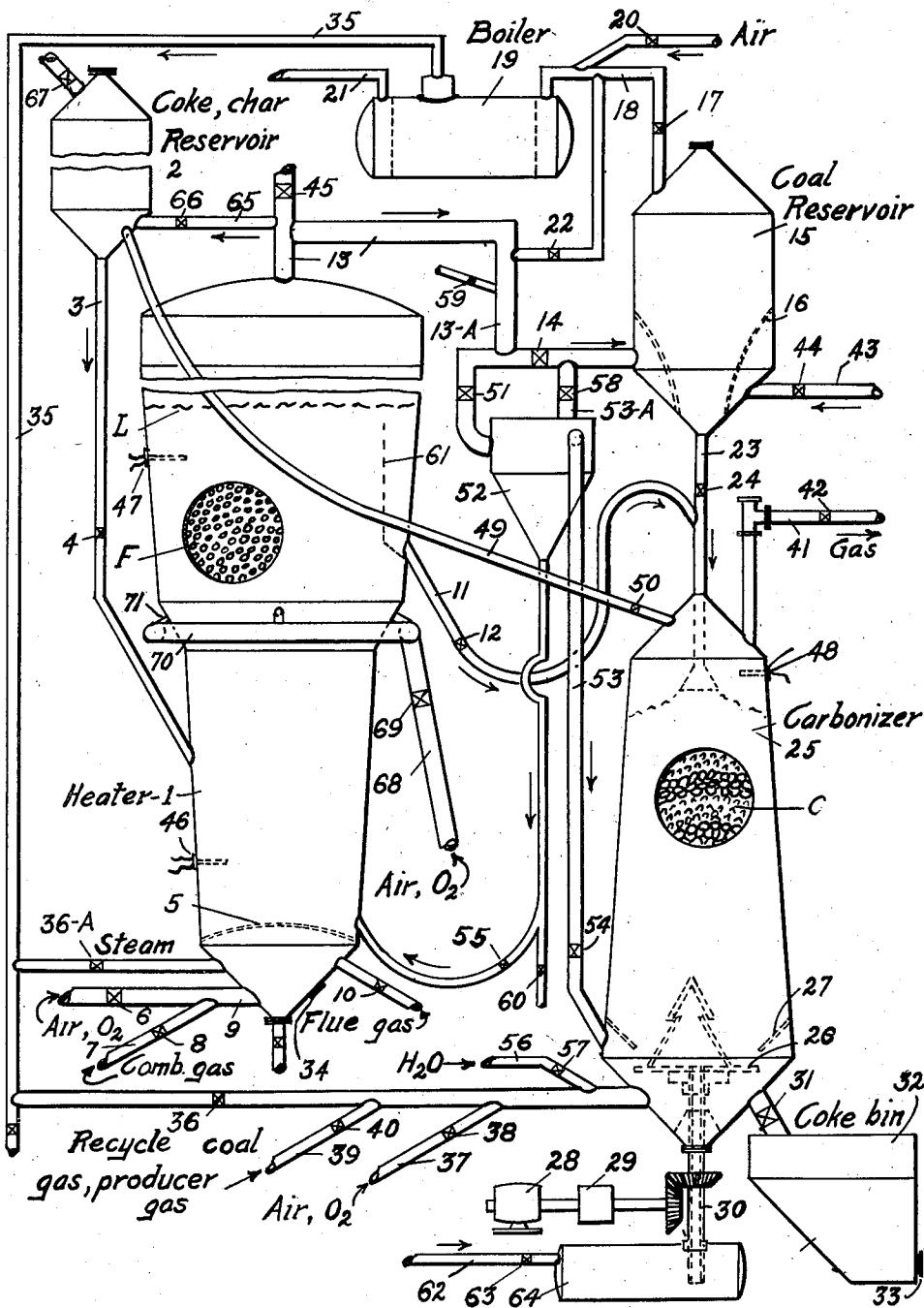


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TREATMENT AT ELEVATED TEMPERATURES AND/OR
CARBONIZATION OF CARBONACEOUS MATERIALS
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**TREATMENT AT ELEVATED TEMPERATURES
AND/OR CARBONIZATION OF CARBONA-
CEOUS MATERIALS**

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This invention relates to the treatment at elevated temperatures and/or carbonization of carbonaceous materials. In particular the invention is concerned with the carbonization of such substances as coal, lignite and briquetted solid fuels, peach pits and other carbonizable solids by supplying the necessary heat within the carbonizer rather than by heat transmitted through refractory walls by conduction from without the carbonizer, and generating combustible gas.

Most processes used or proposed for carbonizing coal depend at least in part on transferring externally applied heat through refractory walls to the coal confined therein, for the purpose of promoting the heating and carbonization of the coal. The modern byproduct coke oven is an example of the latter procedure. Carbonization in a fluidized bed of coal in a stream of the fluidizing gas has been proposed but I find that in order to carry this out effectively without excessive carry-over of the fine sizes entrained in the effluent gas it is essential or at least highly desirable that the size of the coal particles under process of carbonization be confined to narrow limits, thus necessitating extensive screening and preparation equipment. Another difficulty, I find, is the discharging of the carbonized product at the chosen state of carbonization without also discharging some of the uncarbonized coal.

In the present case, in one embodiment of the invention, fluidized solids technique is employed to heat char, coke or a carbonized product, to incandescence in a heating chamber, the thus heated solids are regularly withdrawn and supplied to a carbonizer as a source of heat to promote the carbonization of coal which coal is also supplied to the carbonizer in predetermined relative amounts. The operation of the carbonizer may be continuous or intermittent; the step of heating the char however is continuous, the size of the heating chamber being so proportioned relative to the size and capacity of the carbonizer that interruption of fluidization of the char in the heater is not necessary. The bed in the carbonizer is not fluidized.

One of the objects of this invention is the carbonization of coal and the like continuously, or substantially so, by virtue of heat supplied to the carbonizer from within, namely within the mass of coal in process, rather than by heat transmitted through the carbonizer walls.

Another object is to carbonize carbonaceous fuels at a high rate per dollar of invested capital.

Still another object is the accurate control over the degree of carbonization of carbonaceous solids without materially affecting carbonizer throughput. To clarify this object it may be said that in coking a bituminous coking coal, a coke can be produced containing 5% or 15% volatile matter without materially altering carbonizer throughput of coke.

Still another object is the recovery of distillation products from carbonizable solids without considerable dilution with the products of combustion formed in initially heating the char in the heating chamber.

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A further object is to promote sufficient fusion and cementing together of particles of coal (or coal with char) whereby there is produced coke of mean average size greater than that of the feed coal; this is a major difference from any other process of which I am aware employing fluidized solids technique in carbonizing coal. Other objects will become apparent from the disclosures hereinafter made.

