

July 31, 1962

E. GORIN ETAL
SIZE SEPARATION, PREOXIDATION AND FLUIDIZED
LOW TEMPERATURE CARBONIZATION OF COAL

3,047,472

Original Filed June 11, 1956

2 Sheets-Sheet 1

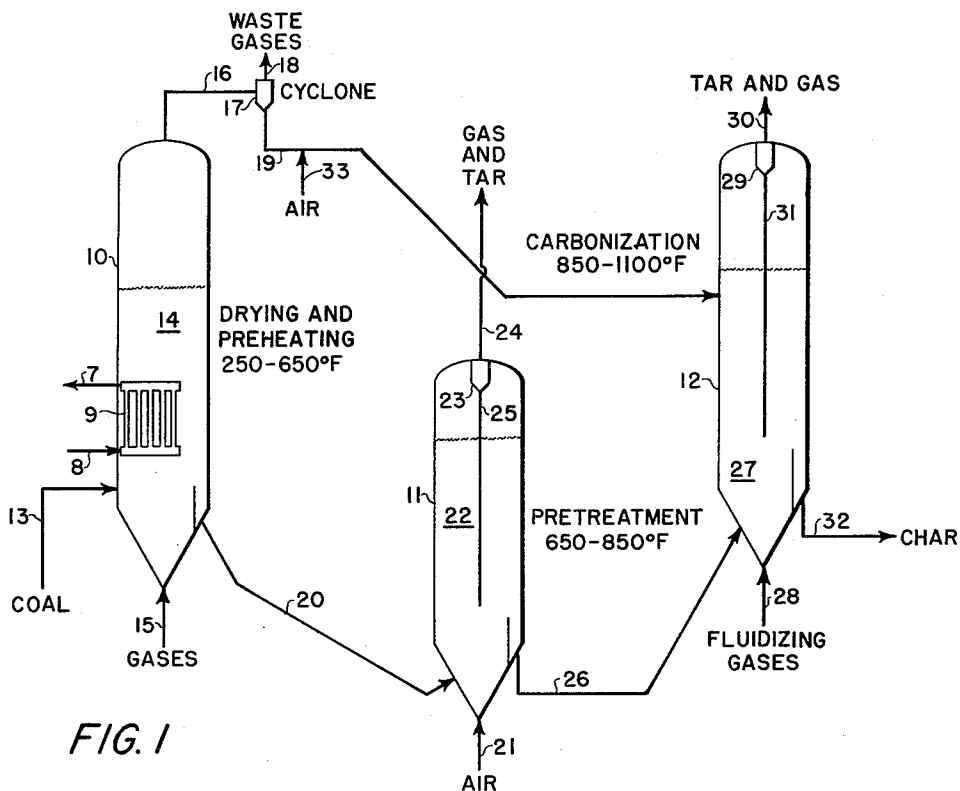


FIG. 1

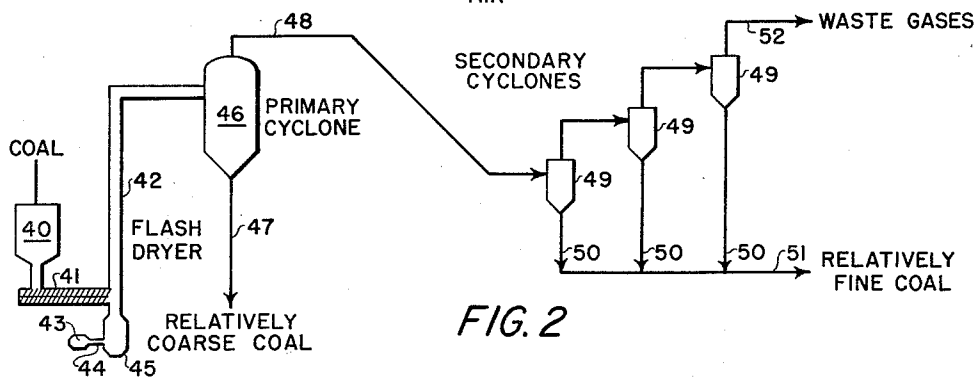


FIG. 2

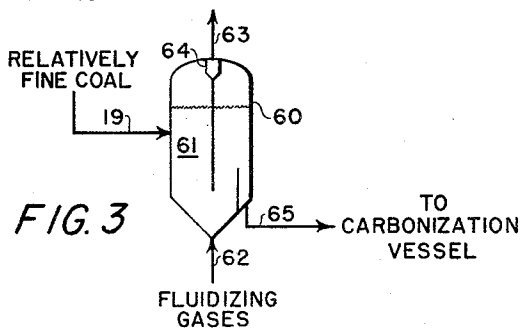


FIG. 3

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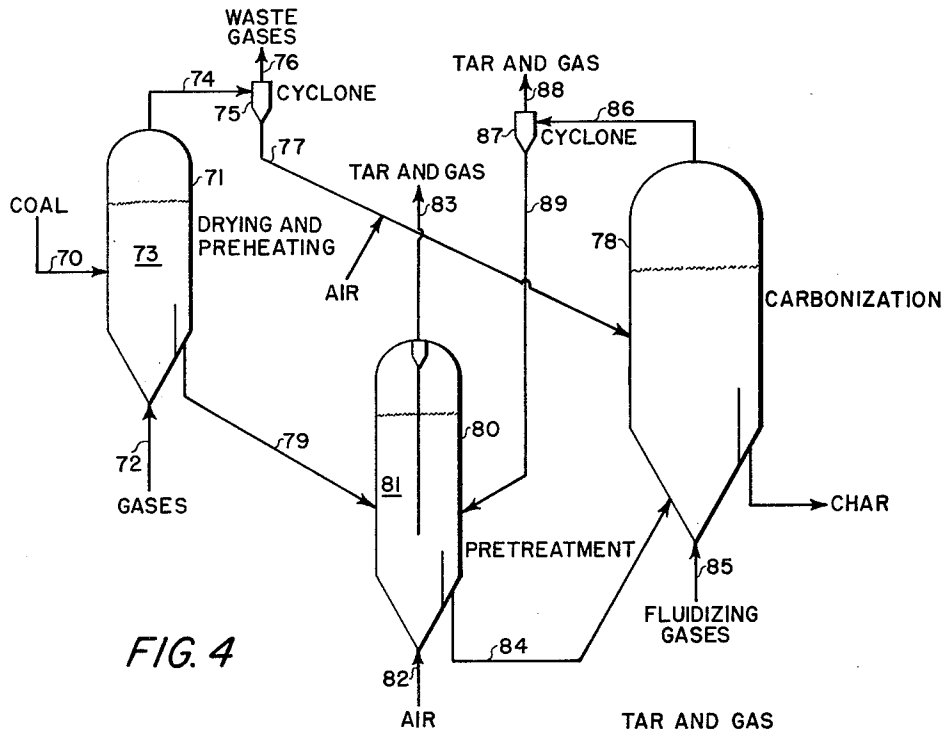


