CONTACTING SOLIDS AND FLUIDS

Filed Dec. 14, 1946 3 Sheets-Sheet 1

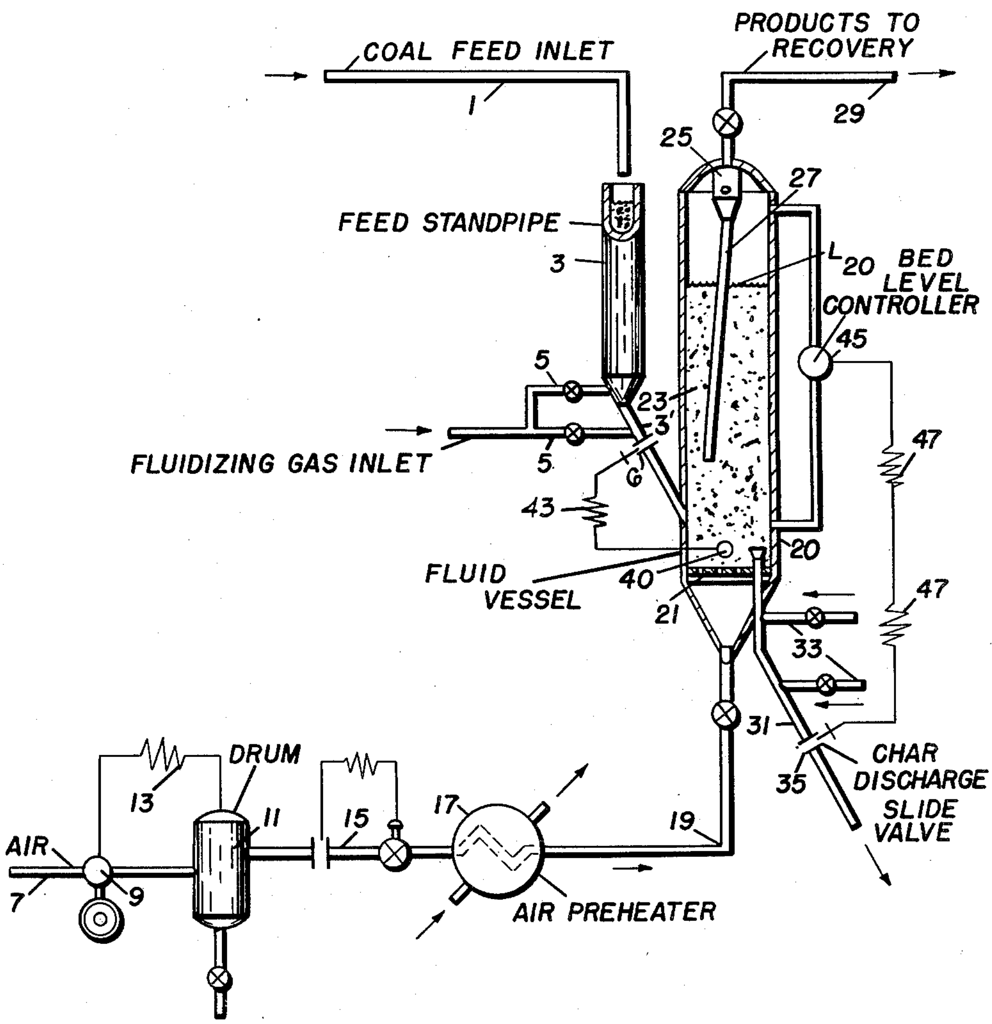

FIG.-1

KARL J. NELSON INVENTOR

BY George J. Gilhooly ATTORNEY

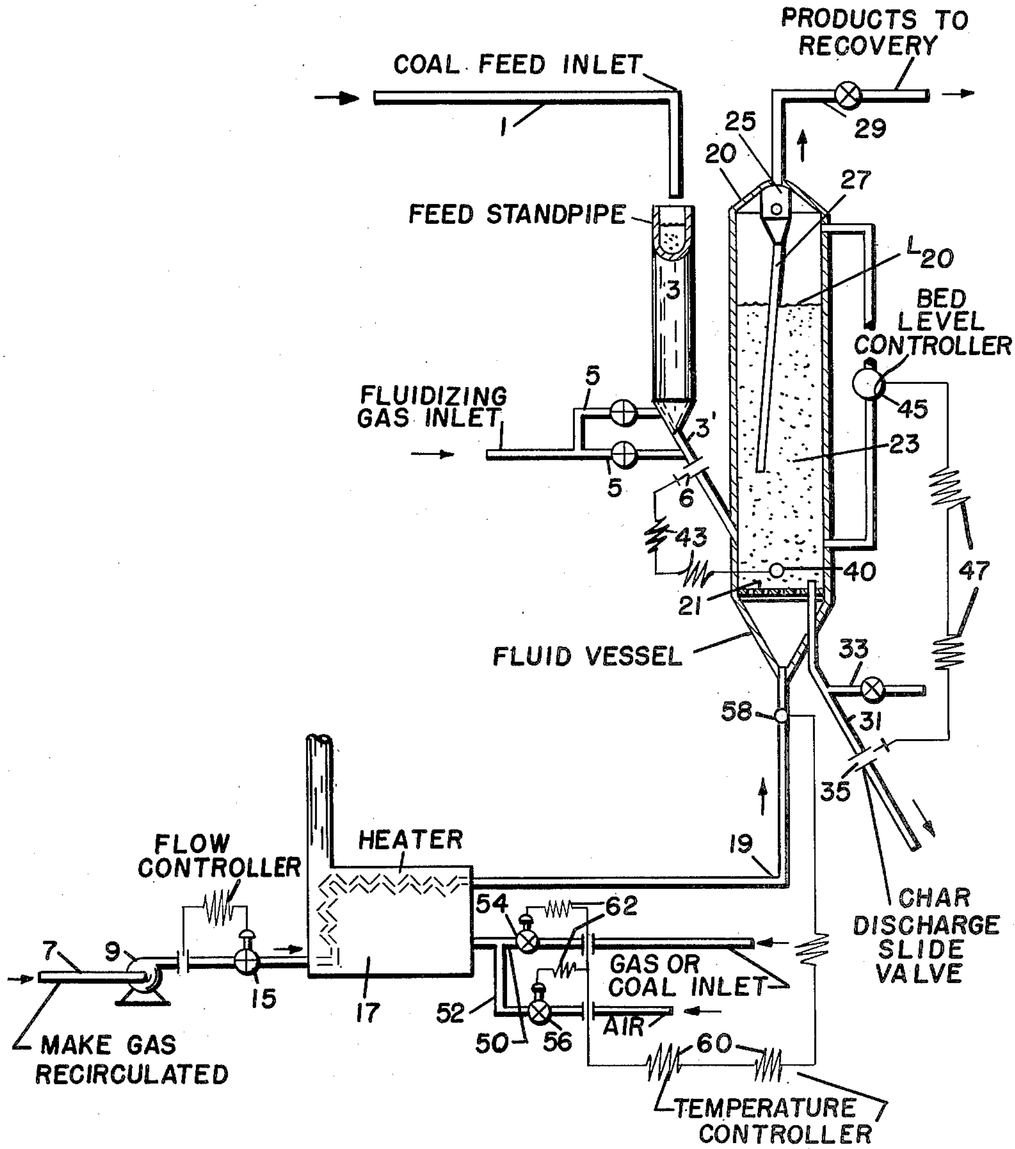

FIG. — 2

Karl J. Nelson INVENTOR

BY George J. Sillany ATTORNEY

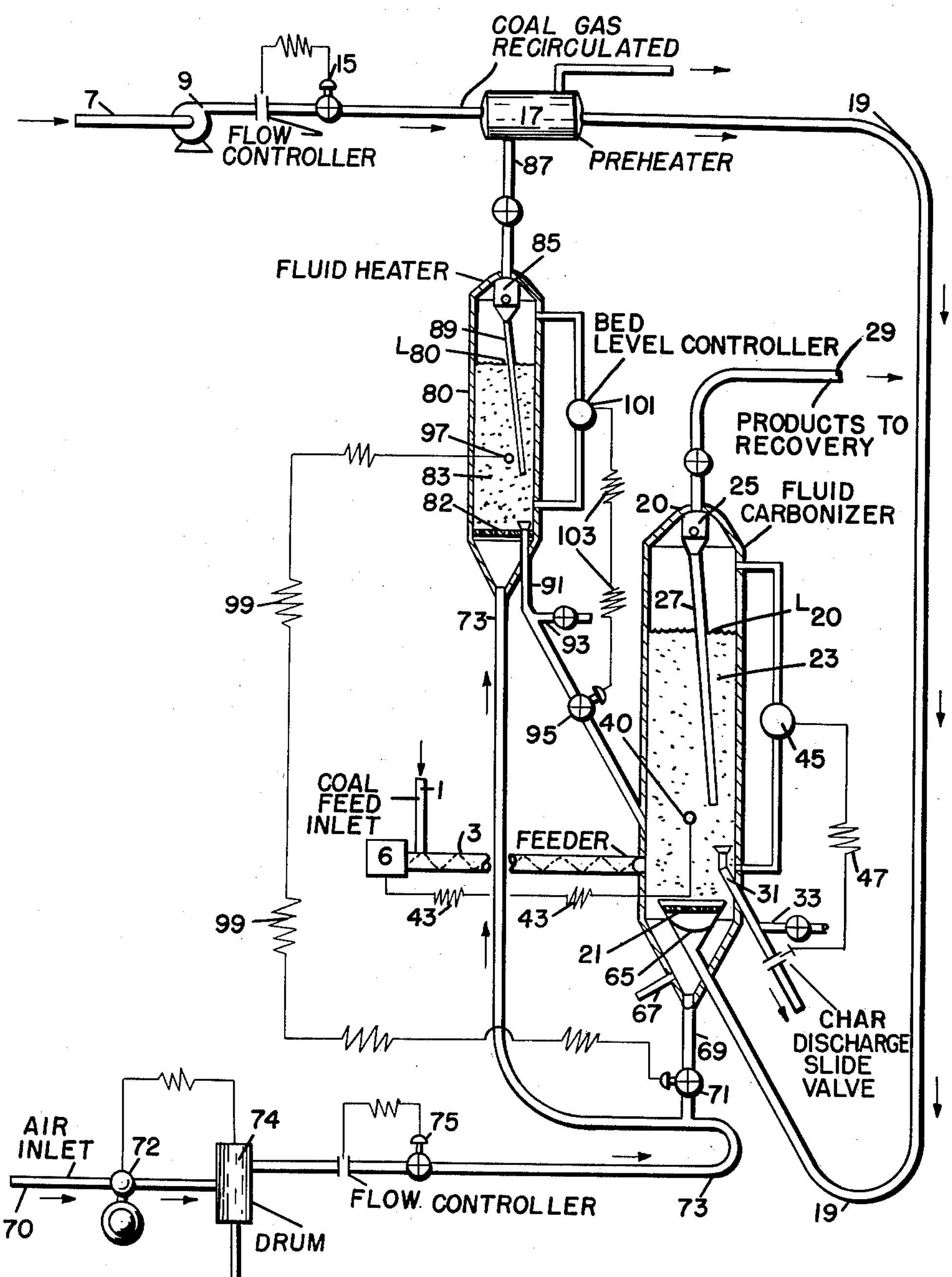

FIG.-3

KARL J. NELSON INVENTOR

BY George J Sidhary ATTORNEY

Patented May 4, 1954

2,677,604

UNITED STATES PATENT OFFICE

2,677,604

CONTACTING SOLIDS AND FLUIDS

Karl J. Nelson, Cranford, N. J., assignor to Standard Oil Development Company, a corporation of Delaware

Application December 14, 1946, Serial No. 716,408

5 Claims. (Cl. 48—206)

1

The present invention is concerned with the control of operating conditions in processes involving the contact of fluidized finely divided solids with fluids. More particularly, the present invention relates to the treatment of carbonaceous materials such as all types of coal, lignites, cellulosic materials including lignin, oil shale, tar sands, coke, oil coke, heavy residues, asphalts and the like into valuable volatile products such as coal gas, water gas, producer gas, light oils, tars and chemicals by preheating, carbonization and/or gasification, in dense turbulent beds of finely divided solids fluidized by an upwardly streaming gas.

