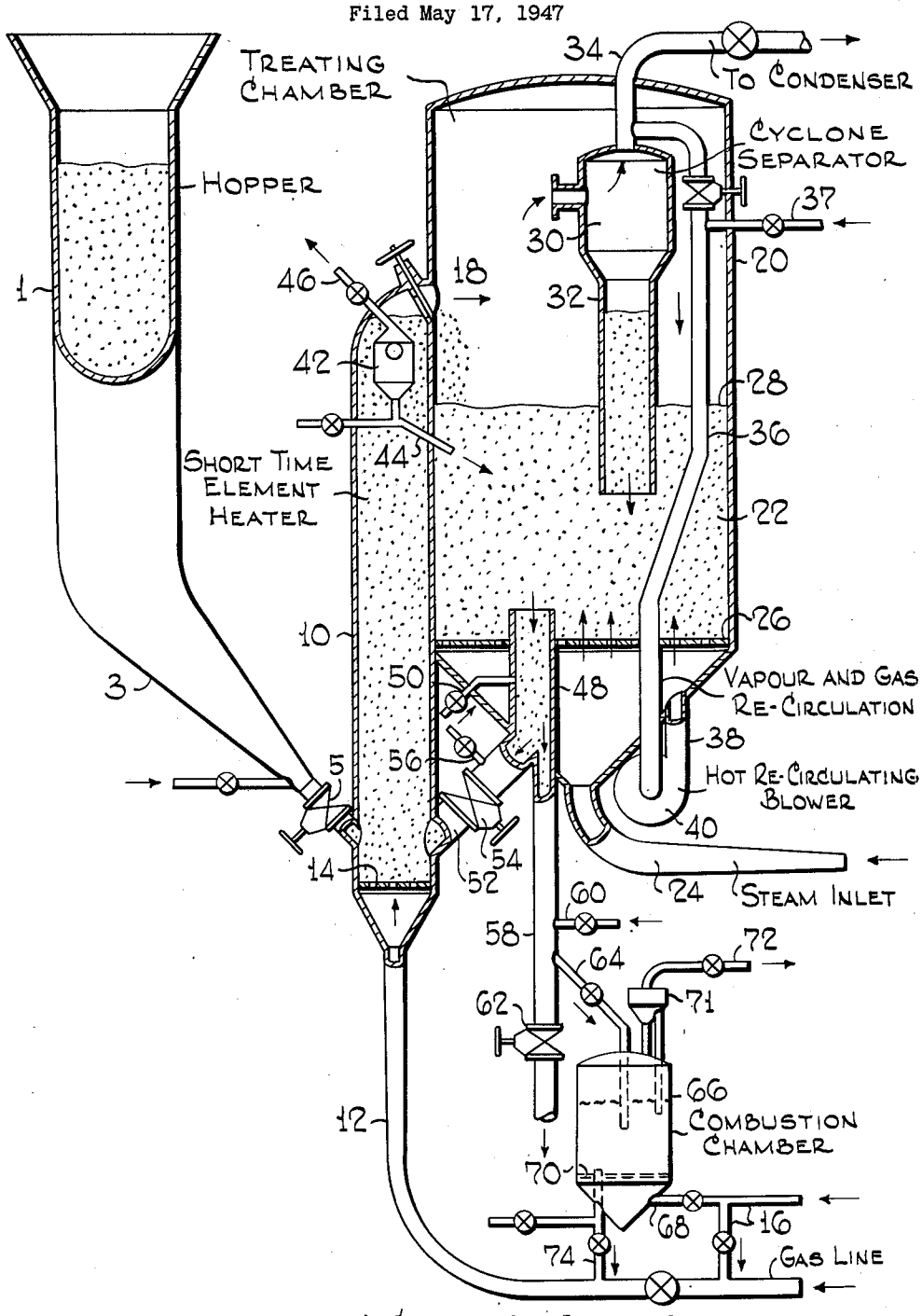
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FLUIDIZED CARBONIZATION OF SOLIDS

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FLUIDIZED CARBONIZATION OF SOLIDS

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The present invention relates to the handling of carbonaceous solids. More particularly, the invention is concerned with the treatment of finely divided carbonaceous solids such as all types of coal, brown coal, lignite, oil shale, tar sands, asphalt, cellulosic materials including lignin, etc. to produce valuable volatile products.

