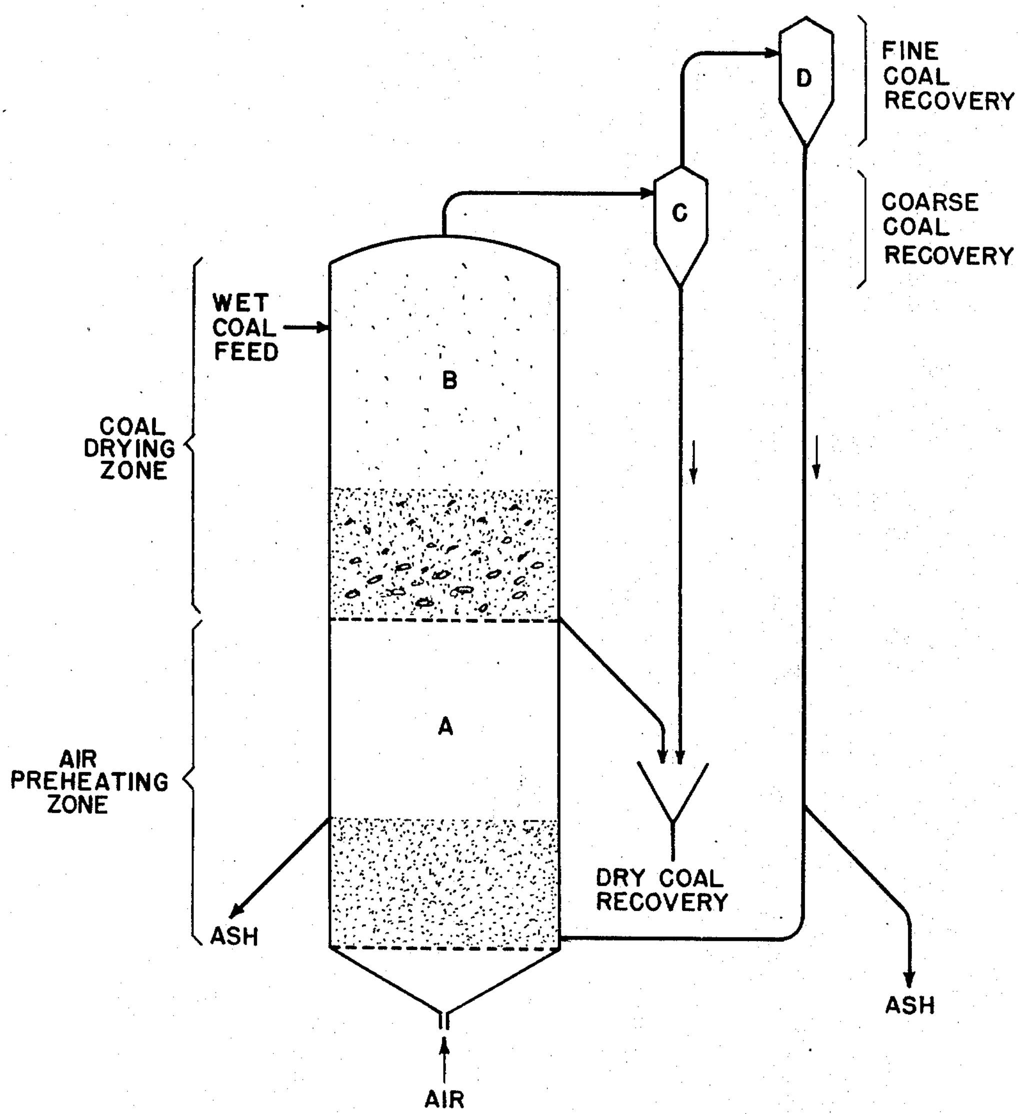
May 19, 1953 W. W. JUKKOLA 2,638,684

PROCESS FOR HEAT-TREATING COMBUSTIBLE SOLIDS

Filed April 7, 1950 3 Sheets-Sheet 1

FIG. I.



