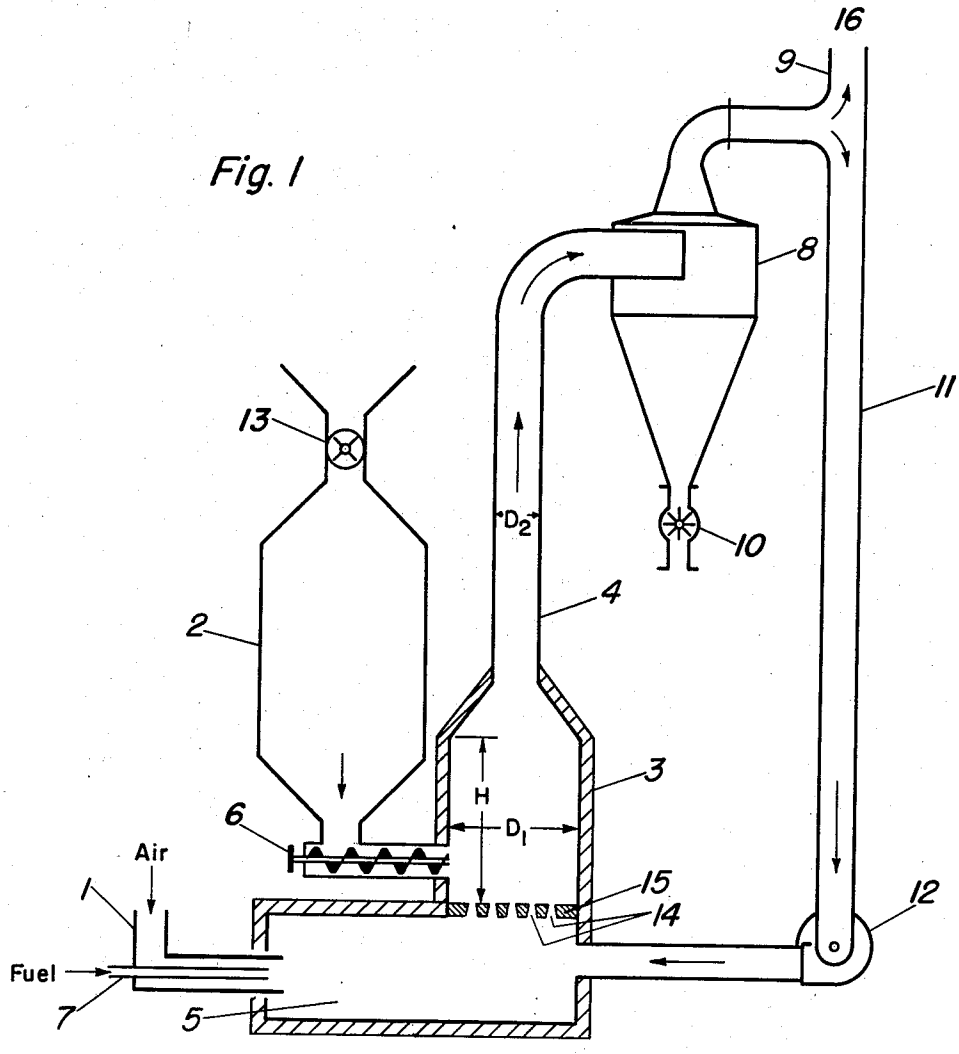
Jan. 19, 1954 V. F. PARRY 2,666,269

METHOD OF DRYING SOLIDS IN A FLUIDIZED BED

Filed Aug. 22, 1949

Fig. 1



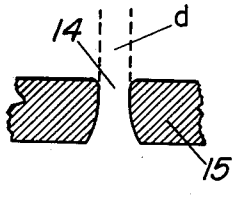


Fig. 2

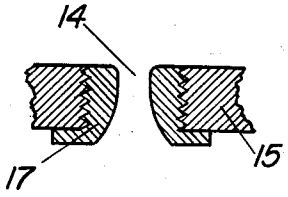


Fig. 3

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METHOD OF DRYING SOLIDS IN A FLUIDIZED BED

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9 Claims. (Cl. 34—10)

(Granted under Title 35, U. S. Code (1952), sec. 266)

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The invention herein described and claimed may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to a method for the rapid continuous heating of crushed solid materials by direct heat exchange with hot gases of high velocity. It relates more particularly to a continuous process characterized by high through-put and high efficiency for heating carbonaceous solids, including lignites, low-rank non-coking coals, and oil shales to drive off the more readily volatile products but without appreciable thermal decomposition of the volatile products. This invention also relates to the apparatus for carrying out the process.