Heretofore, solid carbonaceous materials of the type mentioned above have been treated at elevated temperatures in fixed bed operation to form liquid and gaseous fuels such as light oils, tars, coal gas, producer gas and water gas. However, these processes involve either discontinuous operation or inefficient conversion of the available carbonaceous matter into volatile fuels and heat.

The operation of these processes may be made fully continuous by employing the so-called fluid solids technique in which the reactions take place in dense fluidized beds of finely divided solids maintained in a turbulent ebullient state by means of fluidized gases. This technique has highly desirable additional advantages including greatly improved heat distribution and ease of solids handling.

However, serious difficulties have been encountered in handling the finely divided raw material as a result of its tendency to pass through a plastic state when heated slowly to temperatures within the range of about 500°–1000° F., depending on the character of the solids. When this plastic state is reached, the solid particles tend to agglomerate or "cake" or stick to each other and to equipment walls.

This phenomenon is particularly troublesome when charging solids of this type, for instance bituminous coal, to high temperature treating zones such as carbonization chambers, etc. employing the fluid solids technique at temperatures as high as or higher than the plastic temperature of the solid charge. The raw coal, as it comes from the cleaning plant, normally has a particle size of about 8 mesh or ⅜" by 0 which is suitable for fluidization. However, when fed directly to a "fluid" carbonization chamber operated at temperatures of, say, 900°–1200° F., the fresh coal particles become pasty and form agglomerates which interfere with a proper fluidization by causing plugging, hanging and channelling of the charge, thus invalidating most of the advantages of the fluid solids technique.

The present invention overcomes the aforementioned difficulties and affords various additional advantages. These advantages, the nature of the invention and the manner in which it is carried out will be fully understood from the following description thereof read with reference to the accompanying drawing.

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It is, therefore, the principal object of my invention to provide improved means for handling finely divided carbonaceous solids.

Another object of my invention is to provide means for improving the treatment, in the fluidized state, of finely divided carbonaceous solids passing through a plastic state when heated to the treating temperature.

A more specific object of my invention is to provide improved means for carbonizing finely divided carbonizable solids in the fluidized state while avoiding plasticization of the charge supplied to the fluidized solids undergoing carbonization.

Other and more specific objects and advantages of my invention will appear hereinafter.

In accordance with the present invention these objects and advantages may be accomplished by heating, in a separate heating zone, the fresh finely divided carbonaceous charge beyond its plastic range and at least up to the temperature of the desired treatment, in intimate contact with a large excess of non-plasticizing, hot, finely divided solid residue from the desired treatment, and feeding the mixture of fresh charge and solid residue thus heated to the fluid treating zone proper. The rate of heat supply to the heating zone and the residence time of the fresh charge therein are preferably so controlled that the charge will reach the desired temperature and will enter the treating zone proper without losing substantial proportions of its valuable constituents. The presence of a large excess of non-plasticizing solids eliminates the danger of caking while the fresh charge passes through the plastic stage and the charge enters the fluid treating zone in a non-plastic state whereby fluidization difficulties are avoided therein.

The heat required in the heating zone may be supplied indirectly by a proper contact with suitable heat exchange surfaces or directly as sensible heat of highly heated gases and/or solids. The simplest and least expensive method of heat supply comprises conducting a partial combustion of carbonaceous matter in direct contact with the carbonaceous charge by admitting a controlled amount of air, oxygen or other oxidizing gas to the heating zone just sufficient to support the desired partial combustion.