FIG. 4

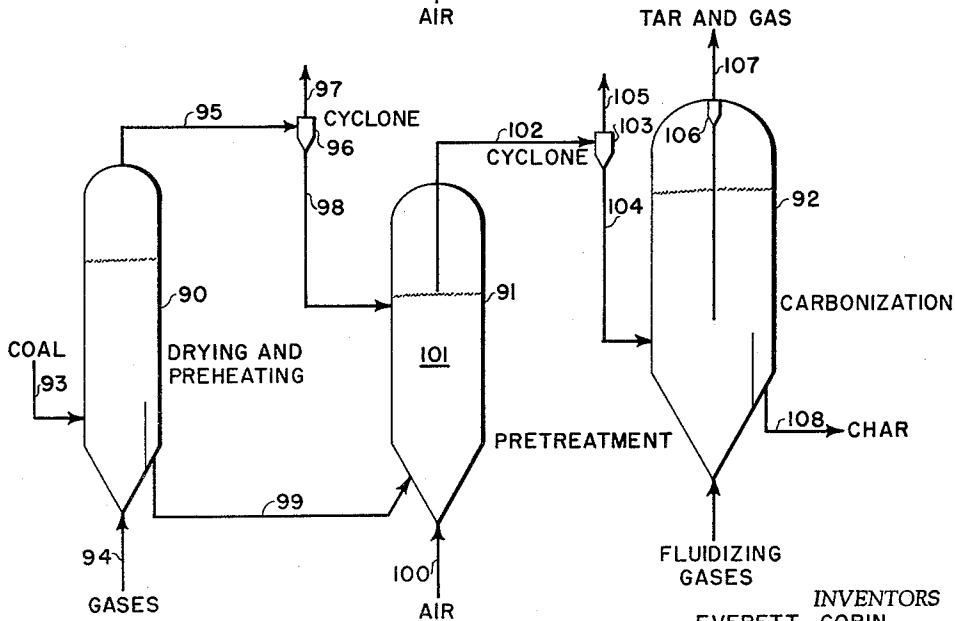


FIG. 5

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SIZE SEPARATION, PREOXIDATION AND FLUIDIZED LOW TEMPERATURE CARBONIZATION OF COAL

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Continuation of application Ser. No. 590,428, June 11, 1956. This application Jan. 9, 1959, Ser. No. 785,888
11 Claims. (Cl. 202-9)

The present invention relates to a method for effecting low temperature carbonization of agglomerative coals under fluidized conditions.

The present application is a continuation of our co-pending application Serial No. 590,428, filed June 11, 1956, now abandoned, and assigned to the assignee of the pending application.

Low temperature carbonization is a coal conversion process in which coal is heated to a temperature within the range 850 to 1100° F. until substantially complete evolution of its volatile matter results. The principal products of low temperature carbonization are non-condensable gases which may be used as fuel gases, condensable vapors which are termed "tar" and a solid distillation residue termed "char." Agglomerative coals are those hydrocarbonaceous solid materials found in nature which exhibit tacky properties when heated to a temperature in their so-called "plastic range." Agglomerative coals are particularly well suited to low temperature carbonization treatment since appreciable quantities of tar are potentially realizable therefrom. However the tacky properties exhibited by agglomerative coals on heating introduces serious mechanical difficulties particularly when the low temperature carbonization is conducted according to fluidized solids contacting techniques. The individual particles of agglomerative coal become tacky during thermal processing and tend to adhere, to form large agglomerates and ultimately to interfere with continued fluidized processing to the extent that the system ceases to be operable.

There exist, inter alia, two general methods for resolving the operability problems of agglomerative coal in fluidized low temperature carbonization. One method is to eliminate the agglomerative tendencies of such coals, or, at least, to reduce the agglomerative tendencies to such a low level that interference with operability does not occur. An example of this first method is the preliminary treatment of agglomerative coal with oxygen. Partial oxidation, especially when conducted at slightly elevated temperatures in the range of 600 to 850° F., is effective in reducing the agglomerative tendencies of the coal. If sufficient oxidation occurs, the coal particles may be rendered wholly non-agglomerative. However, preliminary oxidation of the coal severely diminishes the tar yield which can be realized from low temperature carbonization of the coal. Thus preliminary oxidation permits operability at the expense of a lower yield of valuable tar products. A typical Pittsburgh Seam bituminous coal, for example, may have a potentially realizable tar yield of 40 to 50 gallons per ton of coal. Where the same coal is subjected to sufficient preliminary oxidation to permit its use in a fluidized carbonization system, the tar yield actually realized is from 20 to 30 gallons per ton of coal.

Another method is to eliminate the effectiveness of the tacky property of agglomerative coal without eliminating the property itself. An example of this method is the employment of product "char" in intimate admixture with the coal undergoing treatment. The product "char" has no tacky properties and hence may serve as an inert, finely divided solid diluent. Agglomerative coal particles becoming tacky will acquire a coating of non-tacky char

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particles provided sufficient product char is recycled. Char coated particles do not exhibit agglomerative tendencies. The amount of char which must be recycled to effect operability is appreciable for some typical Pittsburgh Seam bituminous coals being as great as ten tons of char per ton of fresh coal. The effectiveness of this method is increased where the product char being recycled is generally finer in size than the fresh coal.

