FIG 1

FIG 2

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by

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PROCESS AND APPARATUS FOR DRYING WET PARTICULATE MATERIAL TO A DESIRED MOISTURE CONTENT

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4 Claims. (Cl. 34—39)

This invention relates to the continuous drying of particulate solids. More particularly, it relates to the continuous drying of pelletized carbon black. Still more particularly, it relates to an improved method and system for accurately controlling the heat input to a dryer employed for the continuous drying of pelletized carbon black.

Carbon black, being finely divided, is usually subjected to pelletization as an integral part of its manufacture. For dryer which controls the rate of drying is employed. The wet process comprises adding water to carbon black and subjecting the mass to a mixing action in suitably designed pelletizers whereby the carbon black is caused to agglomerate into small pellets. The resulting wet pellets are charged into the upper ramp end of a long, rotary, drum-type dryer in which they are subjected to a temperature sufficiently high to drive off the water, preferably to a moisture content of about 0.1—1.0%.

Because of variables involved in the drying operation, it has heretofore proved difficult to continuously produce pelletized carbon black by the wet process having a substantially uniform moisture content. In an effort to overcome this problem, various automatic control systems have been proposed to properly adjust heat requirements to the dryer. As illustrative of such proposals, for instance, it has been suggested that adjustments in heat requirements be made in response to variations in the rate of water introduction to the carbon black pelletizer. Another suggested control system is based on adjusting heat requirements in response to changes in the temperature of the dried carbon black pellets leaving the dryer. Another type of suggested control system governs adjustments in heat requirements in accordance with the temperature of the exhaust gas in the dryer stack. A still further suggested system makes use of dryer stack exhaust gas temperature to control heat requirement adjustments to the upstream portion of the dryer and the temperature of carbon black pellets discharged from the dryer to control the remaining portion. These various suggestions, however, have not proved to be completely satisfactory since they have failed to take into account all of the various problems that plague continuous drying systems of the type here involved. Among these may be mentioned the lengthy period of time during which the pellets must necessarily remain in the dryer. An additional problem resides in the heat absorption characteristics of the dryer which complicates the relationships between fuel input and drying efficiency. Finally, the rate at which wet carbon black is charged to the upstream end of the dryer is subject to wide fluctuations.

The drying of wet pellet carbon black as it travels through a dryer includes three phases. In the first phase the surface temperature of the pellets rises through heat exchange with the inside surface of the dryer, with the hot vapors passing through the drum and with other pellets that are hotter than itself.

In the second phase, the surface temperature of the pellets remains at a substantially constant value. The temperature remains substantially constant so long as the pellets are coated with moisture and the internal moisture can diffuse to the surface fast enough to replace evaporated surface moisture. Eventually the diffusion rate of the internally held water is not rapid enough to replace the evaporating surface moisture, with the result that the surface moisture disappears and the temperature of the pellets again begins to rise. The location within the dryer where the average surface temperature of the pellets first barely exceeds the aforesaid constant value is the temperature breakpoint, or TBP. The TBP marks the end of the second phase of the drying process and its exact position within the dryer tends to move back and forth as the flow of pellets fluctuates.

During the third phase, the pellets again increase in surface temperature towards the temperature of the dryer itself. During this third phase, evaporation takes place beneath the surface of the pellet. Since the internal moisture content of the pellet must diffuse within the pellet to the plane where evaporation is taking place, and since the vapors resulting from said evaporation escape from the pellet by diffusion, the rate of evaporation is limited by the rate of diffusion of water and steam through the pellet. As the plane of evaporation retreats farther toward the center of the pellet, the surface temperature of the pellet continues to get higher because of the increased thermal gradient required to force heat from the surface to the receding plane of evaporation. This thermal gradient is defined in terms of temperature increase of the pellet per unit of dryer length traveled.

Under the conditions usually found in this third heating zone, a fairly stable temperature gradient may be achieved. This can be determined in the laboratory under conditions approximately those found in a full scale dryer by agitating wet pellet carbon black of known water content in a heated vessel for 70 minutes. As the water evaporates, it is collected and the percentage of water removed periodically calculated. This latter is then plotted against drying time as shown in FIGURE 1 of the drawing. Each time the removed water content is calculated, the temperature of the carbon black bed is also determined. Also plotted in FIGURE 1 is a second absicissa showing the estimating position of pellets in a full scale dryer based on an assumed retention time of 60 minutes and a discharge temperature of 365°F. The curve of FIGURE 2 is obtained by plotting temperature against dryer length. The TBP, i.e., the end of the second, substantially constant material surface temperature drying phase, occurs at approximately 33% of dryer length and is indicated in FIGURE 2 as point "A." The TBP, i.e., the point in the dryer at which the surface temperature barely exceeds the dew point, occurs at approximately 33% of dryer length and is indicated in FIGURE 2 as point "A."