In the present invention, the fine-size char or coke from the carbonizer is heated to incandescence as a fluidized bed in a heating chamber by promoting combustion reactions in the bed by blasting the bed from beneath with a fluidizing agent containing a combustion supporting medium; the latter agent may comprise combustible gas and/or steam as well as oxygen. Air alone may be used as fluidizing agent under conditions which will be described. The resulting hot solids are withdrawn from the heater at about the same rate that fresh char is fed thereto. The thus withdrawn hot char is supplied to the carbonizer and deposited therein along with coal to be carbonized; it supplies at least some of its sensible heat to the coal in the carbonizer raising the temperature of the latter fuel and causing the evolution of volatile matter therefrom. The amount of coal fed to the carbonizer is so proportioned relative to the hot char that it will be heated by the char to a chosen temperature in the carbonizer. The coal is initially crushed to a chosen maximum size usually not larger than 3 inches diameter, and is advantageously free of fines (powdered coal).

The invention may be described best by reference to the drawing which is diagrammatic and shows one form of apparatus suitable for the practice of the invention. The figure shows in elevation, largely as a flow diagram, a suitably connected heater, carbonizer and supply lines whereby coal and other carbonaceous solids may be substantially continuously carbonized.

Referring to the figure, the heating chamber (heater) 1 is supplied with small-size solid fuel, preferably char or coke from a previously performed carbonization step, from reservoir 2, through conduit 3 and valve 4; a bed of this fuel supported on grid 5 is established and is fluidized and maintained in an incandescent condition by virtue of the fluid stream passing up through the grid; air, or other combustion supporting fluid enters through valve 6 and conduit 9 and combustible gas enters through conduit 7, valve 8 and conduit 9. The velocity of the stream passing up through the grid 5 is at least sufficient to densely fluidize the bed (shown through a cutaway portion of the heater at F) with a top level L. The ignited fuel in bed F is kept in a state of incandescence by promoting controlled combustion within bed F; the fuel consumed during this heating operation, which operation is continuous or substantially so, may be the coke of the latter bed or combustible gas admitted through valve 8 or both; a tempering or temperature regulating fluid such as flue gas, CO₂ or steam may be introduced through valve 10. The exit gas stream, which may be called producer gas, and is combustible, passes through offtake 13 and valve 14 to coal reservoir 15, it passes therein through grid 16 and up through the coal therein drying and preheating it, exiting through valve 17 and passing through conduit 18 to boiler 19 wherein it is burned by means of air admitted through valve 20, the flue gas being discharged through conduit 21. Bypass valve 22 is used to conduct producer gas to the boiler in amounts not desired in the coal pre-heating operating. Now, the preheated coal is supplied hot through conduit 23 and valve 24 to carbonizer 25 and controlled relative amounts of incandescent coke are fed to the carbonizer through conduit 11 and valve 12. The heat available as sensible heat of the latter coke is imparted to the coal supplied through valve 24 and as carbonization occurs

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the whole mass (bed C) passes downwardly by the aid of rotating member 26 and baffle 27; motor 28 with gear box 29 is the means of rotating at controllable speed shaft 30 and propelling member 26. The carbonized coal along with particles of coke initially supplied through 11 and 12 and which have not cemented to the coking coal are discharged through valve 31 to char bin 32 from which it passes through 33 to a sizing and separation plant not shown wherein the finer sizes are separated from the larger sizes by known means and known procedures and may be fed to the reservoir 2 through valve 67. A firing port 34 is provided for initially promoting combustion in the heater. Steam generated in the boiler may pass through conduit 35 and valve 36 to the base of the carbonizer and some steam may pass through 35 and valve 36-A to the base of the heater. Air, oxygen or other combustion supporting gas may be introduced into the carbonizer through conduit 37 and valve 38 whereas recycle residual coal gas or other combustible gas may be supplied to the base of the carbonizer through conduit 39 and valve 40. Vaporous products of carbonization pass out of the carbonizer through offtake 41 and valve 42. When it is desirable to use hot flue gas or equivalent to dry and preheat the coal in reservoir 15, such gas is introduced into 15 through conduit 43 and valve 44. In starting operations the first gas produced is conveniently discharged through valve 45 which is normally closed. Thermocouples 46 and 47 in the heater and 48 in the carbonizer are suitably connected (connections not shown), for indicating the temperatures in their respective zones. Bypass means for conducting char directly from reservoir 2 to carbonizer 25 include conduit 49 and valve 50. When high-ash content solid fuel is used in the heater or extra fine size fuel is employed the discharge gas from the heater is conducted through 13, 13-A, valve 51, dust separator 52 and conduit 53-A and valve 58, to the reservoir 15, in which case valve 14 is closed. Some or all of the producer gas may be conducted from dust collector 52 directly to carbonizer 25 through conduit 53 and valve 54. Solids from dust collector 52 may be discharged through valve 60 or returned to the heater through valve 55. Water is supplied to the bottom of the carbonizer through conduit 56 and valve 57; water is supplied to conduit 13-A through valve 59 when and as required for temperature control. A large settling reservoir 61 is provided in heater 1 for collecting hot coke free of fines before discharging the hot coke to the carbonizer; it is sufficiently large to collect settled solids about as fast as the hot coke is supplied to the carbonizer. Means for supplying a reactant such as oxygen above the level of table 26 in the carbonizer includes conduit 62, valve 63, chamber 64, and hollow shaft 30. It is sometimes desirable to preheat the carbonized solids (coke or char) in reservoir 2 and this may be done by passing some of the hot producer gas directly from heater 1 through conduit 65 and valve 66, discharging it through valve 67.

Example 1

Simple carbonization of sized coal, $\frac{1}{8}$ to $\frac{3}{4}$ inch square-mesh-screen sizes; no recirculation of gases.

Coke, from a previous carbonization of coking coal, or char, in the size range about $\frac{1}{8}$ to $\frac{1}{4}$ inch is supplied to heater 1 from coke reservoir 2 through 3 and 4 until a bed of several feet depth has been formed therein. Now combustible gas and air are supplied through 7, 8, and 9, and 6 and 9 respectively and the combustion of the gas is promoted as by initially introducing ignited material through door 34, or by a spark mechanism not shown. The products of combustion are discharged through valve 45; the combined rate of flow of the gases through the bed is somewhat greater than that required to densely fluidize the coke in the bed. The minimum mean superficial velocity of the stream in bed F will usually be about 5.2 feet per second, the exact minimum velocity for this