In accordance with a preferred embodiment of the present invention, the finely divided solid carbonaceous charge of fluidizable particle size of, say, 8–400 mesh, though larger sizes of up to

¼ or ½" may be used, is passed in the fluidized state upwardly through a heating zone. Simultaneously, the heating zone is supplied with a large excess of finely divided, non-plasticizing, carbonaceous solids from the treating zone. These solids should enter the heating zone at a temperature not substantially below and, preferably, at least as high or higher than the treating temperature. The ratio of solid residue to fresh charge may be within the approximate limits of 5–50, preferably 15–30, parts by weight of residue per one part by weight of fresh charge.

The mixture of fresh charge and solid residue, fluidized by an upwardly flowing gas, is rapidly heated, for example, by partial combustion within the heating zone, to at least treating temperature and then discharged into the treating zone proper wherein it is fluidized by an upwardly flowing gas and maintained for a time sufficient to permit completion of the desired treatment. Volatile products are withdrawn overhead from the treating zone and may, at least in part, be recycled to the bottom of the treating zone for purposes of fluidization. Solid residue which has lost its agglutinating or plasticizing constituents during the treatment is withdrawn, preferably, under the pseudo-hydrostatic pressure of the fluidized solids mass in the treating zone and supplied to the heating zone in the proportions indicated above.

When operating in this manner the danger of caking in the treating zone is practically eliminated since the feed enters the treating zone at a temperature above its plastic temperature. Fluidization difficulties in the heating zone are avoided by the presence of a large excess of non-plastic solids.

Further advantages result from the fact that all the heat required for the desired treatment is generated outside the treating zone proper. In this manner, excessive combustion of valuable volatile products and dilution of the volatile product with combustion gases may be avoided. For example, when heat is generated by partial combustion within the heating zone the combustion gases may be either passed together with the heated solids into the treating zone or they may be separated from the solids prior to the discharge of the heated solids into the treating zone. In either case, the combustion of valuable constituents of the charge is kept at an insignificant minimum and in the latter case there is no dilution of volatile products with combustion gases. When heat is generated by partial combustion of solid residue from the treating zone outside the treating zone proper and prior to its entry into the heating zone, the same advantages i. e. elimination of product dilution and product losses by combustion may be secured.

While the present invention affords greatest advantages when applied to the carbonization of carbonizable solids of the type specified to produce valuable volatile products and coke, it may be readily adapted to other treatments of carbonaceous solids including the production of carbon monoxide-containing gases such as water gas or producer gas, by reaction with an oxidizing gas such as steam, CO_2, air, oxygen or mixtures thereof; heat generation by combustion; etc.

Having set forth the general nature and objects, the invention will be best understood from the subsequent more detailed description in which reference will be made to the accompanying drawing which shows a semi-diagrammatic illustration of equipment particularly adapted to carry out a preferred embodiment of the invention.

Referring now to the drawing, the system shown therein essentially comprises a vertical heating zone or heater 10 of relatively small cross-section and a vertical treating zone or chamber 20 of relatively large cross-section, the functions and cooperation of which will be presently explained. In the following detailed description reference will be made to the carbonization in chamber 20 of coal supplied through heater 10. It should be understood, however, that other carbonaceous materials and other treatments may be employed in the same or similar systems in a substantially analogous manner.

When applied to the carbonization of a bituminous carbonization coal having a softening or plastic temperature range of about 700°–800° F., the raw coal having a fluidizable particle size of less than 8 mesh, preferably about 50–200 mesh, is supplied from coal bin or hopper 1 through line 3 provided with control valve 5 to a lower portion of heater 10 by any conventional conveying means, such as an aerated standpipe, a screw conveyor, simple gravity flow or the like. Vessel 1 may itself be fluidized. It may also serve the drying and/or preheating of the coal to any temperature below the plastic range in any manner known per se. The finely divided raw coal entering heater 10 is mixed therein with large amounts of hot non-plastic coke or char supplied from carbonization chamber 20 as will become apparent hereinafter.