The results of the above laboratory determination, as illustrated by the curves of FIGURES 1 and 2, indicate that about 67% of the water content of the pelletized carbon black has been evaporated by the time the TBP has been reached. Thus, approximately two-thirds of the drying is completed within approximately the first third of the dryer length. During the next third of the dryer length, about an additional 27% of the original water content is removed. The TBP, therefore, is located at approximately the mid-point of that portion of the dryer in which 94% of the water is removed and is also at the beginning of the previously discussed third heating zone in which the temperature gradient for the latter stages of drying is established. Movement of the TBP forward and rearward in the dryer will cause variations in the final temperature and moisture content of the discharged pellets.

The improved method and control of this invention are based on the observation that if the TBP can be maintained at a preselected ideal location so that the slope of the temperature gradient curve for the third dry-
ing zone is maintained substantially constant, the moisture content and temperature of the discharged pellets will, in turn, be correspondingly substantially constant. However, inasmuch as the TBP as a practical matter will move forward and rearward because of fluctuations in pellet feed rate and other variables, the objects of this invention are met by making appropriate variations in heat input requirements to the dryer in response to deviations of the actual TBP from a preselected point to compensate for the fluctuations causing such deviations and thus maintain the TBP as close as possible to the preselected point. In this manner, a substantially stable temperature gradient curve can be maintained and a dried pellet product of uniform moisture content obtained.

The process and control system of the present invention may be more adequately described by reference to FIGURES 3 and 4. FIGURE 3 shows a dryer comprising a drum 10, rotatably supported upon wheels 37 and 38 and provided with manifold 11 and conduit 44 communicating with a supply of wet carbon black pellets. The drum 10 constitutes a drying chamber having an inlet and an outlet and providing a flow path for a continuously flowing bed 17 of pellets which gradually flows towards drum end 12 to discharge over drum lip 18 and through spout 19. Heat is supplied to drum 10 by burner assemblies 43, 44, each communicating through conduit 16 with a source of fuel. Moisture-laden air or recycled combustion gas or a mixture thereof is introduced through blower 42 and conduit 43 into drum 10 to be discharged through conduit 41 and suction fan 39.

Provided within drum 10 is a plurality of series connected thermocouples 21-32 bracketed about a preselected theoretically ideal location for the TBP indicated by point "A" in FIGURE 4. In order to provide optimum control in accordance with the process of this invention, the bracket should preferably be mounted in drum 10 so that point "A" is halfway between end thermocouples 21 and 32. The process, however, is still operative whether or not this situation prevails so that when the term 'bracketed about point "A"' is used herein it is meant that the group of thermocouples is mounted so that at least one but preferably half of them is on one side of point "A" and at least one but preferably half of them is on the other side of point "A". The thermocouples are supported from member 20 in a manner to permit their sensing points to be in or actually slightly submerged beneath the surface of the pellet bed 17. These thermocouples, preferably uniformly spaced, are operatively connected through control device 33 and conduit 35 to pneumatic motor valve 34 in conduit 16. Control consists of the known types capable of translating a deviation from a standard E.M.F. into a pneumatic corrective signal. However, a controller having a proportional band control, variable reset rate and rate action or derivative control is preferable. Although the controller is illustrated herein as having pneumatic signalling, any other type of signalling such as electrical, mechanical, hydraulic, or the like is quite acceptable so long as a valve of corresponding type is substituted for the pneumatic motor valve 34. A transmitter may or may not be located between the thermocouples and the controller depending upon the type of controller.

Since the position of point "A" will probably vary from dryer to dryer, it is necessary to be able to readily determine this point for each dryer. According to this invention, this may be accomplished by placing the dryer in operation with a temporary group of independently recording thermocouples suspended at arbitrarily selected points along the length thereof. No particular number of such thermocouples is required, although the greater the number and the greater resultant span of dryer length covered, the greater will be the probability of more accurately locating point "A" during the first trial. Each thermocouple should be in contact with the bed and spaced at intervals of 6-18 inches along about 10% or more of the length of the dryer. The chief distinction between the permanently mounted thermocouples and the temporary group is that the latter are not connected in series; each temporary thermocouple is provided with its own E.M.F. or temperature indicator at a location outside the dryer.

Once the temporary thermocouples are positioned, the dryer is put into operation for a period of time sufficient to bring about reasonably stable operating conditions. The input of wet pellet carbon black as well as other variables are maintained as close as possible to the conditions which will produce a product of a substantially preselected moisture content. Under such conditions, the TBP is stabilized in its theoretically ideal position. The theoretically ideal position of the TBP is, by definition, point "A". The TBP is also, by definition, the location in the dryer at which the second (constant material surface temperature) drying stage ends. Thus, temperature readings are taken from all of the thermocouples and, if necessary, the group of thermocouples is moved closer to either end of the dryer and additional readings are taken until the location of the TBP is found. This location is point "A". The temporary thermocouples are then replaced by the bracket of thermocouples 21-32, thereby being positioned to bracket established point "A".