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size particle will vary with the density of the coke. At any rate standard practice in employing fluidized solids technique is followed and the stream velocity is maintained in the bed F in heater 1 such that the coke bed is maintained densely fluidized and the particles are in ebullient motion in the bed. The bed level is raised to the mark indicated in the figure as L, by gradually adding coke through valve 4. Meanwhile carbonizer 25 is initially about half filled with small size coke as through conduit 49 and valve 50. Now the operation of the carbonizer may begin. Valve 45 is closed and valves 14 and 17 are open and gas offtake valve 42 is open. Hot coke is fed to carbonizer 25 through 11 and 12 and the coal to be carbonized is supplied through 23 and valve 24. The proportional amounts of hot coke and coal thus fed to the carbonizer are quite definite for a chosen degree of carbonization. The motor 28 is started and the gear box 29 adjustments are made so that shaft 30 and table element 26 are rotated to slowly discharge coke from the carbonizer through valve 31. The bed in 25 is allowed to build up substantially to the feed pipe adjacent the top zone of the carbonizer; from this time on, the discharge of coke through 31 is so controlled that the bed height in 25 remains about constant. Likewise the height of the bed of hot coke in heater 1 is maintained about constant by feeding fresh coke about $\frac{1}{8}$ to $\frac{1}{4}$ inch size from 2 through 3 and 4 at a controlled rate. The combustible gas supply is now cut off by closing valve 8 and air is supplied through valve 6 at the fluidizing rate. The hot zone in the carbonizer will tend to travel downwardly unless a cooling fluid is introduced adjacent the bottom of the bed C therein. In this example steam is chosen for this purpose. Quantities and yields obtainable for a given size apparatus and a given set of conditions are as follows:

Mean inside diameter of heater 1, feet.....	4.2
Mean area of horizontal section, sq. ft.	13.85
Volume of fluids (air) supplied to heater per hour, cu. ft.	250,000
Total char fed to heater per hr., lbs.	12,100
Char consumed in heater per hr., lbs.	3,000
Hot char, 1650° F., discharged from the heater and fed to carbonizer, lbs. per hr.	9,000
Steam to carbonizer, lbs. per hr., through valve 36	3,000
Coal to carbonizer, through valve 24, lbs. per hour	8,500
Lbs. of solids, coke and char removed from carbonizer, per hr.	15,250
Percent of coarse size product solids $\frac{1}{4}$ inch and larger in the residue from the carbonizer ..	90.8

The tarry vapors and coal gas evolved in the carbonizer are discharged through 41 and 42 and amount to approximately 25% of the coal charged, including liquor, tar, gas and oils. The speed of rotation of table element 26 is regulated by adjusting gear ratios in box 29, so that the desired rate of discharge prevails for the carbonized solids passing out through 31 into bin 32; the rate in this example is approximately 15,000 pounds per hour of dry product, which product is removed from the bin through door 33.

The coal is fed uniformly through valve 24 so that it mixes substantially uniformly with the hot solids from the heater as they are both fed to the top of the carbonizer. The producer gas made in heater 1 and passing through offtake 13 and valve 14 preheats the coal in reservoir 15 and passes out through 17, and 18 to boiler 19 where it is burned to generate steam, the spent gas (flue gas) exits through offtake 21. With coking coals it is necessary to prevent the coal in reservoir 15 from reaching the plastic state during the preheating stage, this is most conveniently accomplished by employing valve 22 to shunt any excess of producer gas above that required in preheating the coal to 500° to about 650° F. directly

to the boiler; valve 66 may be used for this purpose when desired.

The use of the hot char along with the coking coal functions not only as a heat carrier but keeps bed C in the carbonizer sufficiently open so that steam or other fluid can pass upwardly through the bed without channeling. With strongly coking coals that fuse readily upon heating it is usually helpful to increase the relative amount of hot char supplied to the carbonizer.

Before passing to another example attention is called to the fact that in some cases, instead of supplying the mixed hot char and coal to carbonizer 25 at a continuous uniform rate it is preferable to provide substantially alternately layers of coal and hot char; the layers may vary from an inch to as much as a foot. Employing Elkhorn coal, for example, which does not liquify or become extremely plastic upon heating and is not friable, this practice gives excellent results when the coal is sized up to 2 inches or more in diameter and substantially free of very fine sizes. With such coal in 6 inch layers, including some hot char, alternated between 8 to 12 inches of hot char (coke) permits the production of excellent coke. On the other hand, carbonizing lignite which disintegrates upon heating forming small pieces, there is more resistance to the flow of fluids up through the carbonizer bed C with this method of operation and the preferred procedure is to supply the hot char and the lignite substantially uniformly as a mixture.

It will be understood that the fine sizes produced, smaller than about $\frac{1}{4}$ or $\frac{1}{8}$ inch size, and discharged from bin 32 are returned to the heater via coke reservoir 2. In order to eliminate the blowing over of dust carbon from the heater the feed of char thereto which feed may now contain some dust carbon is supplied to a zone adjacent the bottom of bed F through 3 and 4.

In operating with substantially alternate layers of hot char and the material to be carbonized in the carbonizer, it is preferable and advantageous to supply the hot char at substantially a uniform rate through valve 12 but to supply the coal periodically in moderately rapid succession such that layers say 8 inches thick of char are alternated with layers say 5 to 8 inches thick of chiefly coal but with some hot char mixed therewith.

In Example 1 it is normally desirable to maintain the coking coal in a hot zone for a definite period of time which differs with different coals and which will usually be of the order of 10 to 30 minutes varying with the size of the coal. Taking 15 minutes as the desired time in Example 1 the 15 thousand pounds of solids discharged per hour from bed C should be in that bed for about 30 minutes, the latter half of that period the cooling operation is in effect. Accordingly the mean diameter of the carbonizer bed should be approximately 6 feet for a bed depth of 13 to 14 feet. This depth of bed exerts beneficial pressure on the coal in process and the drop in pressure of the fluid stream passing up through the bed is not excessive. Thus the ratio of approximate mean diameters of heater to carbonizer are advantageously 1:1.5 to about 1:5. With smaller size coke in the heater lower velocities of the fluidizing stream are employed and somewhat lower ratios may be favorable. However, since the capacity of the heater to produce char is limited by the limiting fluidizing velocities in bed F it will be apparent that in order to increase the relative amount of hot char fed to the carbonizer, without decreasing the rate of feed of coal thereto, the diameter of the heater must be increased; diameter ratios of 1:1 to 1 to 4 will be quite satisfactory.

Example 2

Carbonization of bituminous coking coal sized $\frac{1}{2}$ to 1 inch in diameter, i.e. through a 1 inch and on a $\frac{1}{2}$ inch screen, employing combustible gas in the operation, the starting operations being the same as in Example 1.

When the heating operation in heater 1 is promoted by burning some of the solid fuel fluidized therein, powdered

ash is formed which is carried out of 2 entrained in the effluent gas; separators may be required for the removal of this ash and they may be placed at the outlet of the heater, as shown in the figure. When gas is burned as fuel for heating bed F much less solid fuel is consumed in heating. Exothermic reactions such as are shown by Equations 1 to 6 occur, liberating heat and heating the char in bed F.