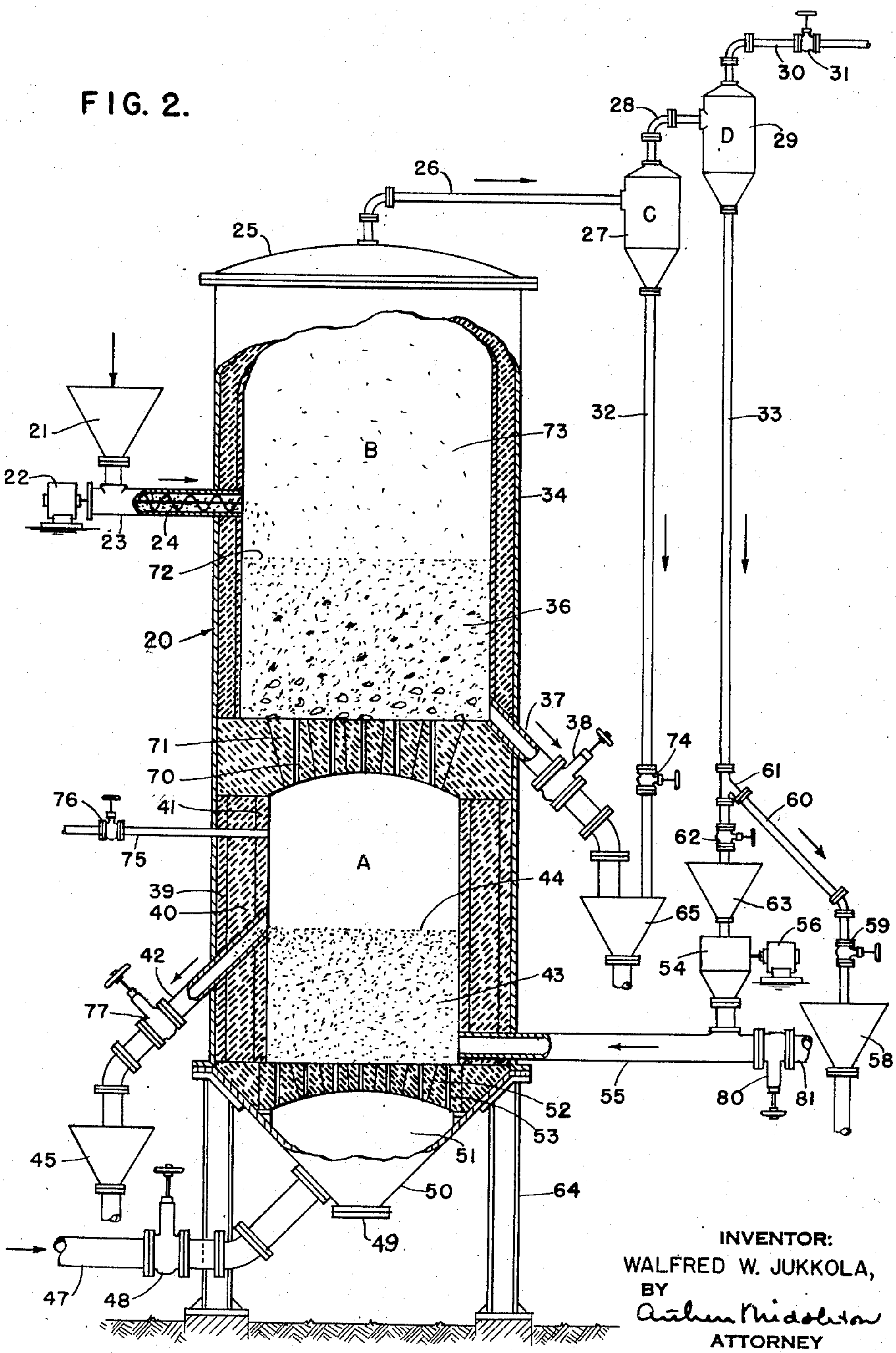
INVENTOR:
WALFRED W. JUKKOLA,
BY
Arthur Middleton
ATTORNEY

May 19, 1953 W. W. JUKKOLA 2,638,684

PROCESS FOR HEAT-TREATING COMBUSTIBLE SOLIDS

Filed April 7, 1950 3 Sheets-Sheet 2

FIG. 2.