The present invention relates in its broadest scope to an improvement in the first method described, i.e., where preliminary oxidation of the coal is employed to diminish the tacky property of the agglomerative coal. In an alternative embodiment, the invention relates to a combination of both the first and second methods.

We have found that preliminary oxidation of coal varies in its effect on the tacky properties according to the size of the coal particle being oxidized and, further, that the extent of oxidation required to permit operability of the coal particles similarly varies with their size. All of the coal particles which are subjected to fluidized low temperature carbonization must be of a fluidizable size consistency. The entire coal feed stream should be capable of passing through a 1/8-inch mesh screen, and preferably through a 14 mesh Tyler Standard screen. Where coal is prepared by comminution in conventional crushing and grinding equipment, the material will contain a usual random distribution of particles of all sizes down to ultra-fines having diameters which are measured in microns. For example, a typical differential and cumulative screen analysis of a comminuted coal suitable for treatment by fluidized low temperature carbonization is presented in the following Table I.

Table I.—Differential and Cumulative Screen Analysis of Comminuted Agglomerating Coal Suitable for Treatment by Fluidized Low Temperature Carbonization

Tyler Screen Size	Weight Percent Retained on Screen	
	Differential	Cumulative
Retained on:		
8.....	Trace	Trace
14.....	0.2	0.2
28.....	5.7	5.9
48.....	14.6	20.5
100.....	28.9	49.4
200.....	19.9	69.3
325.....	9.2	78.5
Pan.....	21.5	100.0

We have found that the relatively fine particles of agglomerative coal can be subjected to fluidized low temperature carbonization with very little preliminary oxidation whereas the relatively coarse particles require substantial oxidation. We have found further that the relatively fine particles are more readily oxidized than the relatively coarse particles. Hence, when the entire coal feed stream is subjected to preliminary oxidation sufficient to render the relatively coarse particles operable in subsequent fluidized low temperature carbonization, excessive oxidation of the relatively fine particles occurs with an accompanying needless diminution of tar yield.

By the phrase "relatively coarse" and "relatively fine," we intend to distinguish two fractions of the coal feed stream which differ significantly in median particle size. The "relatively fine" fraction could comprise principally particles capable of passing through a 200 mesh screen; whereas the corresponding "relatively coarse" fraction would comprise the original coal feed stream from which the "relatively fine" fraction had been removed. The "relatively coarse" fraction, of course, may contain significant quantities of particles capable of passing through a 200 mesh screen, and the "relatively fine" fraction could

similarly contain significant quantities of particles too large to pass through a 200 mesh screen.

According to the present invention, a coal feed stream, comminuted to fluidizable size, is separated into a relatively fine fraction and a relatively coarse fraction by elutriation of the relatively fine fraction from the coal feed stream in an upwardly flowing stream of gas moving in intimate contact with the coal feed stream. The upwardly flowing gas serves to separate the coal feed stream. Where hot gases are employed, the gases themselves also serve to dry and to preheat the coal. Alternatively, the gases may serve to transport the coal through a heat zone which effects the drying and preheating. In both alternatives, however, drying, preheating and separation of the coal is effected in a single treatment zone. The relatively fine fraction and the relatively coarse fraction are separately recovered.

The relatively coarse fraction is subjected to preliminary oxidation under fluidized non-agglomerating conditions. The relatively fine fraction is subjected to a milder preliminary oxidation or no oxidation. The two fractions are recombined for low temperature carbonization treatment under fluidized conditions.

According to an additional improvement, a portion of relatively fine char produced in the fluidized low temperature carbonization process may be combined with the relatively coarse fraction of the coal feed stream to improve the fluidizing characteristics of the fluidized preliminary oxidation zone for the relatively coarse fraction of the coal feed stream. This additional improvement also diminishes the extent of oxidation required to permit operability of the relatively coarse coal in the process by eliminating the effectiveness of the residual tacky tendency of the relatively coarse coal as previously described.

The quantity of relatively fine coal particles which are separately treated should be at least 10 percent and preferably to least 20 percent of the coal feed stream. The quantity of relatively coarse particles which are subjected to preliminary oxidation treatment should be at least 50 percent of the coal feed stream. The preliminary oxidation treatment of the relatively coarse coal is conducted under fluidized conditions with sufficient air to prevent agglomeration of the individual particles from occurring both in the pretreater zone and in the subsequent low temperature carbonization zone. The pretreatment is carried out at a temperature within the range of 600 to 850° F. in order to achieve maximum benefits from the oxidation without excessive loss of potentially realizable tar yield. Preliminary oxidation, if any, of the relatively fine coal may occur during its dilute phase transport through the process or under fluidized conditions.

For most highly caking bituminous coals, the relatively coarse fraction preferably is reacted with from about 4 to about 10 parts of oxygen by weight for each 100 parts of the relatively coarse fraction. The relatively fine fraction preferably is reacted with from about 0.1 to about 4 parts of oxygen by weight for each 100 parts of the relatively fine fraction.

The low temperature carbonization treatment should be conducted at a temperature within the range of 850 to 1100° F.

The fluidized preliminary treatment of the coal should be conducted under "non-agglomerating conditions," i.e., there should be sufficient oxygen-containing gases present to prevent extensive coking of the coal particles considering the selected temperature and quantity of non-tacky recycle char particles which may be available. A reasonable amount of particle size growth in the preliminary treatment zone resulting from agglomeration is to be expected. Similarly a reasonable amount of particle size growth in the low temperature carbonization zone is to be expected. By the phrase "non-agglomerating conditions" we comprehend the presence of sufficient oxygen-containing gases and diluent non-tacky char particles to

avoid extensive coking in the low temperature carbonization zone.

For a more complete understanding of the present invention, reference should be had to the following detailed description and accompanying drawings in which:

FIGURE 1 is a schematic flow diagram illustrating apparatus adapted for conducting a preferred embodiment of the present invention;

FIGURE 2 is a schematic diagram of an alternative means for effecting simultaneous drying, preheating and elutriation of relatively fine coal particles;

FIGURE 3 is a schematic diagram of an alternative embodiment of the present invention in which the relatively fine coal particles are subjected to partial oxidation prior to carbonization;

FIGURE 4 is a schematic diagram of a further alternative embodiment in which relatively fine particles of char produced as product are combined with the relatively coarse particles of the coal feed stream to improve the fluidizing properties of the partial oxidation stage in which the relatively coarse coal particles are treated; and

FIGURE 5 is a schematic illustration of a further alternative embodiment of the invention in which preliminary oxidation of relatively fine and relatively coarse coal is effected in a single processing zone.