- (1) $\text{CH}_4 + 2\text{O}_2 = \text{CO}_2 + 2\text{H}_2\text{O} + 382,000 \text{ B.t.u.}$
- (2) $\text{CH}_4 + \text{O}_2 = \text{CO} + \text{H}_2\text{O} + \text{H}_2 + 10,000 \text{ B.t.u.}$
- (3) $\text{C} + \text{O}_2 = \text{CO}_2 + 174,000 \text{ B.t.u.}$
- (4) $\text{C} + \frac{1}{2}\text{O}_2 = \text{CO} + 54,000 \text{ B.t.u.}$
- (5) $\text{H}_2 + \frac{1}{2}\text{O}_2 = \text{H}_2\text{O} + 123,100 \text{ B.t.u.}$
- (6) $\text{CO} + \frac{1}{2}\text{O}_2 = \text{CO}_2 + 122,400 \text{ B.t.u.}$

At the high temperatures prevailing in bed F, which may be chosen from say 1200° to say 2000° F. or higher, endothermic reactions occur to a definite extent, the amount being greater in the higher temperature range. These reactions are typified by Equations 7 to 11 as follows.

- (7) $\text{CO}_2 + \text{C} = 2\text{CO} - 70,200 \text{ B.t.u.}$
- (8) $\text{H}_2\text{O} + \text{C} = \text{CO} + \text{H}_2 - 71,000 \text{ B.t.u.}$
- (9) $\text{H}_2\text{O} + \text{CH}_4 = \text{CO} + 3\text{H}_2 - 108,110 \text{ B.t.u.}$
- (10) $2\text{H}_2\text{O} + \text{CH}_4 = \text{CO}_2 + 4\text{H}_2 - 108,840 \text{ B.t.u.}$
- (11) $2\text{H}_2\text{O} + \text{C}_2\text{H}_4 = 2\text{CO} + 4\text{H}_2 - 124,875 \text{ B.t.u.}$

Now, in operating the invention in this example, combustible gas is supplied to the heater through valve 8 and air for its combustion is introduced through valve 6 and the gas is burned in bed F. The velocity of the total fluid stream up through the bed is regulated as in Example 1 so that the fuel solids in the lower zone, but above grid 5, are densely fluidized without settling. It is desirable that the velocity in the top of bed F be close to or at the settling velocity of the larger size particles of char therein to minimize solids entrainment. In this manner the char in heater 1 is heated largely by combustion of combustible gas although a small amount of the char therein is reacted endothermically in an upper zone above the bottom zone of bed F. Using thermocouples 46 and 47 to guide in controlling temperatures in bed F one may introduce flue gas at the base of the heater through valve 10 to avoid any local overheating in the bottom half of the bed. When steam is used for this purpose, admitted through valve 36-A, the heating value and hydrogen content of the gas passing through offtake 13 are higher than when steam is not used. This step of using some steam during the heating operation not only raises the calorific value of the heater-effluent gas but it also increases the volume of it for a given bed temperature. After establishing a chosen mean temperature in the fluidized bed F, of 1600° to 1800° F. in this example this temperature is maintained therein by the proper adjustment of relative quantities of combustible gas and air supplied to bed F, using steam and/or excess of gas or air as a temperature equalizing agent, as well as controlling and regulating the rate of feed of char from reservoir 2. As in Example 1 the hot effluent gas passes out through 13, 14 to coal reservoir 15 in sufficient amount to preheat the coal therein to a chosen mean discharge temperature which in this example is 600° F. The total amount of gas generated is in excess of that required to preheat the coal hence some of the gas is diverted through valve 22 the combined stream passing through 18 to boiler 19 where it is burned to generate steam which steam passes out through 35. When desired the surplus of producer gas may be discharged through valve 45 and used as fuel gas to the heater, this is particularly desirable when the char is relatively valuable. Again, when the fine char is of low value it is advantageous to introduce an appreciable amount of steam to make more combustible gas in bed F and to recycle a portion of this to the heater as fuel. After the temperature of the bed F is established and an initial bed of

char is confined in the carbonizer, hot char is supplied to the carbonizer thru valve 12 at a substantially uniform rate. After a layer of hot char approximately 10 inches deep is established on the top of the char in bed C and while the hot char is still being supplied thereto coal is allowed to pass from reservoir 15 through 23 and 24 until an amount of coal equivalent to a layer of 6 inch depth is supplied to bed C. This layer of coal will comprise about 10 to 30 percent hot char in this example and the remainder is coal. This cyclic supply of coal and continuous supply of hot char is continued and as stated above the bed C is maintained at a substantially constant level in the carbonizer, by discharging the product solids over table 26, through valve 31 to bin 32 at a continuous or intermittent controlled rate. A cooling fluid is passed into the carbonizer adjacent the bottom of bed C and this fluid passes upwardly through this bed and out with the coal gas through 41 and 42. Steam was mentioned as the cooling agent in Example 1 but because the steam thus used must ultimately be cooled and condensed and because steam is sometimes more valuable for other uses, coal gas is used in this example advantageously along with some steam; the steam promotes a certain amount of endothermic reactions in bed C by virtue of reactions such as are shown in Equations 7 to 11, and these reactions not only cool the hot char but the steam is consumed to the extent that it is reacted. Thus a marked economy is made by circulating a combustible gas along with steam up to as much as 50% or more of the total gas-steam coolant. If the high calorific value of the coal gas is important a hydrocarbon, for example propane may be used at least in part as coolant; it will be partly cracked to methane ethylene and hydrogen, and some of it will react with steam forming CO and H₂. The fluid stream passing up through the layers in bed C as the char is discharged through 31 maintains the hot zone in the top half of the bed. Similarly as in Example 1 the small-size char, through about 1/4 inch diameter screen, is fed to the heater through valve 4 at a rate adapted to maintain a substantially uniform depth of bed therein. Operating at the temperature of this example much of the volatile matter is expelled from the coal upon carbonizing and hence the yield of byproducts is increased and the yield of coke is less than in Example 1. A somewhat larger amount of fines (coke-char) may be produced in the carbonizer than in Example 1 but some good size coke is made larger than in Example 1, in fact larger than 1-inch diameter. This lump fuel (coke) is excellent for use in oxygen-steam gas producers for making synthesis gas and the like; the fine sizes being returned to the heater as fuel. The coal gas is admitted through valve 40 and the steam through valve 36. At this point it seems important to draw attention to the fact that the solid fuel supplied to the heater is introduced therein at a point considerably below the top of bed F, this allows residence time in that bed for substantially complete consumption (combustion) of the powder-size particles of char which may thus be fed to the bed along with larger size particles. The top portion of bed F is advantageously of greater diameter than the remainder of bed F so that the fine-size fuel particles may have greater residence time in that bed; the stream velocity is lower in this expanded zone.