Many coals in the United States as mined have a high percentage of mineral inorganic substances, or extraneous ash. It is recognized that a substantial portion of the ash from such coals can be removed by various cleaning methods, most of which involve washing the coal with aqueous solutions or suspensions under controlled conditions. Such coals after cleaning with an aqueous medium, are discharged from the cleaner with a film of water on each particle, and hence the reduction in ash content is accompanied by a substantial increase in the percentage of moisture in the treated coals. Other coals, including lignites and some of the low-rank non-coking bituminous coals, are characterized by a high moisture content, sometimes amounting to thirty-five percent or more.

For many industrial uses, moisture in excess of about five percent is undesirable, particularly for hydrogenation processes and in some gas manufacturing operations at high temperatures.

It has been proposed to dry crushed solids, including coal, with temperature control by passing a heated gas upwardly through the mass of crushed coal contained in a chamber, at such a velocity that the pieces of coal are in constant motion and the mass assumes in the fluidized condition the properties of a boiling liquid. The particles assume limited motion, without being entrained in the gas. United States Reissue Patent No. 21,526 broadly described such a process, mentioning that a temperature above 212° F. is preferred. This same patent also mentions that oil shale can be treated in like manner with steam whereby its oil is distilled.

The well known fluidized bed technique for reacting solids with gas usually employs space velocities in the range of 1 to 5 feet per second to maintain a dense, stable bed. If the reaction within the fluid bed is highly endothermic, such as that involved in moisture evaporation, the capacity of the system is low because the sensible heat transferred from the carrier gas is limited by the relatively low space velocity of the normal fluid bed. In order to increase the rate of heat transfer between the gas and solids, it is necessary to increase the space velocity of the carrier gases.

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Flash drying or the evaporation of moisture from granular materials by entrainment in hot gases is a well known industrial process which operates successfully on many materials, current flash drying processes extract hot gases from a combustion system with a suction fan which directs the gas upwardly through the drying column. One such circulation drier is described in United States Patent No. 2,156,924 and another in United States Patent No. 1,585,511. The fine material is entrained and dispersed in the drying column where heat is transferred from the gas to the solids. Such systems are limited as to the temperature of the hot gas in order to protect the fan from deterioration. Furthermore the efficiency of fans operating on hot gases is low.

In practice, flash drying of entrained materials is usually accomplished with inlet hot gases at temperatures less than 1300° F. In the generation of hot gases in a combustion chamber excess air is admitted to reduce the flame temperature the desired amount whereby the generated gases are within the proper temperature range. By so doing much useful heat is wasted. The efficiency of fuel utilization and the rate of drying entrained materials would be considerably higher if hot gas, at say 2600° F. could be employed. This, however, is not feasible in prior flash drying systems.

An object of the present invention is to provide an improved method of heating granular solid material, to volatilize water therefrom by entraining said solids in gases of a high-temperature range impossible of utilization in conventional flash drying. It is an additional object of the present invention to remove water from wet coals and other solid substances by heating at optimum speed to temperatures just short of their thermal decomposition, which is attained by initially heating these solids in a fluidized bed by employing a gas of that high temperature range not conventionally employed then entraining them by increasing the velocity. It is moreover an object of the present invention to treat

lignite and reactive low rank coals at maximum capacity by heating under controlled conditions to temperatures close to, yet below, their point of thermal decomposition by dispersing such pulverized solids by employing a very high temperature gas, then entraining them in the same gas by increasing the velocity. A still further object is to separate the highly heated carbonaceous solids from which the water has been removed to secure one portion which is finer than the rest and return this to the furnace as a source of fuel in generating the highly heated gases for the process. Likewise it is an object to provide an apparatus for carrying out this process of removing volatiles from carbonaceous solids below point of thermal decomposition at optimum speed, using less gas for entrainment than any now known and returning to the furnace the more finely divided recovered solids as a source of fuel.