Referring to FIGURE 1, a process is illustrated for subjecting agglomerative coal sequentially to drying and preheating in a vessel 10, partial oxidation of the relatively coarse portion of the coal feed stream 11, and low temperature carbonization of the entire coal feed stream in a vessel 12. Agglomerative coal, crushed to a fluidizable size consist, is introduced into a drying and preheating vessel 10 through a conduit 13. A fluidized bed 14 of fluidizable size coal particles is established under the influence of gases flowing upwardly through the vessel 10 from a conduit 15. Where hot gases are employed for effecting drying and preheating, they are provided in sufficient quantity and at a temperature sufficiently high to remove moisture from the coal particles and to heat the dried particles to an elevated temperature in order to minimize the heat input requirements for further coal processing.

Alternatively heating tube bundles or heating coils 9 may be embedded within the fluidized bed 14 to provide the heat needed for drying and preheating. A heat exchange medium such as hot oil, hot sand and the like may be supplied to the heating element 9 through a conduit 8 and removed for reheating through a conduit 7. Exit temperature of the coal particles from the drying and preheating vessel 10 should be from about 250 to about 650° F., preferably from about 400 to about 550° F. The coal particles should not be subjected to temperatures at which agglomeration will occur during the drying and preheating step. The gases rise through a fluidized bed 14 and are recovered from the vessel 10 through a conduit 16 with substantial quantities of relatively fine coal particles entrained therein. The entrained relatively fine coal particles are separated from the gases in a separation device such as a cyclone 17. Solids-free gases are eliminated through a conduit 18. Relatively fine coal particles are recovered from the cyclone 17 through a conduit 19. Regulation of the upward linear velocity of the hot gases in the drying and preheating vessel 10 permits control of the fraction of the coal feed stream which will be entrained and recovered through the conduit 19 as the relatively fine coal fraction.

Referring again to the drying and preheating vessel 10, the relatively coarse particles from the coal feed stream are not entrained in the fluidizing gases and may be withdrawn from the vessel 10 through a conduit 20 and introduced into a pretreatment vessel 11. Air is introduced into the bottom of the pretreatment vessel 11 through a conduit 21 to serve as the fluidizing gas for maintaining therein a fluidized bed 22 of relatively coarse coal particles which are pretreated with the air to effect

a reduction in agglomerating tendencies. If desired, the air introduced through the conduit 21 may also be employed as a carrier gas for conveying the relatively coarse coal particles withdrawn from the vessel 10 through the conduit 20 into the pretreatment vessel 11. If desired, the fluidizing gas introduced through conduit 21 may be air, or air and recycled product gases, and/or added oxygen. Air passes upwardly through the fluidized bed 22 and is withdrawn, substantially free of solids, through a cyclone separator 23 and a discharge conduit 24. The pretreatment vessel 11 is maintained at a temperature of about 650 to about 850° F. Where the pretreatment vessel 11 is maintained at a temperature above the initial distillation temperature of the relatively coarse coal particles, a quantity of tar vapors may be recovered from the discharge conduit 24. Reaction of coal with air introduced through conduit 21 should provide the heat required to maintain the desired temperature in the pretreatment vessel 11. Any solid particles of coal which may be entrained by the fluidizing gases are returned from the cyclone separator 23 to the fluidized bed 22 by means of a dipleg 25.

Partially oxidized relatively coarse coal particles from the pretreatment vessel 11 are withdrawn through a conduit 26 and introduced into a fluidized carbonization vessel 12 maintained under low temperature carbonization conditions. The temperature of the vessel 12 is maintained from about 850 to about 1100° F., preferably from about 900 to about 1000° F. The relatively fine coal particles from conduit 19 also are introduced into the fluidized carbonization vessel 12. The coal feed stream, thus recombined, comprises a fluidized bed 27 maintained within the vessel 12 by fluidizing gases passing upwardly therethrough from a conduit 28. The fluidizing gases for the carbonization step may comprise carbonization recycle gases; or the pretreatment gases recovered in conduit 24; or air; or even a combination of those gases to which oxygen may be added if desired.

Tar vapors and spent fluidizing gases are recovered from the vessel 12 through a cyclone separator 29 and a recovery conduit 30. Any particles of solid carbonization residue entrained in the fluidizing gases are returned from the cyclone separator 29 through a dipleg 31 to the fluidized carbonization bed 27. Product char is recovered from the carbonization vessel 12 through a conduit 32.

If desired, the relatively fine coal particles may be conveyed from the cyclone separator 17 through the conduit 19 as a suspension in air which is introduced through a conduit 33. The ratio between relatively fine coal and air in the conduit 19 will determine the extent of pre-oxidation of the relatively fine coal particles. With certain coals, it may be unnecessary to subject the relatively fine coal particles to partial oxidation prior to carbonization.

According to the embodiment illustrated in FIGURE 1, agglomerative coal may be dried, preheated and separated in a single treatment zone, and thereafter each fraction may be selectively pretreated to permit fluidized low temperature carbonization thereof under conditions which tend to diminish the tar loss attributable to pre-oxidation. For the purposes of illustration, the coal feed stream may be considered to be a crushed agglomerative coal capable of passing through a 14 mesh Tyler Standard screen. Upwardly flowing fluidizing gases through the vessel 10 will strip out from the fluidized bed 14 a substantial portion of the relatively fine particles contained in the coal feed stream, for example, a substantial portion of those particles capable of passing through a 200 mesh Tyler Standard screen. The efficiency of the elutriation as well as the size fraction which is stripped from the fluidized bed 14 may be regulated by controlling the upward velocity of the fluidizing drying gases entering the vessel 10 through the conduit 15. With some coals, the relatively fine particles, recovered through con-

duit 19, may be subjected to fluidized low temperature carbonization without deliberate preliminary treatment to reduce their agglomerating tendencies with oxygen. Where the coal feed is severely agglomerative, some pretreatment of the relatively fine coal particles with air may be desirable, although to a lesser extent than that required for the relatively coarse coal.