In order to minimize the amount of suspended solids in the coal gas and tarry vapors exiting through 41 and 42 it is advantageous, not only to feed coal from 15 that is substantially free of fines but it also is advantageous to settle hot char in the heater just before discharging it to the carbonizer; a settling means is shown at 61. In this manner fines will not be present in appreciable amounts in the hot char fed to the carbonizer if the settling reservoir 61 is of such size that settled char is present therein at all times. It will be understood that when coal gas, or effluent from the carbonizer, is recirculated back

to the bottom of the carbonizer valuable components thereof may be removed before such recirculation by known procedures and means not shown in the drawing; the recycle gas enters the carbonizer through valve 40 of the figure. In this manner the tar, benzol, toluol light oil and other products may be recovered.

The temperature of the effluent gas from 1 passing through 13 and 14 in this example is so high that in some cases it is too hot to directly contact coal in reservoir 15; when this is the case a coolant gas is also supplied to 15 as through conduit 43 and valve 44.

As in Example 1 the carbonized product is removed from the carbonizer by passing over rotating element, table 26, actuated by motor 28, passing thence through valve 31 to char bin 32.

It will be observed that when char is oxidized or burned in heater 1 below the softening temperature of the ash, the resulting finely divided ash is carried out entrained in the gaseous effluent passing through the coal in reservoir 15 and/or passing to boiler 19 through valve 23. In cases where considerable solid fuel is thus burned in the heater, and when the ash content is high it is advantageous to pass the effluent gas from 1 through 13, 13-A, valve 51, separator 52, offtake 53-A, and valve 58 before passing it into coal reservoir 15, removing entrained ash in the separator and discharging it through valve 60; this is an aid in keeping the ash content of the product char from the carbonizer at a minimum.

In practicing this invention as described in Example 2, it is sometimes found to be desirable to hasten coking and operate at high mean temperatures in the hot zone of the carbonizer with a minimum amount of recirculation of hot char and/or without maintaining excessive temperatures in bed F of the heater; this is accomplished by maintaining a temperature of say 1600° F. in bed F and discharging hot char therefrom through 11 and 12 at that temperature, and introducing a relatively small amount of air or oxygen, into the carbonizer while feeding the coolant fluid thereto. This air is advantageously supplied through conduit 62, valve 63, chamber 64, and hollow shaft 30, although it may be supplied through 37 and 38. The thus admitted air, introduced below table 26, becomes heated as it cools the coke in the bottom zone of the carbonizer bed C and finally reaches a temperature where it is capable of generating heat by oxidation reactions such as are indicated by Equations 1 to 6. In this manner an upper zone of bed C is heated to a higher temperature than the mean temperature of the hot char and coal fed thereto through conduits 11 and 23. The latter hot zone is below the top zone of bed C. In this practice coal can be carbonized at temperatures of say 1400°, 1600° or 1800° F. even though the quantity and temperature of the hot char fed from the heater are inadequate to cause such carbonization. This is an important part of this invention. Although the product gas exiting through 41 is somewhat diluted by such addition of air to bed C the advantages include:

(a) Lower temperatures may be maintained in the bed F in the heater.

(b) Higher rate of throughput (coal carbonized per unit of time).

(c) Absolute control of the completeness of carbonization of the coal.

(d) Increase in rate of production of coal gas, tar and total gas discharged from carbonizer.

(e) The completeness of carbonization is not entirely dependent on the temperature of the hot char from the heater.

(f) The coal initially fed to the carbonizer as lump-coal is completely carbonized throughout the lumps not merely on the surface.

(g) Less fuel need be burned in heater 1 per ton of coke product recovered.

Operating conditions and quantities of materials for a

particular set of temperature conditions are presented in Example 3 including the features just described.

Example 3

Producing coke by carbonizing coking coal at 1620° F. employing fine char from bed F at 1600° to 1650° F. and coal sized ½ to 1½ inch diameter.

A bed of fine size char, through ¼ inch and on ½ inch screen is heated in bed F as described and hot char is supplied to carbonizer 25 until the latter vessel is about ¾ full. The specific operations of this example now begins, for a heater having a mean inside diameter of 4.2 feet.

Air supplied to heater per hour, cu. ft.	250,000
Char fed to heater, from 2, per hour, lbs.	14,300
Char consumed in heater per hour, lbs.	2,500
Hot char at 1600° F. fed to carbonizer per hour through conduit 11, lbs.	11,600
Product coal gas 460 B.t.u. per cu. ft. fed to heater per hour through 7 and 8, cu. ft.	37,000
Producer gas exiting through 13, cu. ft. per hour ..	292,000
B.t.u. of the producer gas, per cu. ft.	100
Coal fed to carbonizer per hr. through 23 and 24, lbs. at 550° F. to 600° ..	10,000
Water supplied to carbonizer as through 56 and 57, per hour, lbs.	3,000
Product coal gas recycled back to carbonizer per hour, cu. ft.	20,000
Air fed to carbonizer per hour, through 62, 63, 64, and 65, cu. ft.	15,000
Product gas 460 B.t.u. discharged through 41 and 42 per hour, cu. ft.	65,000
Char burned in carbonizer per hr., lbs., about ..	125
Carbonized coal (coke and/or char) discharged from the base of carbonizer, lbs. per hr. is approximately, lbs.	18,400

It will be noted that the steam formed by vaporization of water mist injected through 56 and 57 into the carbonizer, along with air, passing upwardly in the carbonizer cools the heat-treated solids descending therein and themselves become heated to about 900° to 1000° F. or higher before combustion is initiated since that usually is the approximate ignition temperature of the gas and the solids (coke and char). In this manner the extra heat is provided by combustion in a zone of the carbonizer above the bottom zone thereof where it is most needed to promote completion of carbonization. The rate of discharge of the cooled solids product through 31 into bin 32 is controlled by regulating the speed of rotation of table 26 by making proper adjustments of the gear controls in 29; the coal should "soak" in the hot zone for sufficient time so that the solid product shows a satisfactory degree of carbonization. For a given rate of solids discharge through 31, the volatile content of the coke made can be varied; increased by decreasing the amount and/or temperature of the hot char fed to the carbonizer through 12, by increasing the rate of feed of coal through 24 or by decreasing the supply of air to the base of the carbonizer or by combinations of these procedures. Contrarywise, the degree and rate of carbonization can be increased by increasing the supply of air to the base of the carbonizer and/or by increasing the supply of hot char thereto per unit of coal treated.

Example 4

Carbonizing coking coal and making coke and rich coal gas with a high yield of by-products, tar, light oil and ammonia.

In this example the operation is started much the same as in Example 3. The temperature of the hot char fed to the carbonizer 25 through 12 is of the order of 1600° to 1650° F. Instead of circulating air to the base of the carbonizer as through 37 and 38, valve 38 is closed and only combustible gas (coal gas in this case) and steam are passed up through bed C. The steam may be generated as in Example 3 by injecting a water mist through 56 and

57 or supplied through valve 36; the coal gas, freed of valuable byproducts, is supplied through valve 40, the product gas passing out of the carbonizer as in the previous example through 41 and 42.

The operating dates are as follows for a heater having a mean diameter of about 5.5 feet.