The application of the so-called fluid solids technique to the preheating, carbonization and/or gasification of carbonaceous solids is well known in the art. In these processes, finely divided carbonaceous solids such as coal or coke having a fluidizable particle size of, say about, 50–400 mesh are fed to a treating or conversion zone such as a preheating, carbonization or gasification zone wherein they are maintained at treating temperatures in the form of a dense turbulent fluidized bed of finely divided solids forming a well defined upper level.

The heat required for the treatment is usually supplied either by blowing superheated steam, hot product gas or flue gas upwardly through the treating zone; or by burning a portion of the combustible constituents of the charge with the aid of an oxidizing gas such as air and/or oxygen passed upwardly through the treating zone; or by burning solid carbonaceous conversion residue in a separate heater and recirculating hot solid combustion residue to the treating zone.

Fluidization is accomplished by controlling the linear velocity of either the process and heating gases or of an extraneous fluidizing gas introduced into the treating zone, at about 0.3–10 ft. per second. Volatile products are withdrawn overhead while solid residues are recovered from the upwardly flowing vapors and gases and/or from a fluidized solids stream leaving the treating zone in a downward direction under the pseudo-hydrostatic pressure of the dense fluidized bed.

The advantages of this procedure over fixed bed operation are great in number and importance. The temperature throughout the fluidized beds is perfectly uniform and may be easily controlled over the wide range of from, say, about 700° to about 2500° F. The yields of volatile and solid conversion products may be substantially improved and readily varied with respect to product qualities and relative product amounts by suitable variations of temperature, pressure and/or reaction time. The processes may be made fully continuous and may be applied to any type of carbonaceous charge. There is highest flexibility with respect to the type of heating employed. Investment and operating cost is likewise more favorable as compared with fixed bed operation.

2

However, in order to secure these advantages, it is important to maintain constant operating conditions, particularly of temperature and contact time, in the treating zones. This invention relates, in its more specific aspects, to the control of systems of the treatment of carbonaceous solids employing the fluid solids technique at substantially constant operating conditions.

It is, therefore, the principal object of my invention to provide means for controlling the operating conditions of processes involving the contact of fluidized solids with gases.

Another object of my invention is to provide improved means for converting carbonaceous materials into more valuable volatile products.

A more specific object of my invention is to provide means for treating carbonaceous solids in the form of a dense turbulent fluidized mass of finely divided solids at constant operating conditions.

A still further object of my invention is to provide means for controlling the operating conditions of processes for converting carbonaceous solids into volatile products employing the fluid solids technique.

Another object of my invention is to provide improved apparatus for carrying out processes of the type specified.

Other and further objects and advantages of my invention will appear hereinafter.

In accordance with the present invention, the temperature and contact time of processes involving the contact of a fluidized solid with a gas are maintained at the desired values by maintaining a constant heat supply while varying the solids feed as a function of temperature variations and the solids withdrawal as a function of the fluid bed level which determines the bed hold-up, i. e. the weight of solids in the reaction zone at any given time. Hold-up on the other hand is one of the major factors determining solids residence time.