Referring to FIGURE 2, an alternative embodiment is illustrated for conducting the combined drying, preheating and elutriation function.

In FIGURE 2, we have illustrated an alternative embodiment of the means for simultaneously drying, preheating and elutriating a coal feed stream employing the so-called "flash dryer" principle. Fluidizable size coal is introduced into a coal surge hopper 40 and fed uniformly through a screw conveyor 41 into a flash dryer chimney 42. Hot gases are generated by combustion in a combustion chamber 43 and are passed through a flue 44 into a hot gas chamber 45 which is in open communication at its upper end with the bottom of the flash drying chimney 42. Hot gases are blown upwardly through the flash drying chimney 42 at sufficient velocity to carry the coal particles from the screw conveyor 41 upwardly therethrough. The hot gases and suspended solids are introduced into an inefficient primary cyclone separator 46 which removes the more readily separable coal particles from suspension in the hot gases for recovery through a conduit 47. Generally these particles recovered through the conduit 47 will be the relatively coarse particles of the coal feed stream. The hot gases with entrained particles of coal which are more difficult to separate leave the cyclone separator 46 through a conduit 48 and the gas passes sequentially through a plurality of more efficient secondary cyclone separators 49 which remove the more-difficult-to-separate particles of relatively fine coal. These particles of relatively fine coal are recovered through the cyclone diplegs 50 and combined in a manifold conduit 51. Following passage through the plurality of efficient secondary cyclone separators, the solids-free hot gases are removed from the system through a conduit 52.

The relatively coarse coal in the conduit 47 thereupon may be treated as are the solids in the conduit 20 shown in FIGURE 1. The relatively fine coal in the manifold conduit 51 may be treated as the relatively fine coal in conduit 19 of FIGURE 1.

An alternative embodiment for pretreating the relatively fine fraction of coal obtained in the conduit 19 of FIGURE 1 is illustrated in FIGURE 3. Referring to FIGURE 3, the relatively fine coal is introduced from the conduit 19 into a pretreatment vessel 60 and confined therein as a fluidized bed 61. A fluidizing gas containing oxygen, preferably air, is introduced into the vessel 60 through a conduit 62. If desired, the relatively fine coal from the conduit 19 may be suspended in the air from conduit 62 and the resulting suspension introduced into the pretreatment vessel 60. Fluidizing gases are removed through a conduit 63 after being freed of entrained solids in a cyclone separator 64. Relatively fine coal particles which have been treated with air to reduce their agglomerating properties are recovered from the vessel 60 through a conduit 65 and thereafter subjected to fluidized low temperature carbonization as in the vessel 12 of FIGURE 1. The extent of oxidation occurring within the vessel 60 may be limited to that required for permitting operability in a subsequent fluidized low temperature carbonization system without resulting in over-oxidation of the relatively fine coal particles with the concomitant adverse decrease in tar yield.

Removal of the relatively fine coal particles from the coal feed stream may introduce some operability difficulties in maintaining smooth fluidization properties of the remaining coarse coal particles which are treated independently in a fluidized pretreatment zone such as the vessel 11 in FIGURE 1. Smooth fluidization properties

require that the solid particles undergoing fluidization contain a significant quantity of relatively fine particles. Selective removal of the relatively fine particles as described in connection with FIGURES 1 and 2 will introduce severe slugging tendencies in the fluidized bed 22 of the pretreatment vessel 11. As the coarseness of the relatively coarse coal particles increases, the slugging tendencies increase in severity. The slugging is deleterious in that the solids-and-gas contacting efficiency is diminished under slugging conditions and also the tendency of the solid particles to plug entrance and exit orifices of the fluidizing vessel and also solids transfer conduits is increased.

FIGURE 4 illustrates an alternative embodiment of the present process which avoids the increased slugging tendencies otherwise inherent in this process. The alternative embodiment of FIGURE 4 additionally provides a further realizable increase in tar yield by permitting reduction of the extent of oxidation required for the relatively coarse coal particles.

Referring to FIGURE 4, fluidizable size coal is introduced through a conduit 70 into a drying and preheating vessel 71 for drying, preheating and separation of the coal in a single treatment zone as described in connection with FIGURE 1. Gases are introduced into the vessel 71 through a conduit 72 for fluidizing a bed 73 of coal confined therein. The fluidizing gases entrain relatively fine coal particles which are removed as a solids-in-gas suspension through a conduit 74. Solids-free gases are removed from a cyclone 75 and discharged through a conduit 76. Relatively fine coal particles are recovered from the cyclone 75 through a conduit 77 and introduced into a fluidized low temperature carbonization vessel 78. Relatively coarse coal particles are recovered from the drying and preheating vessel 71 through a conduit 79 and introduced into a preliminary oxidation vessel 80 to form therein a fluidized bed 81 of relatively coarse coal particles.

Air for fluidization and preoxidation is introduced into the vessel 80 through a conduit 82. If desired, the solids from conduits 79 may be suspended in the gases from conduit 82 and the resulting suspension introduced into the pretreatment vessel 80. Fluidizing gases are removed as a solids-free gas through a conduit 83. Carbonaceous solid particles from the fluidized bed 81 are withdrawn from the vessel 80 through a conduit 84 and introduced into the fluidized low temperature carbonization vessel 78. Fluidizing gases are introduced into the carbonization vessel 78 through a conduit 85 and are recovered overhead therefrom through a conduit 86.

In passing through the carbonization vessel 78, the fluidizing gases entrain relatively fine particles of char which are separated from suspension in a cyclone separator 87. Solids-free gases and tar vapors are recovered through a conduit 88. The relatively fine char particles are withdrawn from the cyclone separator 87 through a conduit 89 and introduced into the preliminary oxidation vessel 80 to provide the relatively fine solid particles requisite for smooth fluidization properties in the bed 81. Thus the bed 81 is comprised of relatively coarse coal particles (which are introduced through the conduit 79) in admixture with relatively fine char particles (which are introduced through the conduit 89). Since the relatively fine particles entering the vessel 80 through the conduit 89 already have been exposed to low temperature carbonization conditions, their contribution to the tar yield already has been realized and their further exposure to oxidation conditions in the vessel 80 will not result in an objectionable reduction of tar yield. The presence of both fine and coarse particles within the bed 81 permits operation of the preoxidation stage with smooth fluidization characteristics.

