed and removed from the other end of the retort, and a combustion zone is maintained intermediate the retort and the entrance of the retort, introducing coal and oxygen-containing gas into the retort in a relationship to a rate adapted to maintain a combustion zone of limited vertical extent, regulating the rate of coal and gas introduction into the combustion zone to maintain said zone intermediate the ends of the charge, burning a minor portion of the coal and all oxygen in said combustion zone, maintaining the remainder of the coal substantially at coking temperatures without igniting the coal after its movement beyond the combustion zone, and withdrawing coke and combustion gas separately and from the discharge end of the retort.

2. A continuous process for destructive distillation of coal, which comprises passing coal in a progressive movement through a confined treatment zone of substantial vertical extent, introducing an oxygen-containing gas into the moving coal intermediate the vertical limits of said zone in an induced flow directed in a direction related to said progressive movement, establishing a combustion front of limited vertical extent in said moving coal intermediate said vertical limits, said oxygen-containing gas being introduced in such an amount that the available oxygen is consumed within said limited vertical extent of said combustion front, directing hot gases occurring away from said front so as to maintain a distillation temperature therein without igniting the coal and to conduct evolved products to a point of discharge adjacent an end of said zone, removing evolved products and associated gases from the treatment separately from the solid carbonaceous residue, and cooling said residue below its spontaneous ignition temperature before discharge from the treatment to atmosphere.

3. A continuous process for destructive distillation of coal, which comprises passing coal in a progressive movement through a heat-insulated confined treatment zone of substantial vertical extent, introducing an oxygen-containing gas into the moving coal intermediate the vertical limits of said zone in an induced flow directed in a direction related to said progressive movement, establishing a combustion front of limited vertical extent in said moving coal intermediate said vertical limits, said oxygen-containing gas being introduced in such an amount that the available oxygen is consumed within said limited vertical extent of said combustion front, directing hot gases occurring away from said front so as to maintain a distillation temperature therein without igniting the coal and to conduct evolved products to a point of discharge adjacent an end of said zone, removing evolved products and associated gases from the treatment separately from the solid carbonaceous residue, and cooling said residue below its spontaneous ignition temperature before discharge from the treatment to atmosphere.

4. A continuous process for destructive distillation of coal, which comprises passing coal in a progressive upward movement through a confined treatment zone of substantial vertical extent, introducing an oxygen-containing gas into the moving coal intermediate the vertical limits of said zone in an induced flow directed in a direction related to said progressive movement, establishing a combustion front of limited vertical extent in said moving coal intermediate said vertical limits, said oxygen-containing gas being introduced in such an amount that the available oxygen is consumed within said limited vertical extent of said combustion front, directing hot gases occurring away from said front so as to maintain a distillation temperature therein without igniting the coal and to conduct evolved products to a point of discharge adjacent an end of said zone, removing evolved products and associated gases from the treatment separately from the solid carbonaceous residue, and cooling said residue below its spontaneous ignition temperature before discharge from the treatment to atmosphere.

5. A continuous process for destructive distillation of coal, which comprises passing coal in a progressive movement through a confined treatment zone of substantial vertical extent, introducing an oxygen-containing gas into the moving coal intermediate the vertical limits of said zone in an induced flow directed in a direction related to said progressive movement, establishing a combustion front of limited vertical extent in said moving coal intermediate said vertical limits, said oxygen-containing gas being introduced in such an amount that the available oxygen is consumed within said limited vertical extent of said combustion front, directing hot gases occurring away from said front so as to maintain a distillation temperature therein without igniting the coal and to conduct evolved products to a point of discharge adjacent an end of said zone, removing evolved products and associated gases from the treatment separately from the solid carbonaceous residue, and cooling said residue below its spontaneous ignition temperature before discharge from the treatment to atmosphere.

6. A continuous process for destructive distillation of coal, which comprises passing coal in a progressive movement through a confined treatment zone of substantial vertical extent, introducing an oxygen-containing gas into the moving coal intermediate the vertical limits of said zone in an induced flow directed in a direction related to said progressive movement, establishing a combustion front of limited vertical extent in said moving coal intermediate said vertical limits, preheating coal in advance of said front below its spontaneous ignition temperature and introducing oxygen-containing gas being introduced in such an amount that the available oxygen is consumed within said limited vertical extent of said combustion front, directing hot gases occurring away from said front so as to maintain a distillation temperature therein without igniting the coal and to conduct evolved products to a point of discharge adjacent an end of said zone, removing evolved products and associated gases from the treatment separately from the solid carbonaceous residue, and cooling said residue below its spontaneous ignition temperature before discharge from the treatment to atmosphere.
its spontaneous ignition temperature before discharge from the treatment to atmosphere.