As used herein, the term "fluidized bed" has the conventional meaning of a mass of solid particles which exhibits the liquid-like characteristics of mobility, hydrostatic pressure, and an observed upper free surface or boundary zone across which a marked change in concentration of particles occurs. This fluidized condition is also characterized by a turbulent motion whereby the bed of solids has the appearance of a boiling liquid.

Further objects and advantages of the invention will be apparent from the following description of a preferred form of embodiment thereof taken in connection with the attached drawing which is a diagrammatic view.

In accordance with my invention granular carbonaceous material, such as oil shale, lignite or wet low rank coal, is continuously fed into the heat transfer chamber where it is jetted with upwardly directed gases which have a temperature of the order of 2000–3000° F. This impingement with such hot, high velocity gases causes virtually instantaneous heat transfer to the solids. The space velocity of the gases which is between 5 and 15 feet per second puts the solids in a state of ebullient motion, or fluidized state resembling a boiling liquid. The particles at this stage are not entrained in the gas but are in vibrant motion and possess the turbulent motion of a boiling fluid. The rate of feed of the solids and gases is adjusted to result in a temperature of the fluidized mass at the top of this chamber of about 300° F.

The boiling mass of fluidized solids is then entrained as a result of the higher space velocities produced by a decrease in the diameter of the superimposed chamber and moved upwardly. The velocities will usually be in the order of 30 feet per second so as to move the solids upwardly vertically. A greater space velocity than 30 feet per second is necessary, if material larger in size than ⅛ inch is originally processed. The entrained treated solids flow to suitable separators where they are separated from the spent, hot gases and volatilized products.

Where it is desired to recover the coarser products without admixture with dust and finer product, this may be effected readily by means of two separators in series, the coarser material being collected in the first separator and the finer material being collected in the second separator. When drying coal, oil shale or like carbonaceous substance, the finer solids may be returned to serve as fuel to the combustion zone located below the chamber where the incoming granular

solids are brought into a hot fluidized state. The amount of finer material returned will decrease to the same extent the quantity of fuel which would be required from an outside source.

The proportion of air to total fuel is gauged to generate the highest practical flame temperature. The fuel and air are admitted under pressure to the combustion zone. The primary products of combustion are then mixed with re-circulated spent gases from the tail end of the process i. e., coming from the cyclone. Only a portion of the spent gases are however re-cycled; the greater volume is discarded.

The proportion of re-circulated spent gases is adjusted to develop the desired mixture temperature of the hot gases which pass through the series of openings in the diaphragm separating the combustion chamber from the heat transfer chamber (fluidizing chamber). The diameter of the openings and the pressure of the gas mixture should be so related that the velocity of gases issuing through them is greater than 30 feet per second. This will prevent the granular material undergoing treatment from falling into the combustion chamber.

The accompanying drawings show, more or less diagrammatically, a system embodying my invention. Figure 1 shows a heater and associated solids handling apparatus, while Figure 2 is an enlarged view of a hot gas inlet port at the bottom of the heater and Figure 3 an alternate form.

Referring to Figure 1, a substantially cylindrical vertical feed hopper is shown at 2, preferably with a sloping bottom portion in open communication with a feeding means 6 for transferring solids to the heater 3. Although the fuel feeding means 6 is shown as a worm conveyor, other mechanical feeding devices may be employed. For some types of operation it is preferable to utilize gravity or pneumatic feeding devices. Feeder 6 discharges material into the base of heater 3.