Moreover, the presence of relatively fine char particles in the preoxidation vessel 80 serves to reduce the overall oxidation required for the incoming relatively coarse coal particles since the char is a non-agglomerative solid dil-

uent. The presence of added inert particles offsets somewhat the agglomerating tendency of the relatively coarse coal particles so that fluidized preliminary oxidation in the vessel 80 and fluidized low temperature carbonization in the vessel 78 can be carried out with coal particles which individually do not require a reduction of their agglomerating tendencies to the same extent that would be required if the added particles of finely divided char were absent. Thus the relatively coarse coal particles can be employed in the system without the extensive preliminary exposure to oxidation otherwise required for operability. The net result is that increased yields of tar can be recovered from the relatively coarse coal particles.

In addition, the recirculation of relatively fine char particles at a carbonization temperature serves to supply some of the heat required to maintain the desired temperature in the preliminary oxidation vessel 80.

FIGURE 5 illustrates a further alternative embodiment of the present invention in which a single preliminary oxidation vessel may be employed for pretreatment of both the relatively coarse coal and the relatively fine coal. Referring to FIGURE 5, three fluidized treatment zones are illustrated including a fluidized drying and preheating vessel 90, a fluidized preliminary oxidation vessel 91, and a fluidized low temperature carbonization vessel 92. Coal of a fluidizable size consist is introduced through a conduit 93 into the fluidized drying and preheating vessel 90. Gases are introduced through the conduit 94 into the vessel 90 to fluidize and elutriate the coal feed stream. Fluidizing gases and entrained relatively fine coal particles are recovered through the conduit 95 and introduced into a cyclone 96. Spent fluidizing gases are discharged through a conduit 97. Relatively fine coal particles are recovered through a cyclone withdrawal conduit 98. Relatively coarse coal particles are recovered from the fluidized drying and preheating vessel 90 through a conduit 99 and introduced into a preliminary oxidation vessel 91 near its bottom. The relatively fine coal particles are introduced into the preliminary oxidation vessel 91 from the cyclone withdrawal conduit 98 at a point near the top of the vessel 91. Air is introduced into the vessel 91 through a conduit 100 to serve as fluidizing and treating gas. Thus a fluidized bed 101 is established within the preliminary oxidation vessel 91 comprising principally the relatively coarse coal particles at its bottom, and comprising both the relatively fine and relatively coarse coal particles at its top. Fluidizing gas and tar vapors, if any, are recovered from the vessel 91 along the partially oxidized coal particles through a conduit 102. Fluidizable coal, including both relatively fine and relatively coarse particles, is separated from entrainment in the vapors in a cyclone 103 and introduced through a dipleg conduit 104 into the low temperature carbonization vessel 92 for final processing. Separated fluidizing gases and vapors are discharged through the conduit 105. If desired, the cyclone 103 may be eliminated and the entire stream of gases and entrained solids from the conduit 102 may be introduced into the carbonization vessel 92 whereby the gases thus introduced will comprise portions of the fluidizing gases in the carbonization vessel 92.

Gases and tar vapors are recovered from the carbonization vessel 92 through a cyclone 106 and a conduit 107. Product char is recovered through a conduit 108.

By introducing the relatively fine coal particles into the upper portion of the preliminary oxidation vessel 91, these particles experience only a limited residence time under exposure to oxidizing conditions and hence experience a very limited oxidation. The relatively coarse particles, on the other hand, being introduced into the bottom of the vessel 91 have a longer residence time and hence a longer exposure to oxidizing conditions. Finally the presence of readily oxidizable material in the form of relatively fine coal particles in the upper portion of the vessel 91 serves to effect nearly complete consumption of the oxygen employed in the treatment

and prevents unused oxygen from breaking through the upper level of the fluidized treating bed 101 and appearing in the effluent gases from the treatment zone.

It may be desirable in some installations to effect the drying, preheating and elutriation stage of the present invention in the presence of air or other oxygen-containing gases which will react slightly with the coal even at the relatively low temperatures of the drying and preheating stage. Where the process is operated in this manner, the preliminary oxidation of the relatively coarse fraction in the pretreatment stage supplies the added oxidation required for operability. Further preliminary oxidation of the relatively fine fraction frequently may be avoided in this situation.

According to the provisions of the patent statutes, we have explained the principle, preferred construction, and mode of operation of our invention and have illustrated and described what we now consider to represent its best embodiment. However, we desire to have it understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically illustrated and described.

We claim:

1. The method for processing finely divided caking bituminous coal under fluidized low temperature carbonization conditions which comprises introducing said finely divided coal into a stream of gases moving upwardly through a drying and preheating zone maintained at a temperature within the range 250 to 600° F., which serves to separate said coal into two fractions, comprising a dried relatively coarse fraction which contains at least 50 percent of said coal and a dried relatively fine fraction which contains at least 10 percent of said coal, said relatively coarse fraction comprising coal particles of larger median size than the coal particles comprising said relatively fine fraction, reacting said relatively coarse fraction with sufficient oxygen-containing gases under fluidized non-agglomerating conditions at a temperature within the range of 600 to 850° F. to render said relatively coarse fraction non-agglomerating in a subsequent fluidized low temperature carbonization treatment, recovering both of said fractions and subjecting them in admixture to low temperature carbonization under fluidized non-agglomerating conditions at a temperature within the range of 850 to 1100° F. and recovering as products solid carbonization residue and evolved gases and tar vapors.