When applying my invention to the treatment of fluidized carbonaceous solids at constant operating conditions, the heat supply is maintained constant by feeding a constant amount of oxygen to the treating zone to generate a constant amount of heat of combustion; or by supplying a constant amount of sensible heat of gases or solids to the treating zone by feeding constant amounts of heating gases or solids preheated to a constant temperature. The temperature of the treating zone is kept constant by decreasing or increasing the amount of fresh carbonaceous solids supplied to the treating zone as a function of temperature fluctuations. The bed hold-up and thus the solids residence time at any given solids feed rate are kept constant by allowing the height of the fluidized carbonaceous solids bed to control the speed of withdrawal of treated solids from the fluidized bed.

In cases in which heat is supplied as sensible heat of preheated gases or solids, the temperature of the gas or solids preheater may be controlled by the desired temperature of the heat carrier as a further means of excluding independent variables.

It will be understood that the installation of automatic controls of the type specified makes permanent supervision of the process conditions superfluous.

Having set forth the general nature and objects, my invention will be best understood from the more detailed description hereinafter in which reference will be made to the accompanying drawing wherein:

Figure 1 represents a unit for the conversion of carbonaceous solids into volatile products using partial oxidation within the conversion zone as a means of supplying heat of conversion;

Figure 2 represents a similar unit using the sensible heat of an externally heated gas as a means of heat supply; and

Figure 3 illustrates a conversion unit using the sensible heat of externally heated solids as a means of heat supply.

Referring now to Figure 1, the numeral 20 designates a fluid solids conversion zone which hereinafter will be referred to as a carbonizer for the carbonization of coal although other treatments of carbonaceous solids and other materials may be carried out therein in a substantially analogous manner.

In operation, finely divided carbonization coal having a particle size between about 10 and 400 mesh, preferably between 50 and 200 mesh, although larger sizes up to about ¼ to ½ inch diameter may be used, is supplied to carbonizer 20 from line 1 by any suitable means known in the art such as a standpipe 3 aerated through taps 5 with small amounts of a fluidizing gas such as air, flue gas, product gas, steam or the like. The flow if solids through feed pipe 3′ is regulated by a slide valve 6.

An oxidizing gas such as air and/or oxygen is supplied from line 7 by compressor 9 via a knockout and surge drum 11 pressure controlled at 13 and through a flow controller 15 and, if desired, a preheater 17, to line 19 which leads to the lower conical portion of carbonizer 20.

The oxidizing gas enters carbonization zone 23 of carbonizer 20 through a distributing grid 21. The amount of oxygen supplied should be sufficient to cause a limited combustion of combustible coal constituents adequate to generate at least the major portion of the heat required for carbonization in zone 23. About 0.1 to 0.8 lb. of air or a corresponding amount of oxygen per pound of carbonization coal is generally sufficient to establish carbonization temperatures of about 800° to 1400° F. within zone 23.

The finely divided coal and coke in zone 23 is fluidized by the flue gases and volatile carbonization products to form a dense turbulent mass of solids resembling a boiling liquid and forming a well defined upper level (L_{20}). Linear gas velocities within the approximate limits of about 0.3 and 10 ft. per second are generally suitable to establish a fluidized mass of an apparent density of about 5–60 lbs. per cu. ft. in zone 23 at the particle sizes mentioned above.

Volatile carbonization products such as coal gas, light oils, tars, etc. pass overhead from level (L_{20}) through a conventional gas-solids separator such as cyclone 25. In order to prevent tar condensation and plugging in cyclone 25 an efficient heat transfer from zone 23 or an additional heat supply should be effected, preferably by any of the means disclosed and claimed in the copending applications, Serial No. 700,684, filed October 2, 1946, now Patent No. 2,549,117, granted April 17, 1951 and Serial No. 702,020, filed October 8, 1946, now Patent No. 2,537,153, granted September 1, 1951. Carbonaceous solids fines separated in cyclone 25 may be returned to zone 23 through pipe 27.

Product vapors and gases, substantially free of solids are passed through line 29 to a conventional product recovery system (not shown). Carbonized coal consisting substantially of coke is withdrawn downwardly under the pseudo-hydrostatic pressure of the fluidized bed in zone 23 through bottom drawoff pipe 31 which may be aerated through taps 33. The speed of solids withdrawal through pipe 31 is regulated by a slide valve 35.