The non-plastic char supplied to heater 10 at a ratio of about 15–30 times the weight of fresh coal entering through line 3 has, preferably, a temperature higher than the plastic temperature of the fresh charge and not substantially lower than the carbonization temperature within chamber 20. Char temperatures within the range of 800°–1400° F. are generally suitable for the purposes of the invention.

A fluidizing gas, such as steam, flue gas, product gas, or the like, is admitted through line 12 and distributing grid 14 to the bottom of heater 10 at such a linear velocity that the mixture of fresh coal and char is fluidized by the gas and moves as a highly turbulent fluid-like suspension upwardly through heater 10 to overflow finally through a preferably adjustable orifice 18 into chamber 20.

The conditions of solids residence time and phase density within heater 10 are functions mainly of the rate of solids feed and withdrawal to and from heater 10, solids particle size and composition and the superficial linear velocity and composition of the fluidizing gas admitted to heater 10. These variables together with the heat supplied to heater 10 should be so adjusted and correlated to the heater dimensions that the fresh coal charged to heater 10 will just reach carbonization temperature while avoiding excessive carbonization, within the residence time provided for in heater 10. Gas velocities of about 1–20 ft. per sec., preferably about 5–10 ft. per sec., giving densities of about 1–30 lbs. per cu. ft. in heater 10 are suitable for this purpose at the particle sizes indicated. The fluidizing gas supplied to line 12 may be preheated to any desired temperature, preferably by a suitable heat exchange with volatile and/or solid carbonization products, in any conventional manner.

In order to heat the fresh charge to the desired carbonization temperature of about 900°–1400° F. and to maintain the solids within chamber 20 at this carbonization temperature, heat

must be supplied to the system. For this purpose a controlled combustion may be carried out within heater 10 by adding sufficient oxidizing gas such as air and/or oxygen through line 16 to gas line 12 to support such a controlled combustion. Depending on the relative temperatures and amounts of solids and gases supplied to heater 10 and the temperature desired in chamber 20, the amount of oxidizing gas may vary within wide limits. It may be said, however, that for a carbonization and char recycle temperature of about 900°–1400° F., a fresh feed temperature of about 60°–250° F. and a char to fresh coal feed ratio of about 15–30:1, and oxygen supply of about .03 to .3 lb. per lb. of fresh coal charged is sufficient. The total amount of fluidizing and oxidizing gas supplied to heater 10 should be controlled within the approximate limit of .02 to 4.0 per cu. ft. of gas per lb. of total solids fed to heater 10 so as to maintain an apparent density of the suspension within heater 10 of about 1–30 lbs. per cu. ft.

The dimensions of heater 10 are so chosen that at the prevailing gas and solids feed rates and temperatures, the fresh coal charge attains the desired carbonization temperature in the uppermost portion of heater 10. In this manner, the time for which the fresh charge remains in heater 10 at carbonization temperature is cut to a minimum and no excessive amounts of volatile carbonization products are liberated within heater 10. Total residence times of fresh coal in heater 10 of the order of 5–100 sec. are generally sufficient at the conditions stated, although longer residence times may be desirable in certain cases.

The mixture of fluidized fresh and spent carbonaceous solids together with fluidizing and combustion gases may be withdrawn from the top of heater 10 and discharged through an adjustable orifice 18 into an upper portion of carbonization chamber 20. As a result of the decrease in linear gas velocity within the large-diameter carbonization chamber, a major proportion of the entrained mixed solids drops down immediately upon entering chamber 20 to form a relatively dense solids phase 22 undergoing carbonization. A fluidizing gas, such as steam, product vapors and gases, or the like may be supplied through line 24 and distributing grid 26 to the bottom portion of chamber 20 in amounts sufficient to maintain the solids phase 22 in the form of a dense, turbulent, ebullient, fluidized mass having a well defined upper level 28. Linear fluidizing gas velocities of about 0.1–5 ft. per sec. are generally suitable to maintain dense phase 22 properly fluidized at an apparent density of about 15–50 lbs. per cu. ft. The fluidizing gas supplied through 24 may be preheated to any desired temperature by a conventional heat exchange with volatile and/or solid carbonization products.