2. The method for processing finely divided caking bituminous coal under fluidized low temperature carbonization conditions which comprises introducing said finely divided coal into a stream of gases moving upwardly through a drying and preheating zone maintained at a temperature within the range 250 to 600° F., which serves to separate said coal into two fractions, comprising a dried relatively coarse fraction which contains at least 50 percent of said coal and a dried relatively fine fraction which contains at least 10 percent of said coal, said relatively coarse fraction comprising coal particles of larger median size than the coal particles comprising said relatively fine fraction, reacting said relatively coarse fraction with sufficient oxygen-containing gases under fluidized non-agglomerating conditions at a temperature within the range of 600 to 850° F. to render said relatively coarse fraction non-agglomerating in a subsequent fluidized low temperature carbonization treatment, reacting said relatively fine fraction with sufficient oxygen-containing gases under non-agglomerating conditions at a temperature within the range of 600 to 850° F. to render said relatively fine fraction non-agglomerating in a subsequent fluidized low temperature carbonization treatment, recovering both of said fractions thus reacted and subjecting them in admixture to low temperature carbonization under fluidized non-agglomerating conditions at a temperature within the range of 850 to

1100° F. and recovering as products solid carbonization residue and evolved gases and tar vapors.

3. The method for processing finely divided caking bituminous coal under fluidized low temperature carbonization conditions which comprises introducing said finely divided coal into a stream of gases moving upwardly through a drying and preheating zone maintained at a temperature within the range 250 to 600° F., which serves to separate said coal into two fractions, comprising a dried relatively coarse fraction which contains at least 50 percent of said coal and a dried relatively fine fraction which contains at least 10 percent of said coal, said relatively coarse fraction comprising coal particles of larger median size than the coal particles comprising said relatively fine fraction, treating said relatively coarse fraction with sufficient oxygen-containing gases under fluidized non-agglomerating conditions at a temperature within the range of 600 to 850° F. to effect reaction of 4 to 10 parts of oxygen by weight with each 100 parts of said relatively coarse fraction, treating said relatively fine fraction with sufficient oxygen-containing gases under non-agglomerating conditions at a temperature within the range of 600 to 850° F. to effect reaction of 0.1 to 4 parts of oxygen by weight with each 100 parts of said relatively fine fraction, recovering both of said fractions thus treated and subjecting them in admixture to low temperature carbonization under fluidized non-agglomerating conditions at a temperature within the range of 850 to 1100° F. and recovering as products solid carbonization residue and evolved gases and tar vapors.

4. The method for processing finely divided caking bituminous coal under fluidized low temperature carbonization conditions which comprises introducing said finely divided coal into a stream of gases moving upwardly through a drying and preheating zone maintained at a temperature within the range 250 to 600° F., which serves to separate said coal into two fractions, comprising a dried relatively coarse fraction which contains at least 50 percent of said coal and a dried relatively fine fraction which contains at least 10 percent of said coal, said relatively coarse fraction comprising coal particles of larger median size than the coal particles comprising said relatively fine fraction, reacting said relatively coarse fraction with sufficient oxygen-containing gases under fluidized non-agglomerating conditions in a pretreatment zone at a temperature within the range of 600 to 850° F., to render said relatively coarse fraction non-agglomerating in a subsequent fluidized low temperature carbonization treatment, reacting said relatively fine fraction with sufficient oxygen-containing gases under non-agglomerating conditions at a temperature within the range of 600 to 850° F. to render said relatively fine fraction non-agglomerating in a subsequent fluidized low temperature carbonization treatment, recovering both of said fractions thus reacted and subjecting them in admixture to low temperature carbonization under fluidized non-agglomerating conditions at a temperature within the range of 850 to 1100° F., recovering a portion of relatively fine particles of solid carbonization residue and recirculating said portion to said pretreatment zone to improve fluidization properties of the solids undergoing treatment therein, and recovering as products solid carbonization residue and evolved gases and tar vapors.

5. The method for processing finely divided caking bituminous coal under fluidized low temperature carbonization conditions which comprises introducing said finely divided coal into a drying and preheating zone in the presence of a stream of upwardly flowing hot gases, recovering therefrom hot gases and at least 10 percent of said coal as a relatively fine fraction suspended in said gases, separately recovering from said drying and preheating zone at least 50 percent of said coal as a relatively coarse fraction, said relatively coarse fraction comprising coal particles of larger median size than the coal particles comprising said relatively fine fraction, re-

acting said relatively coarse fraction with sufficient oxygen-containing gases under fluidized non-agglomerating conditions at a temperature within the range of 600 to 850° F. to render said relatively coarse fraction non-agglomerating in a subsequent fluidized low temperature carbonization treatment, reacting said relatively fine fraction with sufficient oxygen-containing gases under non-agglomerating conditions at a temperature within the range of 600 to 850° F. to render said relatively fine fraction non-agglomerating in a subsequent fluidized low temperature carbonization treatment, recovering both of said fractions thus reacted and subjecting them in admixture to low temperature carbonization under fluidized non-agglomerating conditions at a temperature within the range of 850 to 1100° F. and recovering as products solid carbonization residue and evolved gases and tar vapors.

6. The method for processing finely divided caking bituminous coal under fluidized low temperature carbonization conditions which comprises introducing said finely divided coal into a stream of gases moving upwardly through a drying and preheating zone maintained at a temperature within the range 250 to 600° F., which serves to separate said coal into two fractions, comprising a dried relatively coarse fraction which contains at least 50 percent of said coal and a dried relatively fine fraction which contains at least 10 percent of said coal, and relatively coarse fraction comprising coal particles of larger median size than the coal particles comprising said relatively fine fraction, treating said relatively coarse fraction with sufficient oxygen-containing gases under fluidized non-agglomerating conditions in a pretreatment zone at a temperature within the range of 600 to 850° F. to effect reaction of 4 to 10 parts of oxygen by weight with each 100 parts of said relatively coarse fraction, treating said relatively fine fraction with sufficient oxygen-containing gases under fluidized non-agglomerating conditions in the aforesaid pretreatment zone at a temperature within the range of 600 to 850° F. to effect reaction of 0.1 to 4 parts of oxygen by weight with each 100 parts of said relatively fine fraction to render said relatively fine fraction non-agglomerating in a subsequent fluidized low temperature carbonization treatment, recovering from said pretreatment zone both of said fractions thus reacted and subjecting them in admixture to low temperature carbonization under fluidized non-agglomerating conditions at a temperature within the range of 850 to 1100° F. and recovering as products solid carbonization residue and evolved gases and tar vapors.