Air supplied to heater, cu. ft. per hr.	220,500
Temperature of air supplied heater, ° F.	600
Product coal gas supplied to heater, cu. ft. per hr.	50,000
Total producer gas discharged from heater per hr., including recycle, cu. ft.	300,000
B.t.u. per cu. ft. of total producer gas	115
Temperature of char supplied to carbonizer, ° F.	1,600
Weight of char supplied carbonizer per hr., lbs.	10,000
Coal supplied to carbonizer per hr. lbs.	9,000
Temperature of coal fed to carbonizer, ° F.	600
Size of coal fed to carbonizer 0.5 to 1.25 inch diameter. Coke, ½-inch and smaller fed to heater per hr., lbs.	12,100
Calorific value of gas from carbonizer, B.t.u. ..	510
Recycle of 510 B.t.u. gas back to carbonizer per hr. cu. ft.	50,000
Coke recovered per hr., lbs.	16,500

The product (coke) discharged from the carbonizer through 31 is a low-temperature coke much of which is in the size range ¾ inch to 1¼ inches. The fines, ½ inch and smaller are returned to the heater through reservoir 2, and conduit 3. The hot char is fed to the carbonizer at a uniform rate through 11 and 12 but the coal supplied to the carbonizer through 23 and 24 is preferably fed intermittently by regulating valve 24. Thus alternate layers of hot coke and mixed coal and hot coke. The tar and light oils are removed from the coal gas before it is recycled in the system.

In view of the foregoing examples it is believed that one skilled in the art can practice the invention without limitation to those examples. For example, when the coke is not of particular value and combustible gas is more valuable the carbonizer may be operated with a minimum amount of recirculation of coal gas, and air (or oxygen) can be supplied to the bottom of bed C along with a coolant fluid such as steam; in this manner water gas is produced by reaction of Equation 8 and heat for the reaction is supplied by reactions such as are represented by Equations 3 and 4. In this case it is necessary to proportion the amounts of endothermic and exothermic fluid reactants fed to the carbonizer so that a suitable temperature is maintained in the upper zone of bed C. Again, when hydrocarbons are available at sufficiently low cost they can readily be re-formed in the carbonizer carrying out the basis operations substantially as described but using as the cooling fluid the reactants H₂O, O₂ and the hydrocarbon to be re-formed. The combination of reactions occurring are represented by Equations 1, 3, 7, 8, 9, 10 and 11. However the quantities are presented here for the re-forming of butane, as an example.

Operating the heater with a bed temperature of about 1600° to 1800° F. and circulating the hot char to the carbonizer in this range, one may introduce into the carbonizer adjacent the bottom of bed C, 200 lbs. of steam and 1600 cubic feet of oxygen for each 1000 cu. ft. of butane vapor. The oxidation of coke in the carbonizer will approximate 34 lbs. (30 lbs. carbon) for each 1000 cu. ft. of butane thus used. It is desirable to supply coal to the carbonizer in this instance in amounts sufficient to produce the necessary char for the heater. The hot char circulation rate is maintained sufficiently high to supply any needed heat; with a high rate less oxygen is required. The re-formed gas thus made, figured free of coal gas, amounts to 12,500 cu. ft. per M c.f. of butane

used; its composition when air is used to supply the oxygen is substantially as follows:

	Cubic feet	Percent	B.t.u.
CO ₂ -----	1,417	7.6	
CO-----	3,285	17.7	57.1
C ₂ H ₄ -----	172	1.0	16.2
CH ₄ -----	100	0.6	6.0
H ₂ -----	7,570	40.8	132.7
N ₂ -----	6,010	32.3	
	18,554	100.0	212.0

With the above proportions of oxygen and steam the heat necessary for the gas-making reactions is supplied chiefly by the exothermic reactions in the gas stream.

When the hot solids are circulated to the carbonizer at a high rate, so as to supply a large portion of this heat of reaction considerably less oxygen is required in the carbonizer but more combustion must be promoted in the heater; thus less coke is made and more fine size char (coke) is consumed in the operations. The economic balance or usual limit is reached when just sufficient coke is made to supply the amount of solid fuel consumed in the heater plus the amount used in water gas reactions in the carbonizer. Twenty five hundred lbs. of coke at 1800° F. contain enough heat energy as available sensible heat for the conversion of 400 cu. ft. of butane vapor plus 140 lbs. of steam to approximately 6,000 cu. ft. of re-formed gas, when the reactants, butane and steam are preheated in the bottom of bed C as in this invention to reaction temperature and no oxygen is fed to the carbonizer. It is preferable to admit some oxygen with the steam and butane and not only to reduce the rate of circulation of the hot char but to increase gas-making capacity and to maintain a thicker hot reaction zone adjacent the top of bed C. The temperature in the latter zone must be maintained for good conversion, by circulation of solids and the inclusion of oxygen as a reactant along with steam and the hydrocarbon. It will be noted that a high temperature, above about 1500° F. is usually required for satisfactorily re-forming hydrocarbons when making chiefly CO and H₂; this means that all of the sensible heat of the circulated hot char is not utilizable for directly supplying the heat of reaction of steam and the hydrocarbon. Summarizing, particularly satisfactory results are obtained with quantities, employing air as the exothermic reactant, are as follows:

Hot solids supplied to carbonizer per unit of time, lbs. at 1800° F. -----	1,000
Steam supplied to carbonizer per unit of time, lbs. -----	150 to 200
Butane vapor per unit of time, cu. ft. ---	1,000
Oxygen to carbonizer per unit of time, cu. ft. -----	1,200 to 1,590
Coke consumed in carbonizer per unit of time, lbs. -----	30 to 34
If coke is burned as fuel in the heater the total coal fed carbonizer per unit of time is approximately, lbs. -----	400

Using appreciably more oxygen than the amounts just given tends to cause the hot zone to travel down in bed C and it also causes the oxidation reactions to occur in a lower zone of the bed; the quantity of oxygen stated is such that flame does not readily propagate through the gasiform mixture in bed C until a rather high temperature is reached in an upper zone thereof, and this is decidedly beneficial. As in other examples water is injected, as a further coolant, at the bottom of the carbonizer to the extent necessary.