In order to operate the process at constant conditions of temperature, pressure and contact time, the system shown in Figure 1 is provided with a control system which operates in accordance with my invention as will be presently described.

Pressure controller 13, flow controller 15 and preheater 17 are preset to establish an oxidizing gas supply of a constant pressure of, say, about 10–500 lbs. per sq. in., preferably about 15–60 lbs. per sq. in., a constant amount per unit of time depending on the size and desired output of carbonizer 20, corresponding to about 1.3 to 10 s. c. f. of air per lb. of coal to be carbonized; and a constant preheating temperature of about 200°–1000° F. In this manner, carbonizer 20 is supplied with a constant amount of oxygen at constant conditions which will liberate a constant quantity of heat by combustion because the fuel supply in carbonizer 20 is present in a very large excess. The pressure in carbonizer 20 is likewise kept constant within narrow limits by the controlled back pressure on the by-product recovery system (not shown).

A temperature-responsive device such as a thermocouple 40 arranged within zone 23 acts on conventional, actuating means 43 which operate slide valve 6. These actuating means are so designed and respond to thermocouple 40 in such a manner that the normal opening of slide valve 6 is reduced when the temperature in zone 23 tends to fall below the desired level and increased if the temperature tends to rise above the desired temperature. In this manner the feed rate of the fresh charge of relatively low temperature is used to keep the carbonization temperature constant within a narrow range of say about 5°–15° F.

The bed hold-up and thus the solids residence time of the coal in zone 23 is controlled by the height of level (L_{20}). In order to maintain level (L_{20}) and thus the bed hold-up and solids residence time in zone 23 constant, a bed level indicator 45 is provided which acts by conventional means on electrical mechanical hydraulic and/or pneumatic actuating means 47 which operate slide valve 35. When level (L_{20}) rises above its normal level, valve 35 is opened beyond its normal opening. When level (L_{20}) drops below its normal level, valve 35 is closed beneath its normal opening. The normal valve opening is restored upon level (L_{20}) reaching its normal position.

It will be appreciated that the control means shown in the drawing permit a fully automatic control of the process at substantially constant operating conditions.

Referring now to Figure 2, I have shown therein a system similar to that illustrated by Figure 1 wherein the sensible heat of a highly preheated gas is used to supply the heat required for carbonization. Like reference numerals designate like elements of the systems of Figures 1 and 2.

The operation of the system of Figure 2 is substantially the same as that described with reference to Figure 1 except for the character, amount, and temperature of the gas supplied through line 19.

This gas may be superheated steam, make or flue gas, or the like and will be referred to as make gas by way of example. Such make gas recovered from the volatile carbonization products is passed from line 7 by a blower or compressor 9 via flow controller 15 to a tube furnace heater 17 wherein it is preheated to a temperature about 100°–800° F. higher than the desired temperature in carbonization zone 23, depending on the amount of gas supplied to said zone per unit of coal processed. Fuel and air are supplied to heater 17 from lines 50 and 52, respectively, provided with control valves 54 and 56. In general, about 5 to 140 s. c. f. of gas preheated in heater 17 to about 950° to 1600° F. is sufficient per lb. of coal to be carbonized to establish a carbonization temperature of about 850°–1400° F. in zone 23.

The amount of make gas fed is kept constant by flow controller 15. In order to maintain the temperature of the heat-carrying gas constant at the desired level, a temperature-responsive means such as a thermocouple 58 is located in line 19 at a point close to its entrance into carbonizer 20. Thermocouple 58 acts on conventional actuating means 60 and 62 which operate fuel control valve 54 and air control valve 56 in a manner known per se to increase or decrease the rate of combustion in heater 17 when the temperature of the gas in pipe 19 drops below or rises above the normal desired temperature. In this manner, the heat supply to zone 23 is kept constant and automatic process control may take place as outlined in connection with Figure 1.

Referring now to Figure 3, the system shown therein will likewise be explained with reference to the carbonization of coal heat for carbonization being supplied as sensible heat of solids highly preheated in an external heater. The reference numerals of Figures 1 and 2 have been used to designate like or corresponding elements.