7. The method for processing finely divided caking bituminous coal under fluidized low temperature carbonization conditions which comprises introducing said finely divided coal into a stream of gases moving upwardly through a drying and preheating zone maintained at a temperature within the range 250 to 600° F., which serves to separate said coal into two fractions, comprising a dried relatively coarse fraction which contains at least 50 percent of said coal and a dried relatively fine fraction which contains at least 10 percent of said coal, said relatively coarse fraction comprising coal particles of larger median size than the coal particles comprising said relatively fine fraction, treating said relatively coarse fraction with sufficient oxygen-containing gases under fluidized non-agglomerating conditions in a pretreatment zone at a temperature within the range of 600 to 850° F. to effect reaction of 4 to 10 parts of oxygen by weight with each 100 parts of said relatively coarse fraction, treating said relatively fine fraction with sufficient oxygen-containing gases under fluidized non-agglomerating conditions in the aforesaid pretreatment zone at a temperature within the range of 600 to 850° F. to effect reaction of 0.1 to 4 parts of oxygen by weight with each 100 parts of said relatively fine fraction to render said relatively fine fraction non-agglomerating in a subsequent fluidized low temperature carbonization treatment, recovering as a suspension in fluidizing gases both

of said fractions thus reacted and introducing the suspension into a low temperature carbonization zone maintained under fluidized non-agglomerating conditions at a temperature within the range of 850 to 1100° F. and recovering as products solid carbonization residue and evolved gases and tar vapors.

8. The method for processing finely divided caking bituminous coal under fluidized low temperature carbonization conditions which comprises introducing said finely divided coal into a stream of gases moving upwardly through a drying and preheating zone maintained at a temperature within the range 250 to 600° F., which serves to separate said coal into two fractions, comprising a dried relatively coarse fraction which contains at least 50 percent of said coal and a dried relatively fine fraction which contains at least 10 percent of said coal, said relatively coarse fraction comprising coal particles of larger median size than the coal particles comprising said relatively fine fraction, introducing said relatively coarse fraction into the bottom of a pretreatment zone with sufficient oxygen-containing gases to maintain fluidized non-agglomerating conditions at a temperature within the range of 600 to 850° F. to effect therein reaction of 4 to 10 parts of oxygen by weight with each 100 parts of said relatively coarse fraction, introducing said relatively fine fraction into the top of the aforesaid pretreatment zone to effect reaction of 0.1 to 4.0 parts of oxygen by weight with each 100 parts of said relatively fine fraction, recovering from said pretreatment zone both of said fractions thus reacted and subjecting them in admixture to low temperature carbonization under fluidized non-agglomerating conditions at a temperature within the range of 850 to 1100° F. and recovering as products solid carbonization residue and evolved gases and tar vapors.

9. The method for processing finely divided caking bituminous coal under fluidized low temperature carbonization conditions which comprises introducing said finely divided coal into a stream of gases containing oxygen moving upwardly through a drying and preheating zone maintained at a temperature within the range 250 to 600° F., which serves to separate said coal into two fractions, comprising a dried relatively coarse fraction which contains at least 50 percent of said coal and a dried relatively fine fraction which contains at least 10 percent of said coal, said relatively coarse fraction comprising coal particles of larger median size than the coal particles comprising said relatively fine fraction, reacting said relatively coarse fraction with sufficient oxygen-containing gases under fluidized non-agglomerating conditions at a temperature within the range of 600 to 650° F. to render said relatively coarse fraction non-agglomerating in a subsequent fluidized low temperature carbonization treatment, treating said relatively fine fraction with sufficient oxygen-containing gases under non-agglomerating conditions at a temperature within the range of 600 to 650° F. to render said relatively fine fraction non-agglomerating in a subsequent fluidized low temperature carbonization treatment, recovering both of said fractions thus treated and subjecting them in admixture to low temperature carbonization under fluidized non-agglomerating conditions at a temperature within the range of 850 to 1100° F. and recovering as products solid carbonization residue and evolved gases and tar vapors.

10. The method for processing finely divided caking bituminous coal under fluidized low temperature carbonization conditions which comprises introducing said finely divided coal into a stream of gases containing oxygen moving upwardly through a drying and preheating zone maintained at a temperature within the range 250 to 600° F., which serves to separate said coal into two fractions, comprising a dried relatively coarse fraction which contains at least 50 percent of said coal and a dried relatively fine fraction which contains at least 10 percent of said coal, said relatively coarse fraction comprising coal particles of larger median size than the coal particles comprising said

relatively fine fraction, treating said relatively coarse fraction with sufficient oxygen-containing gases under fluidized non-agglomerating conditions at a temperature within the range of 600 to 650° F. so that each 100 parts of said relatively coarse fraction are reacted with 4 to 10 parts of oxygen by weight, treating said relatively fine fraction with sufficient oxygen-containing gases under non-agglomerating conditions at a temperature within the range of 600 to 650° F. so that each 100 parts of said relatively fine fraction are reacted with 0.1 to 4.0 parts of oxygen by weight, recovering both of said fractions thus treated and subjecting them in admixture to low temperature carbonization under fluidized non-agglomerating conditions at a temperature within the range of 850 to 1100° F. and recovering as products solid carbonization residue and evolved gases and tar vapors.

11. The method for processing finely divided caking bituminous coal under fluidized low temperature carbonization conditions which comprises separating said coal into two fractions, comprising a relatively coarse fraction which contains at least 50 percent of said coal and a relatively fine fraction which contains at least 10 percent of said coal, said relatively coarse fraction comprising coal particles of larger median size than the coal particles comprising said relatively fine fraction, reacting said relatively coarse fraction with sufficient oxygen-containing gases under fluidized non-agglomerating conditions at a temperature within the range of 600 to 850° F. to render said relatively coarse fraction non-agglomerating in a subsequent fluidized low temperature carbonization treatment, recovering both of said fractions and subjecting them in admixture to low temperature carbonization under fluidized non-agglomerating conditions at a temperature within the range of 850 to 1100° F. and recovering as products solid carbonization residue and evolved gases and tar vapors.

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