I find that less than half of the energy of the fuel consumed in the heater, generating producer gas and heating the char in bed F, appears as sensible heat of the hot char supplied to the carbonizer 25 through 11 and 12; this is

an undesirably low percent when the producer gas is not useful or valuable. It is also found, in attempting to overcome this difficulty by burning producer gas as fuel in bed F of heater 1, that the CO₂ and H₂O formed as products of combustion in the lower half of the bed react with carbon in the upper half of the bed to form CO and H₂, thus diminishing the benefits derived from so using producer gas; this is particularly true with a deep fuel bed in the heater and at high temperatures therein, above 1650° F. This bad feature is largely corrected when some of the combustion-supporting fluid is introduced into bed F in a zone thereof near the top. Thus, when about 50 to 70 percent of the air or O₂ is introduced through 6 and 9 and the remainder is introduced through 68, 69, 70 and ports 71, the CO₂ content of the gas exiting through 13 is higher and more heat is stored in bed F per unit amount of oxygen supplied thereto than when all of the oxygen is admitted through 6 and 9. This is not only true when combustible gas is burned in bed F (supplied through 7 and 8) but also when the char is chief or sole fuel used to heat bed F. Under these conditions, applied to the previous examples, the producer gas is of lower calorific value, and may be as low as 30 to 60 B.t.u. More than twice as much hot char would be produced in Example 3 and hence more than twice as much coal would be carbonized per unit of time when 30 to 50 percent of the air used in that example is introduced through 68, 69, 70, and 71. It will be understood that this upper zone blasting may be employed, and advantageously so, in the above cited examples when the producer gas is not of particular value and carbonizing capacity is most important.

For maximum throughput of coal, and production of the maximum amount of coke, one should employ upper-zone blasting with air or O₂ in bed F, as through 68, 69, 70 and 71 and preferably should also use some air or O₂ with the cooling fluid supplied to the base of the carbonizer. The approximate quantities and yields, conducting the operation along these lines, under a set of conditions similar to that in Example 3 are as follows:

Air to base of heater per hr., cu. ft. -----	140,000
Air to upper zone of heater per hr., cu. ft. -----	110,000
Coal gas to base of heater per hr., cu. ft. -----	37,000
Calorific value of the coal gas, B.t.u. -----	460
Temperature of air to heater, ° F. -----	600
Char (coke), about 1/8 inch size per hour, lbs. -----	20,600
Char consumed in heater, lbs. per hr. -----	2,250
Hot char to carbonizer, lbs. per hr. -----	18,000
Approximate temperature of char, ° F. -----	1,650
Coal gas fed to carbonizer per hr., cu. ft. -----	20,000
Coal fed to carbonizer per hr., lbs. -----	16,000
Temperature of coal to carbonizer, ° F. -----	600
Total hot carbonized solids (coke) discharged from carbonizer per hr., lbs. -----	28,900
Steam and/or water supplied per hr. to base of carbonizer, sufficient for cooling air supplied to the base of carbonizer per hr., cu. ft. -----	20,000

More air may be used, to increase the amount of coal that can be carbonized per unit of time but the calorific value of the product gas from the carbonizer will be decreased. It is always desirable to have ample hot circulated coke from the heater present with the coking coal.

While it will be understood that there is no limit on the pressure employed in chambers 1 and 25, other than technical or economic limits, the pressures in the different vessels should be so adjusted that the pressure in the top zone of carbonizer 25 is less than in the coke feed line 11 so that a ready flow of solids, from 1 to 25 through 11, is obtainable. The drop in pressure in heater 1, with a coke bed 20 feet deep will not be greater than about 4 to 5 pounds per sq. in. hence with an initial pressure in bed F adjacent grid 5 of 10 p.s.i. gage the pressure at the top of the bed will approximate 5 to 6 lbs.; under these con-

ditions the pressure in the top zone of bed C (in the carbonizer) should be somewhat less than 5 to 6 lbs. Since it is normally not economical to pump air, for combustion of fuel in bed F to high pressures, it usually will be found advantageous to employ a pressure in bed F adjacent grid 5 of not more than about 20 lbs. gage. Obviously the bed F in heater 1 normally should be shallow for most economical results unless the calorific value of the producer gas is important; this permits air blasting it at lower pressure thus economizing on pumping costs. The upper zone of bed F is advantageously of greater diameter than the bottom zone thereof to facilitate settling of solids in the top zone into receiver 61, to decrease turbulence in the said top zone and to retain fine-size particles of coke in the bed long enough for substantially complete gasification. The top zone of bed F is substantially, or approximates, a settling zone for the larger pieces of char therein. The superficial velocity of the fluidizing stream through the bottom zone of bed F is advantageously higher than in the top zone thereof in order to minimize overheating of the solid fuel therein and fusing of the fuel ash. A shallow bed also minimizes slugging difficulties; when the coke fluidized in bed F is of relatively large size, say $\frac{3}{8}$ to $\frac{1}{2}$ inch mean particle diameter the depth of the bed advantageously should be limited to about 1.8 or less times the diameter of the bed in order to eliminate slugging effects in the bed.

The diameter of bed C in carbonizer 25 is normally greater adjacent the bottom to facilitate coke removal; this is less essential when the amount of hot char from the heater is much greater than the amount of coking coal fed to the carbonizer; when the coal carbonized is non-coking, and when the size of the coal fed to the carbonizer is smaller than about 1 inch diameter.

Since more time is required to heat the char in bed F with large size particles than with small ones it is usually economical to limit the maximum size of char fed to this bed to $\frac{1}{4}$ inch or even to $\frac{1}{8}$ inch diameter; this permits the use of a shallower bed in the heater 1.

For the purpose of clearness the words "char" and "coke" which have been used largely as synonymous in the foregoing are defined as follows: "Char" is a carbonized solid fuel which may or may not be the result of fusion at high temperatures. Lignite, sub-bituminous coal, and numerous other fuels yield, upon carbonization, small-size solids (residuum) which have many properties similar to those of coke, but they are commonly called char. Certain bituminous coals from Illinois do not completely fuse when carbonized but they do form char, small pieces of which are much the same as coke. The term "coke" is commonly used to define a carbonized coking coal; the coal fuses in the processing. Since an object of this invention is to carbonize solid fuels which might include peach pits, sub-bituminous coals, coking or non-coking coals the word "char" is used to include a solid carbonized fuel which may be coke. When carbonizing coking coal it is quite advantageous that the fuel circulated hot from the heater to the carbonizer be small-size coke rather than a true char from a non-coking coal.

It is believed, in view of the examples, that one skilled in the art can practice the invention without the limitations of the examples. Variations can be made in the quantities of production of producer gas, coke (carbonized product), coal gas (volatile matter from the fuel carbonized), re-formed gas and water gas according to any particular set of economic conditions. Likewise one may choose the kind and amounts of gases supplied to the heater and to the carbonizer in maintaining the chosen temperatures therein.

The invention should be applicable at a mine or other source of carbonaceous substance to be carbonized in the generation of power, the recovery of gas and volatile products of the substance treated, and the recovery of valuable solid products of carbonization. Low-temperature coke,

active carbon, high-temperature coke and the like may readily be produced in the practice of this invention.