The coal feeding means 3 is shown to be a screw-conveyor actuated by an electric motor 6 rather than a standpipe controlled by a slide valve. Line 19 now merely serves to supply a gas for the fluidization of zone 23 at a predetermined constant rate and temperature, controlled by flow controller 15 and preheater 17. The fluidizing gas which may be made gas, steam,

or flue gas preheated to a constant temperature within the range of say 200° to 1200° F. in heater 17 is preferably introduced through a distributing cone 65 covered by grid 21. This arrangement permits a percolation of finely divided coke downwardly around cone 65 into the conical bottom portion of carbonizer 20 for purposes explained below. The superficial linear velocity of the fluidizing gas may be kept within the approximate limits of 0.3 to 10 ft. per second.

The automatic control of temperature, pressure and contact time in zone 23 is substantially the same as that outlined in connection with Figures 1 and 2. However, the means for providing a constant heat supply and for controlling the temperature of the heat carrying agent are different as will be forthwith explained.

The heat required for carbonization is generated by the combustion of char from carbonizer 20 in a separate heater 80 as follows. Finely divided char entering the conical bottom portion of carbonizer 20 from zone 23 around cone 65 is stripped of entrained gas and by-products and maintained in a readily flowing state by introducing small amounts of a stripping gas through one or more taps 67. This char passes downwardly through pipe 69 provided with a control valve 71 into line 73. Air is supplied from line 70 by compressor 72, via pressure-regulated surge and knockout drum 74 and flow controller 75 to line 73 to form with the char from line 69 a dilute suspension of solids-in-gas. This suspension passes under the pressure of the air in line 73 and the pseudo-hydrostatic pressure of the solids column in pipe 69, through line 73 into heater 80.

The amount of air supplied through line 73 should be constant and sufficient to make available the oxygen required to generate heat of combustion adequate to support the carbonization reaction. About 0.7 to 12 s. c. f. of air per pound of coal to be carbonized is normally suitable to maintain a heater temperature about 100°–300° F. higher than the temperature desired in zone 23. This amount of air is based on a char supply of about 0.8 to 20 lbs., through line 73, per lb. of coal to be carbonized. The air enters heater 80 through a distributing grid 82 at a linear velocity of about 0.3 to 10 ft. per second to convert in cooperation with the gases produced, the solids in combustion zone 83 into a dense fluidized mass having an upper level (L_{80}), similar to the fluidized mass in zone 23.

Flue gases are withdrawn overhead from level (L_{80}), passed through a cyclone separator 85 and vented through line 87, if desired, after heat exchange with fluidizing gas in preheater 17. Solids separated in cyclone 85 may be returned to zone 83 through line 89.

Solid combustion residue is withdrawn downwardly from a point above grid 82 through line 91 which may be a standpipe similar to standpipe 3 of Figures 1 and 2, aerated through one or more taps 93. The flow of solids through pipe 91 is controlled by slide valve 95. Solid combustion residue from pipe 91 enters zone 23 substantially at the temperature of combustion zone 83 in amounts of about 0.8 to 20 lbs. of residue per lb. of coal carbonized to supply the heat required in zone 23.

In order to maintain the amount of heat supplied to zone 23 at a constant level, I make the char supply through line 73 dependent on the heater temperature and the supply of hot combustion residue to zone **23** dependent on the bed level of the solids in heater **80**.

For this purpose, a temperature responsive means such as a thermocouple **97** is arranged in zone **83** to act on conventional actuating means **99** which operate valve **71** of line **69**. When the temperature in zone **83** rises above the desired normal level, the opening of valve **71** is increased above the normal width and vice versa. Thus, when maintaining a constant supply of air the temperature of combustion zone **83** is kept constant.

On the other hand, a bed level indicator **101** acts on conventional actuating means **103** which operate valve **95** in line **91** so as to reduce its opening below normal when level (L_{80}) in zone **83** drops below normal and vice versa.