The heater 3 is a substantially vertical cylinder, having an inwardly sloping conical top in open communication with an offtake 4 of relatively smaller cross section D2 as compared with cross section D1 of heater 3. Heater 3 may be constructed of metal or refractory material, capable of resisting the erosion of material moving therethrough. The floor 15 of heater 3 is provided with a plurality of ports 14, preferably substantially over the entire surface, to provide uniform distribution therethrough, of hot gases from furnace 5. Furnace 5 is provided with fuel inlet 7, and air inlet 6, having means (not shown) for controlling the ratios and amounts of fuel and air supplied thereto.

Vertical offtake 4 leads to a separator 8. Which may be a conventional cyclone separator as shown, or other suitable means for removing solids from the gas stream. Solids accumulating in 8 may be discharged at a controlled rate by means of star wheel 10.

Gases and vapors from separator 8 are discharged at 16. A portion of these fluids may be recycled to furnace 5, if desired by means of conduit 11 and blower 12.

As shown in Figure 2, the ports 14 at the bottom of heater 3 are preferably of a diameter (*d*) less than the thickness of partition 15 and are Venturi-shaped so as to provide a jetting action as the hot treating gases flow therethrough into the bed of fluidized solids in the heater.

Ports 14 need not be formed in plate 15 as indi-

cated in Figure 2. An alternate form is shown in Figure 3, wherein the Venturi-shaped port 14 is formed in a plug 17 which is attached to plate 14 by threads 18. If desired, of course, plugs 17 may be force-fitted or welded to plate 15.

Although my invention is applicable to a wide variety of materials, it is primarily designed for drying and preheating coal (or lignite) and oil shale. A practical embodiment of the invention is the drying of a Texas lignite in the above-described apparatus. This fuel contains 37.6 percent moisture as received.

The lignite to be dried is crushed to pass a one-half inch screen. For very high drying rates, the particle size of raw fuel should not exceed one-eighth inch. The crushed and sized fuel is charged to hopper 2, through valve 13, and is forced into heater 3 by feeder 6. In heater 3, the fuel is maintained in a state of violent agitation by streams of hot combustion products passing through the ports 14 from furnace 5. Air and fuel under pressure are injected into furnace 5, preferably in ratios and amounts to produce temperatures ranging up to 3000° F. The velocity of hot gases entering heater 3 at the ports 14 should exceed thirty feet per second to prevent solids dropping through the ports 14 into furnace 5.

Under these conditions, there is substantially instantaneous heat transfer to the fresh incoming solids. The rate of feed of solids and volume of hot gases are adjusted to produce a temperature of about 300° F. in the upper, restricted, zone of heater 3. Space velocity of gases required for agitation and mixing in the bed of solids being treated in heater 3 is from five to fifteen feet.

By restricting the diameter at the upper portion of the heater, as shown, space velocities in excess of thirty feet per second are secured in the upper part of the bed and through offtake 4. Treated solids are thus entrained in the higher velocity effluent gases and vapors and are carried out of heater 3 into separator 8.

The height of the heating zone, shown at H in Figure 1, determines the residence time in heater 3, since the time of contact or residence of solids in the fluidized heating zone is directly proportional to this height. For drying lignite under the described conditions a satisfactory residence time is effected with a zone of from five to six feet. The drying capacity of the heat transfer zone is proportional to the space velocity and temperature of the gases injected into the fuel bed, in accordance with the following empirical formula:

$$C=\frac{3.2(SV)T_1.96}{M_1}$$

Where

C=pounds/hour/square feet (excluding radiation losses)

SV=space velocity of gases in the column at 300° F. and 30'' Hg

T_1=temperature of hot gas injected into fluid bed, °F.

M_1=moisture content of coal feed, percent.