Referring to FIGURES 3 and 4 relative to a description of the operation of the process and system of this invention, it can be seen that the abscissa of the graph of FIGURE 4 has been placed directly above the dryer drum 10 in FIGURE 3 and has been made of equal length thereby in order to correlate the location of the thermocouples 21-32 in FIGURE 3 with the location of point "A" in FIGURE 4. For purposes of this description, it should be assumed that the thermocouples are of the Iron-Constat type and that the reference temperature is 32° F. It should also be assumed that point "A" is at a point located at a distance of approximately one-third of the length of the dryer from the upstream end thereof.

When the dryer is operating with a steady input, thermocouples 21-32 will register the E.M.F.'s set forth at the ends of the reference lines pointing upward therefrom. The total E.M.F. under these assumed conditions will be 64.74. If the controller 33 is properly calibrated with the motor constant set such that a move of the valve is made at the correct rate to maintain the conditions shown by the graph in FIGURE 4. If, however, the input rate increases, the heat input will no longer be adequate to produce a product of uniform moisture content. Accordingly, the temperature rise at the burner will increase and the temperature drop toward the outlet end of dryer 10, thus changing the slope of the curve of FIGURE 4 in the region of the thermocouples and resulting in a lower total E.M.F. In response thereto, the controller 33 will increase the signal transmitted to valve 34 which will allow a faster flow of fuel to the burners until such time as the slope returns to normal within the thermocouple region and the TBP returns to its normal position of coincidence with point "A". A similar type of action follows if the input rate diminishes, except that all the various factors mentioned above will be reversed to produce a diminished flow of fuel until the TBP returns to its normal position.

Theoretically, two thermocouples bracketed about point "A" would be sufficient to do the job of sensing the movement of the TBP and controlling the gas flow. From a practical point of view, however, a larger number of thermocouples is desirable, since the E.M.F. deviation is thereby magnified for a given extent of movement away from point "A". It should be understood that the length of the span of thermocouples may be increased or decreased at will, and that the dryer may be operated successfully with a bracket of thermocouples which spans the entire length of the drum interior. The minimum length of the span may readily be determined.
for any particular dryer by one skilled in the art. It should, of course, be sufficiently great so that movement of the TBP will not exceed the limits thereof. There will invariably be a delay between the time a change in heat input is established by the controller and the time the change is effected. The proportional band mode on the controller which adjusts the corrective action in proportion to deviation, and the rate action or derivative mode which further adjusts the corrective action in proportion to the rate of deviation are very useful in compensating the time lag.

I claim:

1. In a process for the drying of wet particles bearing surface and internal moisture, which particles, when traveling through a dryer provided with an inlet, an outlet and heating means, rise in surface temperature during a first drying phase, remain at a substantially constant surface temperature during a second drying phase and again rise still further in surface temperature drying a third drying phase, the location in said dryer where said second, constant surface temperature phase ends being known as a TBP, temperature breaking point, said TBP being apt to move towards said inlet and outlet as the flow of wet particulate material through the dryer fluctuates, the improvement which comprises: varying the heat input to said dryer in response to movements of the TBP for maintaining the TBP as close as possible to a predetermined point, said heat input being increased in response to movements of the TBP toward the dryer outlet and decreased in response to movements of the TBP toward the dryer inlet, whereby a substantially uniform temperature gradient may be maintained in the third drying phase and a product of correspondingly substantially uniform moisture content may be obtained.

2. A process according to claim 1, wherein said particles are wet carbon black pellets.

3. A dryer system comprising: a rotary chamber having an inlet and an outlet for wet particulate material, said rotary chamber providing a flow path for said material; burner means associated with said rotary chamber for heating it; a conduit connected with said burner means for supplying fuel for combustion therein; valve means in said conduit for controlling the flow of fuel through said conduit; a plurality of temperature sensing means mounted within said rotary chamber at longitudinally spaced points along said flow path for at least about 10 percent of the length of said rotary chamber for measuring the temperature of said particulate material at each of said points, said temperature sensing means generating signals representative of the sum of temperatures at the aforesaid spaced points; and means, responsive to said signals and connected with said valve and said temperature sensing means, for controlling said valve and the heat output of said burner.

4. Apparatus according to claim 3 wherein the temperature sensing means are thermocouples connected in series and the signals produced thereby are the totals of the E.M.F.'s produced by the thermocouples.

References Cited by the Examiner

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NORMAN YUDKOFF, Primary Examiner.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,204,341

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It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 57, for "relationships" read -- relationship --; column 2, line 19, for "exaporation" read -- evaporation --; lines 47 to 51, strike out "The TBP, i.e., the point in the dryer at which the surface temperature barely exceeds, the dew point, occurs at approximately 33% of dryer length and is indicated in FIGURE 2 as point "A"."; column 5, line 19, for "drying" read -- during --.

Signed and sealed this 10th day of May 1966.

(SEAL)

Attest:

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