Volatile carbonization products admixed with fluidizing gas from chamber 20 and fluidizing and flue gases from heater 10 having suspended therein minor amounts of finely divided carbonaceous solids, are withdrawn from chamber 20 through a conventional gas-solids separator, such as cyclone separator 30. Separated solids are returned from cyclone 30 through return pipe 32 to dense phase 22. Gases and vapors, now substantially free of entrained solids, leave the system through pipe 34 to be treated in a conventional product recovery system (not shown).

In accordance with a preferred embodiment of my invention, at least a substantial proportion of the hot vapors and gases leaving cyclone 30 is recycled through lines 36 and 38 to the bottom of chamber 20 below grid 26 by means of a circulating blower or similar means 40. This cycle stream may completely replace or supplement the fluidizing gas supplied through line 24. This arrangement has the advantage of dispensing with the requirement of a separate supply of fluidizing gas to chamber 20 and of separate preheating equipment for such fluidizing gas. In addition, the residence time of the volatile carbonization products is considerably increased with the result that undesirabe high boiling tarry materials may be cracked down to more valuable low boiling volatiles. It is important, however, that the product gas is passed from cyclone 30 through blower 40 to the bottom of chamber 20 without any significant heat loss in order to avoid tar condensation in, and plugging of, blower 40 and the circulating lines. This may be readily accomplished by maintaining an intimate heat exchange between circulating pipe 36 and carbonization phase 22 as shown in the drawing. In addition a small amount of an oxidizing gas may be admitted through line 37 to add heat by allowing a limited combustion of the recycle products. In this manner the danger of plugging within pipe 36 is substantially eliminated.

So far I have described the discharge of the solids from heater 10 through orifice 18 into chamber 20 by means of dense phase overflow or in the form of a relatively dilute suspension of solids-in-gas. While this arrangement is the simplest and least expensive from the point of view of equipment cost and maintenance, it leads to a dilution of the volatile carbonization product with flue gases from heater 10. If it is desired to recover from chamber 20 a volatile product substantially free of such diluting gases, the solids-in-gas suspension reaching the top of heater 10 may be passed through a conventional gas solids separator, such as cyclone 42 while orifice 18 is closed. Solids separated in cyclone 42 may be withdrawn downwardly therefrom and passed by gravity flow through pipe 44 to dense carbonization phase 22. Pipe 44 may have the form of an aerated standpipe in order to assure satisfactory flow from separator 42 to carbonization phase 22. Gases substantially free of solids may be vented through line 46. It will be understood that more than one separator 42 may be used, if necessary, to accomplish efficient separation and satisfactory solids flow.

Returning now to dense carbonization phase 22, it is noted that the dimensions of this phase should be large enough to permit solids residence times therein affording substantially complete carbonization of the fresh coal charged thereto. These residence times are normally considerably longer than the heating time in heater 10. Absolute values for the dimensions of dense phase 22 and the residence time of the charge in phase 22 depend on many variable. However, residence times of about 2–60 minutes are usually sufficient completely to carbonize the fresh coal charged at the conditions indicated.

Substantially completely carbonized solids, consisting essentially of non-plastic hot char, are withdrawn downwardly under the pseudo-hydrostatic pressure of the fluidized solids phase 22 through a bottom drawoff 48 which may be aerated through one or more taps 50 to facilitate solids flow. Non-plastic char, substantially at the temperature of carbonization phase 22, may be passed through pipe 52 directly to the bottom

portion of heater 10. The rate of char circulation through pipe 52 may be controlled by slide valve 54 at a level of about 15–30 parts by weight of char per part by weight of fresh coal supplied through line 3. Aeration pipes 56 may be provided to facilitate the solids flow through pipe 52. Product char may be withdrawn through branch pipe 58 aerated through taps 60 and controlled by slide valve 62.