7. A continuous process for destructive distillation of coal, which comprises passing coal in a progressive movement through a confined treatment zone of substantial vertical extent, introducing an oxygen-containing gas into the moving coal intermediate the vertical limits of said zone in an induced flow directed in concurrent relation to said progressive movement, establishing a combustion front of limited vertical extent in said moving coal intermediate said vertical limits, preventing coal in advance of said front below its spontaneous ignition temperature by flowing recycled gas through the coal advancing to said front, said oxygen-containing gas being introduced in such an amount that the available oxygen is consumed within said limited vertical extent of said combustion front, directing hot gases concurrently through the coal which is moving away from said front so as to maintain a distillation temperature therein without igniting the coal and to conduct evolved products to a point of discharge adjacent an end of said zone, removing evolved products and associated gases from the treatment separately from the solid carbonaceous residue, and cooling said residue below its spontaneous ignition temperature before discharge from the treatment to atmosphere.

8. A continuous process for destructive distillation of coal, which comprises passing coal in a progressive movement through a confined treatment zone of substantial vertical extent, introducing a mixture of recycle and oxygen-containing gas into the moving coal intermediate the vertical limits of said zone in an induced flow directed in concurrent relation to said progressive movement, establishing a combustion front of limited vertical extent in said moving coal intermediate said vertical limits, said oxygen-containing gas being introduced in such an amount that the available oxygen is consumed within said limited vertical extent of said combustion front, directing hot gases concurrently through the coal which is moving away from said front so as to maintain a distillation temperature therein without igniting the coal and to conduct evolved products to a point of discharge adjacent an end of said zone, removing evolved products and associated gases from the treatment separately from the solid carbonaceous residue, and cooling said residue below its spontaneous ignition temperature before discharge from the treatment to atmosphere.

9. A continuous process for destructive distillation of coal, which comprises passing coal in a progressive movement through a confined treatment zone of substantial vertical extent, introducing an oxygen-containing gas into the moving coal intermediate the vertical limits of said zone in an induced flow directed in concurrent relation to said progressive movement, establishing a combustion front of limited vertical extent in said moving coal intermediate said vertical limits, said oxygen-containing gas being introduced in such an amount that the available oxygen is consumed within said limited vertical extent of said combustion front, maintaining a combustion front temperature at a range of 1100° to 2000° F., directing hot gases concurrently through the coal which is moving away from said front so as to maintain a distillation temperature therein without igniting the coal and to conduct evolved products to a point of discharge adjacent an end of said zone, removing evolved products and associated gases from the treatment separately from the solid carbonaceous residue, and cooling said residue below its spontaneous ignition temperature before discharge from the treatment to atmosphere.

10. A continuous process for destructive distillation of coal, which comprises passing coal in a progressive movement through a confined treatment zone of substantial vertical extent, introducing an oxygen-containing gas into the moving coal intermediate the vertical limits of said zone in an induced flow directed in concurrent relation to said progressive movement, establishing a combustion front of limited vertical extent in said moving coal intermediate said vertical limits, said oxygen-containing gas being introduced in such an amount that the available oxygen is consumed within said limited vertical extent of said combustion front, maintaining a combustion front temperature at a range of 1100° to 2000° F., directing hot gases concurrently through the coal which is moving away from said front so as to maintain a distillation temperature therein without igniting the coal and to conduct evolved products to a point of discharge adjacent an end of said zone, removing evolved products and associated gases from the treatment separately from the solid carbonaceous residue, and cooling said residue below its spontaneous ignition temperature before discharge from the treatment to atmosphere.
a point of discharge adjacent an end of said zone, maintaining a substantially uniform fill in said confined zone by balancing the rate of coal feed to the rate of solid residue discharge from the treatment, removing evolved products and associated gases from the treatment separately from the solid carbonaceous residue, and cooling said residue below its spontaneous ignition temperature before discharge from the treatment to atmosphere.

14. A continuous process for destructive distillation of coal, which comprises directing coal at a substantially uniform rate of progressive movement through a confined treatment zone of substantial vertical extent and of increasing volume in the direction of coal movement, introducing an oxygen-containing gas into the moving coal intermediate the vertical limits of said zone in an induced flow directed in concurrent relation to said progressive movement, establishing a combustion front of limited vertical extent in said moving coal intermediate said vertical limits, said oxygen-containing gas being introduced in such an amount that the available oxygen is consumed within said limited vertical extent of said combustion front, directing hot gases cocurrently through the coal which is moving away from said front so as to maintain a distillation temperature therein without igniting the coal and to conduct evolved products to a point of discharge adjacent an end of said zone, removing evolved products and associated gases from the treatment separately from the solid carbonaceous residue, and cooling said residue below its spontaneous ignition temperature before discharge from the treatment to atmosphere.

References Cited in the file of this patent

UNITED STATES PATENTS

1,536,696 Wallace .................. May 5, 1925
1,669,024 Runge .................. May 8, 1928
1,772,189 McIntire .................. Aug. 5, 1930
1,781,766 Smith .................. Nov. 18, 1930
2,501,133 Berg .................. Mar. 21, 1950
2,723,225 Elliott .................. Nov. 8, 1955
2,954,329 Dhandt et al. ........ Sept. 27, 1960

FOREIGN PATENTS

468,405 Great Britain ............ July 5, 1937