Having described by invention so that one skilled in the art can practice it, I claim:

1. The process of carbonizing carbonizable solid fuels by contacting hot, small-size coke with said fuels in a subdivided state and initially at a relative lower temperature producing additional coke and vaporous products of carbonization, comprising, heating previously prepared, sized coke, sized smaller than about $\frac{1}{2}$ -inch diameter, to a carbonizing temperature above about 1250° F. while it is confined in a heating zone by promoting combustion reactions in said zone in contact with said prepared coke, separating the thus heated coke from gaseous products of combustion and feeding it as a substantially continuous stream to the top of a deep, enclosed carbonization zone, simultaneously introducing also subdivided solid fuel to be treated which is substantially in the size range 0.5 to 1.5 inches diameter into the top of the latter zone at a particular rate contacting the heated coke and said solid fuel in said carbonization zone, passing the whole mass slowly downwardly through said carbonization zone substantially as a continuous fixed bed column, introducing adjacent the bottom of the columnar mass a gasiform stream initially comprising oxygen and water vapor at a temperature much lower than that of said heated coke, and passing it up through said mass substantially continuously thereby cooling said mass in the bottom portion of the carbonization zone and simultaneously heating said gasiform stream, causing the thus heated stream to facilitate the transfer of heat from said heated char to said subdivided fuel as it passes up through the upper portion of said mass, promoting combustion reactions in the latter stream in a portion of said columnar mass only above the bottom zone thereof with consumption of said oxygen generating heat therein to further aid carbonization of said fuel, thereby carbonizing said subdivided fuel in transit through said carbonization zone, discharging said gasiform stream along with volatile products of carbonization and products of combustion from above said mass, and discharging the coke and solid product of carbonization from adjacent the bottom of said carbonization zone substantially continuously; said particular rate being such that alternate layers (strata) are formed in said column initially comprising chiefly hot coke in one layer and chiefly said subdivided fuel in an alternate layer thereby making from said fuel coke of larger size than $\frac{1}{2}$ -inch diameter, meanwhile separating the large size product coke from the fines in a known manner and circulating some of the latter fines back to the heating zone as said prepared coke.

2. The process defined in claim 1 in which the readily condensable products of carbonization are removed from the discharged gasiform stream by known means and at least some of the uncondensed gaseous portion thereof is burned as fuel to heat said char in said heating zone.

3. The process defined in claim 1 in which the readily condensable products of carbonization are removed from the discharged gasiform stream by known means and at least a portion of the uncondensed gaseous fraction thereof is supplied to the carbonization zone as part of the gasiform stream initially comprising oxygen and water vapor, and in which the latter portion is at least partly reacted with said oxygen to generate heat in a portion of said mass above the bottom zone thereof.

4. The process of carbonizing carbonizable solid fuels the particles of which have some agglomerating properties when heated to carbonizing temperatures, by contacting them in a subdivided state with hot small-size char producing additional char and vaporous products of carbonization, comprising, heating a mass of previously prepared char, sized smaller than about $\frac{1}{2}$ -inch in diameter, to a carbonizing temperature above about 1250° F. while it is confined in a heating zone by pro-

moting combustion reactions in said zone in contact with said prepared char, separating the thus heated char from gaseous products of combustion and feeding it substantially continuously as a stream to the top of a deep, enclosed carbonization zone, simultaneously but intermittently introducing also into the top of said carbonization zone subdivided, lump, solid fuel to be carbonized which lump fuel is sized larger than said heated char, so controlling the rates of feed of the heated char and the lump fuel to the latter zone that a fixed bed is established therein comprised initially of alternate strata, one stratum being largely said heated char and an alternate stratum being largely said lump fuel, thus contacting said lump fuel with said heated char, passing the whole bed slowly down through said carbonization zone, introducing at substantially the bottom of said fixed bed a gasiform stream comprising oxygen, water vapor and combustible gas at a temperature initially much lower than that of said heated char and passing the latter stream up through said bed as a heat transfer medium and a flushing agent at such a rate that the lower portion of said bed is cooled as the gasiform stream absorbs sensible heat therefrom and is itself heated, promoting combustion reactions in the thus heated stream in a portion of said bed above the bottom zone thereof with consumption of said oxygen and at least some of said combustible gas thereby further heating said gasiform stream, promoting carbonization of said lump fuel with some agglomeration thereof as the latter stream passes on through the strata in the upper zone of said bed, discharging said gasiform stream along with volatile products of carbonization from above said bed, and discharging the solid product of carbonization substantially continuously from the bottom of said carbonization zone, thereby making from said lump fuel combustible char of larger size than about 1/2-inch.

5. The process defined in claim 4 in which the lump fuel is initially preheated to a temperature of 500° to 650° F. before it is introduced into the carbonization zone.

6. In the process of carbonizing carbonizable fuels and producing volatile products and a solid combustible residue by virtue of heat imparted to said fuels by association with preheated small-size char, the steps comprising, preheating a mass of small-size char to an elevated temperature of the order of 1250° to 1650° F. by promoting combustion reactions in contact therewith in a confined heating zone, feeding the thus heated solids to a deep enclosed carbonization zone along with a subdivided solid fuel to be carbonized in such a manner that a fixed bed is established in the latter zone comprised of alternate strata, one stratum comprised largely of said fuel with some of said heated char, an alternate stratum being comprised largely of said heated char, carbonizing said fuel producing additional char by passing a gasiform fluid stream up through said bed in such a manner that it cools the bottom zone of said bed, becomes preheated itself by contact with the solids thereof and causes a transfer of heat from the said heated char to the subdivided fuel during its travel through the different strata in a zone of said bed above the bottom zone thereof, meanwhile slowly and substantially continuously passing the said bed down through said carbonization zone, removing the cooled carbonized fuel from the bottom

portion thereof, discharging said gasiform stream along with volatile products of carbonization from above said bed.

7. In the process of carbonizing carbonizable solid fuels which have some agglomerating properties when heated to carbonization temperatures, by contacting them in a subdivided state and initially at a relatively low temperature with small-size hot char producing additional char and vaporous products of carbonization, in combination the steps comprising, feeding substantially continuously, a stream of previously prepared small-size char at a temperature above about 1250° F. into the top of a deep enclosed carbonization zone, simultaneously but intermittently also introducing into the top of said zone such a fuel to be carbonized while it is at a temperature of 500° to 650° F. and largely in a size range larger than 1/2-inch diameter forming in said zone a deep, fixed bed of solids comprising char and said fuel comprising initially a plurality of different strata of different thickness, so controlling the rates of feed of said hot char and said fuel to said zone that alternate layers of chiefly said hot char are disposed between thinner layers of a mixture of said fuel and said hot char, passing said bed slowly down through said zone substantially as a columnar mass substantially continuously, passing a gasiform fluid including water vapor at a much lower temperature than that of said hot char through said bed from bottom to top substantially continuously, so controlling the rate of flow of said fluid that it cools the said solids in the bottom zone of said bed thereby becoming preheated itself and transfers heat from said hot solids to said fuel in zones of said bed above the bottom zone thereby promoting carbonization of said fuel with agglomeration of particles of said fuel in said bed, removing the vaporous products of carbonization in the fluid stream from above said bed and recovering them, discharging the solid-fuel product of carbonization substantially continuously from the bottom of said carbonization zone and recovering it.

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