As mentioned before, it may be desirable to supply heat to heater 10 and carbonization chamber 20 predominantly or exclusively in the form of sensible heat of circulating solids in order substantially to reduce or completely to eliminate the combustion of valuable volatile constituents of the fresh coal in heater 10. For this purpose, at least a portion of the char withdrawn through pipe 48 may be passed, for instance, through pipes 58 and 64 to a separate combustion zone 66 wherein it is highly heated by a partial combustion of its carbonaceous constituents. Oxidizing gas, preferably air, if desired diluted with flue gas or the like, may be supplied from line 16 through line 68 and grid 70 to the bottom of combustion zone 66 to support the desired combustion and maintain the solids therein in a dense fluidized phase. Flue gases are vented through cyclone 71 and line 72 and highly heated char may be withdrawn through aerated standpipe 74 to be suspended in line 12 in a fluidizing gas such as steam, product gas, or the like and passed from there to the bottom of heater 10. This arrangement has the additional advantage that dilution of the volatile carbonization products with flue gases is avoided and that gas solids separation at 42 becomes superfluous. It will be appreciated that optimum conditions of temperature and solids flow through combustion zone 66 may be readily adjusted to the heat requirements of the system.

While heater 10 may be completely separated from carbonization chamber 20, best results with respect to heat economy are obtained when an intimate heat exchange between these two elements of the system is accomplished. For this reason, heater 10 is shown in the drawing to form an integral part of combustion chamber 20 to permit heat exchange through the wall separating the two-system elements. While I have shown aerated standpipes 48, 52, 58 and 74 to be used for the withdrawal of fluidized solids from vessels 20 and 66, it should be understood that other conventional means for conveying fluidized solids may be used instead, such as mechanical conveyors or the like. The process may be operated in a fully continuous manner by continuously feeding process solids and gases and continuously withdrawing spent solids and carbonization products.

High temperature treatments, different from the carbonization of carbonizable solids, may be carried out in chamber 20. For example, water gas may be produced by raising the temperature of zone 22 to about 1500–2500° F. and introducing an amount of steam through line 24 sufficient to support the desired conversion of carbon into carbon monoxide and hydrogen.

Other modifications of the invention will occur to those skilled in the art.

The invention will be further illustrated by the following specific example.

Example

Operating conditions for the carbonization of Pittsburgh seam-bituminous coal in a system of the type illustrated in the drawing, without plugging difficulties, may be chosen as given below.

Raw coal feed to heater 10:	
Feed rate, lbs./hr.	2000
Moisture, per cent	5
Coal temperature, °F.	60
Particle size:	
On 8 mesh	0.2
On 14 mesh	22.2
On 42 mesh	77.2
On 100 mesh	88.8
On 200 mesh	96.2
Through 200 mesh	3.8
Temperature in heater 10, °F.	900
Air to heater 10, s. c. f. m.	170
Superficial gas velocity in heater 10, ft./s.	10
Char from treating chamber 20 recycled to heater 10, lbs./hr.	20,000
Temperature of recycle char, °F.	900
Height of heater 10, ft.	20
Conditions in treating chamber 20:	
Temperature, °F.	900
Superficial gas velocity, ft./sec.	0.4
Bed density, lbs./cu. ft.	25
Average solids residence times, minutes	30
Gas recycled through line 36, c. f. m. (at conditions)	150
Yields:	
Char, weight per cent of coal charged	71.6
Gas, M. M. B. t. u./hr.	1.28
B. t. u./cu. ft.	124
Tar, gals./hr.	22.4

While the foregoing description and exemplary operations have served to illustrate specific applications and results of my invention, other modifications obvious to those skilled in the art are within the scope of my invention. Only such limitations should be imposed on the invention as are indicated in the appended claims.