In drying a Texas lignite as described, the following data were obtained:

Coal charging rate, lb./hr./sq. ft.	1,358
Moisture in raw coal, percent (M_1)	37.6
Moisture in dried coal, per cent (M_2)	4.6
Furnace fuel (natural gas), cu. ft./lb. coal	.597
Air for combustion, cu. ft./lb. coal	5.9

Recirculated products of combustion, cu. ft./lb. coal	4.5
Net heat supplied, B. t. u./lb. coal	525
Temperature of hot gas, °F. (T_1)	1,950
Temperature of fluid bed, °F. (T_2)	300
Dry coal recovered, lb./hr./sq. ft.	837
Drying efficiency (excluding radiation), percent	92.2
Overall efficiency, percent	87.2

The drying of lignite in accordance with my process is accompanied by a shrinkage in particle size, amounting in some cases to about 90 percent of the equivalent liquid volume of the moisture removed. This reduction in particle size is not due to attrition, as the amount of fines produced is too small to account for the change in particle size, and has not been observed in other drying processes. The dried fuel, particularly in the smaller sizes, has little tendency to pack, and readily flows through conduits like a liquid, under static pressure head concurrently with moisture removal, it is also possible in my process to modify the chemical properties of fuels being treated, if desired. Thus, by control of the fuel-air ratio in furnace 5, the hot gases injected into heater 3 may have sufficient excess oxygen to effect a mild oxidation of the fuel. In this manner, for example, the tendency of certain fuels toward spontaneous combustion when dry may be materially reduced. Furthermore, a mild oxidation of certain high-volatile coals may be obtained by my process while preheating and/or drying them for use in coke-ovens, thereby improving the coking properties of such coals.

With or without modification of the chemical properties, preheating and/or drying of coal for coke-oven charges is highly desirable. By drying and preheating to 500° F., in accordance with my invention, a typical coke-oven charge, the heat for carbonization may be reduced from 1,265 B. t. u. to 980 B. t. u. per pound of coke produced. This represents a saving of about 22 percent of the oven heat, or approximately equivalent increase in the oven capacity.

While I have thus described my invention for the drying of carbonaceous material such as coal and oil shales, it should be understood that it is not limited thereto. Other solid substances may likewise be treated with hot gases to effect physical and/or chemical changes therein at low temperatures. Temperatures at the top of the bed may be as low as 250° F. for some coals. Having thus described the nature of my invention and the means of practicing the same, but without intending to limit the invention to such details save as expressly set forth in the appended claims.

I claim:

1. A method of drying solids in a fluidized bed comprising continuously feeding a moist solid in granular form to the lower portion of a fluidized bed, injecting substantially inert gases at a temperature of the order of 2000°–3000° F. into the said moist solid, controlling the rate of feed of said moist solid and the volume and temperature of said gases whereby the temperature at the top of said bed is of the order of 300° F., entraining dried solid at the top of said bed by increasing the velocity of the effluent gas stream and then separating the entrained solid from the effluent gases.

2. The method according to claim 1 in which the moist solid is lignite.

3. The method according to claim 1 in which the moist solid is a low-rank bituminous coal.

4. The process according to claim 1 in which the moist solid is oil shale.

5. In a method for drying carbonaceous minerals in a fluidized bed, the improvement which comprises continuously feeding a granular carbonaceous mineral containing a substantial moisture content to the lower portion of said bed, and rapidly heating said mineral by impingement with combustion products at a temperature of the order of 2000°–3000° F., the rate of feed of said mineral and the volume and temperature of said combustion products being so proportioned that the temperature in the upper portion of said bed is of the order of 300° F.

6. The method set forth in claim 5 in which the carbonaceous mineral is a low-rank fuel.

7. The method set forth in claim 5 in which the carbonaceous mineral is lignite.

8. The method set forth in claim 7 in which the dried lignite is removed from the fluidized bed by entrainment in the gases flowing from the upper portion of the fluidized bed.

9. The process of drying moisture containing low-rank solid fuels which comprises generating combustion gases under pressure and at a temperature substantially within the range of 2000°–3000° F., passing said hot gases, without further compression, upwardly through a column of the granular fuels at a velocity of from about 5 to about 15 feet per second to maintain said fuel as a fluidized bed, continuously dispersing fresh granular fuel to be dried in the lower portion of said fluidized bed with the hot combustion products entering said bed, controlling the rate of feed of said hot gases and of said fresh fuel so that the temperature of the upper portion of the bed is in the order of 300° F., substantially increasing the velocity of the gas stream adjacent the upper portion of said bed, thereby entraining solids of substantially reduced moisture content, and separating the entrained solids from the effluent gases.

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