It will be appreciated that these automatic controls regulating the heater operation secure the supply of a constant amount of heat to zone **23** and cooperate with the control means of carbonizer **20** to establish constant operating conditions and fully automatic control of the entire process.

While I have referred in the above examples to the carbonization of carbonizable solids, other reactions may be carried out in zone **23** in a substantially analogous manner. For example, zone **23** may serve as a preheating zone by merely reducing the preheating and operating temperatures below the temperature of beginning carbonization and/or plasticization of the feed. Water gas may be produced in zone **23** by raising the heating temperature to a gasification level such as 1600°–2500° F. and supplying adequate amounts of steam through line **19** to support the gasification reaction. Other analogous applications of my invention, which will occur to those skilled in the art, are within the scope of the invention.

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 the invention. Only such limitations should be imposed on the invention as are indicated in the appended claims.

I claim:

1. The method of contacting fluids with a dense turbulent mass of finely divided solids having a well defined upper level in a treating zone at constant conditions of treating temperature and solids residence time, which comprises passing said fluids upwardly through said mass, supplying a substantially constant amount of finely divided solids heated to a temperature not below said treating temperature at a substantially constant temperature to said mass to supply a constant amount of heat thereto, said amount of heat being sufficient to maintain said temperature, feeding a stream of fresh finely divided solids having a temperature substantially below said treating temperature to said mass, said heated finely divided solids being supplied independently of said fresh solids, withdrawing a stream of finely divided treated solids from said mass, changing the rate of flow of said stream of fresh solids in the same direction as said treating temperature changes so as to maintain said treating temperature substantially constant and changing the rate of flow of said treated solids in

the same direction as the height of said mass changes so as to maintain said level substantially constant.

2. The process of claim 1 wherein said fresh solids are carbonizable and said treating conditions are carbonization conditions.

3. The process of claim 1 wherein said treating conditions are preheating conditions.

4. The process of claim 1 wherein said fresh solids are carbonaceous, said gas comprises steam and said treating conditions are conducive to the formation of water gas.

5. The process of treating carbonaceous solids in the form of a dense turbulent mass of finely divided solids fluidized by an upwardly flowing gas to form a well defined upper level in a treating zone at constant conditions of treating temperature and solids residence time, which comprises supplying to said mass a finely divided heat-carrying solid combustion residue heated to a constant temperature not below said treating temperature, at a substantially constant rate and in amounts sufficient to maintain said temperature, feeding a stream of fresh finely divided carbonaceous material having a temperature substantially below said treating temperature to said mass, said heat-carrying solids being supplied independently of said fresh material, withdrawing a stream of finely divided treated solids from said mass, changing the rate of flow of said stream of fresh material in the same direction as said treating temperature changes so as to maintain said treating temperature constant, changing the rate of flow of said stream of treated solids in the same direction as the height of said mass changes so as to maintain said level constant, passing at least a portion of said withdrawn stream of solids to a separate fluid solids combustion zone operated at a combustion temperature higher than said treating temperature, supplying a constant amount of air of substantially constant temperature to said combustion zone, passing highly heated solids from said combustion zone to said treating zone to supply said heat-carrying solids, changing the flow rate of said portion passed to said combustion zone in the same direction as said combustion temperature changes so as to maintain said combustion temperature constant and changing the flow rate of said heat-carrying solids passed from said combustion zone to said treating zone in the same direction as the bed height of the fluidized solids in the combustion zone changes so as to maintain said last-named bed height constant.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
1,899,887	Thiele	Feb. 28, 1933
1,984,380	Odell	Dec. 18, 1934
2,399,050	Martin	Apr. 23, 1946
2,438,728	Tyson	Mar. 30, 1948
2,480,670	Peck	Aug. 30, 1949
2,482,187	Johnson	Sept. 20, 1949
2,534,051	Nelson	Dec. 12, 1950

FOREIGN PATENTS

Number	Country	Date
301,975	Great Britain	Dec. 13, 1928