I claim:

1. The process of carbonizing a subdivided carbonaceous solids charge having a plastic temperature range, at a carbonization temperature above said plastic range, in the form of a dense turbulent mass of finely divided solids fluidized by an upwardly flowing gas which comprises passing a predetermined amount of said carbonaceous solids charge in intimate contact with a substantially larger amount of subdivided solid non-plastic carbonization residue and agitated by an upflowing gas upwardly through a heating zone at a heating temperature and for a time sufficient to heat said carbonaceous solids charge at least to said carbonization temperature said time being insufficient to carry out a substantial portion of said carbonization, maintaining said heating temperature by conducting a controlled combustion of combustible constituents of the solids within said heating zone, passing a mixture of carbonaceous solids charge and solid carbonization residue so heated from said heating zone to a separate carbonization zone wherein said mixture is maintained at carbonization conditions of temperature and residence time in the form of a dense turbulent mass fluidized by a fluidizing gas to carry said carbonization to completion, withdrawing product vapors and gases from said mass, withdrawing solid carbonization residue from said mass and returning at least a portion of said residue to said heating zone.

2. The method of claim 1 in which at least

a substantial portion of the heat required in said carbonization zone is generated by said controlled combustion.

3. The method of claim 1 in which a portion of the heat required in said heating and carbonization zones is generated by a controlled combustion of a portion of said residue outside said zones, and supplied to said zones as sensible heat of hot solid combustion residue circulated through said zones.

4. The method of claim 1 in which said heating zone is in heat exchange with said mass through a common heat transfer surface.

5. The process of claim 1 in which the temperature within said heating zone and the residence time of said solids charge therein are so correlated that said charge reaches said carbonization temperature shortly prior to its passage to said carbonization zone.

6. The process of claim 1 in which the temperature of said residue returned to said heater is not substantially below said carbonization temperature.

7. The process of claim 1 in which at least a portion of said product vapors and gases withdrawn from said mass is returned to the bottom of said mass substantially at said carbonization temperature.

8. The process of claim 1 in which about 15–30 parts by weight of solid residue is returned to said heating zone for each part by weight of solids charge supplied thereto.

9. The process of carbonizing a subdivided carbonaceous solids charge having a plastic temperature range, at a carbonization temperature above said plastic range, in the form of a dense turbulent mass of finely divided solids fluidized by an upwardly flowing gas, which comprises passing a predetermined amount of said carbonaceous solids charge in intimate contact with a substantially larger amount of subdivided solid non-plastic carbonization residue and agitated by an upflowing gas upwardly through a substantially vertical heating zone at a heating temperature and for a heating time sufficient to heat the solids at least to said carbonization temperature by the time it reaches the upper portion of said heating zone but insufficient to carry out a substantial portion of said carbonization, maintaining said heating temperature by conducting a controlled combustion of combustible constituents of the solids within said heating zone, passing a mixture of solids charge and solid carbonization residue so heated from said upper portion to the upper portion of a separate carbonization zone wherein said mixture is maintained at carbonization conditions of temperature and residence time in the form of a dense turbulent mass fluidized by a fluidizing gas to carry said carbonization to completion, withdrawing product vapors and gases from said mass, withdrawing solid carbonization residue from a bottom portion of said mass and returning at least a portion of said residue to said heating zone without substantial heat loss.

10. The process of claim 9 in which gases and solids reaching the upper portion of said heating zone are passed to the upper portion of said carbonization zone.

11. The process of claim 9 in which gases and solids are separated in the upper portion of said heating zone, separated solids are passed to said carbonization zone and separated gases are withdrawn from the system.

12. The process of claim 9 in which said solid carbonization residue is returned to said heating zone under the pseudo-hydrostatic pressure of a fluidized column of finely divided solids.

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