INVENTOR:
WALFRED W. JUKKOLA,
BY
Arthur Middleton
ATTORNEY

May 19, 1953 W. W. JUKKOLA 2,638,684

PROCESS FOR HEAT-TREATING COMBUSTIBLE SOLIDS

Filed April 7, 1950 3 Sheets-Sheet 3

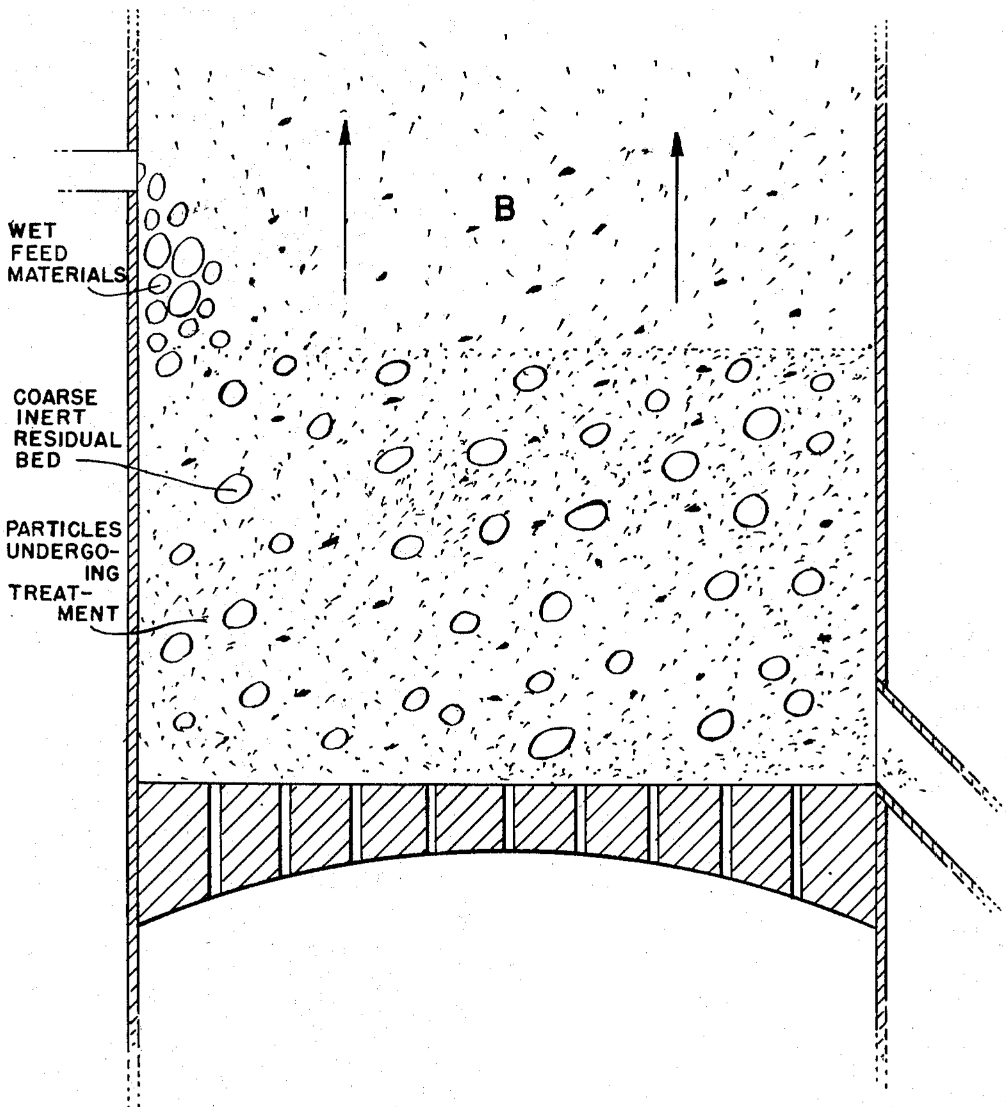


FIG. 3.

INVENTOR:
WALFRED W. JUKKOLA,
BY
Arthur Middleton
ATTORNEY

Patented May 19, 1953

2,638,684

UNITED STATES PATENT OFFICE

2,638,684

PROCESS FOR HEAT-TREATING COMBUSTIBLE SOLIDS

Walfred W. Jukkola, Westport, Conn., assignor to The Dorr Company, Stamford, Conn., a corporation of Delaware

Application April 7, 1950, Serial No. 154,473

8 Claims. (Cl. 34—9)

1

This invention relates to a method of drying moistened or damp combustible solid materials by drying them under conditions whereby the materials to be dried are maintained in a fluid-like state. More specifically, this invention relates to a method and apparatus for drying coal whereby the coal fines are burned under pressure to furnish the heat necessary to dry the coal.

In modern coal or ore treatment operations, it is customary to subject raw material being recovered from the veins to an upgrading operation whereby the valuable constituents of the mined material are separated from rock, slate or other gangue. These upgrading processes are usually conducted in a liquid medium wherein the heavy materials sink and the lighter constituents float, thus effecting the separation. Coal thus recovered from such an operation is necessarily saturated with water and/or other liquids. Coal is also subjected to various types of washings to clean it, remove slag, etc. and is also upgraded by flotation processes. All of these operations leave the coal with a considerable moisture content which causes solidification of coal cars in freezing weather, and increases shipping costs, and decreases B. t. u. value per ton.

It is thus the principal object of this invention to discover a method of drying these coals or ores or other combustible solids while they are in the solids-fluidization state so that the aforementioned difficulties will be overcome. It is a further object to effect a separation of finer particles of coal or ore from the larger pieces so that these fine particles will not be present in the finished product, thus decreasing the amount of dusting present when handling the material. It is yet another object to discover a method of utilizing the latent heat values present in these fine particles of coal or ore so that the heat may be used to dry the desired material and also to eliminate the disposal problem attendant to the fine particles.

In connection with this object, it is necessary to discover a means of burning the fine coal in a pressurized vessel which must operate at a back pressure of more than two or three inches of water.

As a broad object of the invention it might be said that it is to use coal or ore in some fashion to dry the wet material, principaly because the material itself when used as fuel would normally be the most available source of heat directly at the mine.

This invention accomplishes the above objects,

2

and others which are disclosed in the later description, by carrying out the drying process in a reactor in which the coal or ore to be dried is maintained in a fluidized condition. If coal is maintained in this condition, gases to maintain this condition are forced upwardly through the fluidized bed and by adjusting the velocity of these fluidizing gases, the size and amount of the particles which are entrained in the gas stream can be controlled. Thus a classification can be effected in the reactor. The larger particles remain behind in the bed and are subjected to drying. The dried finer particles of coal are carried along in the gas stream and removed from the main body of the coal. These finer particles, by this invention, are separated from the gas stream by any sort of conventional solids-diminishing equipment, such as a cyclone or a settling chamber. As an alternative, an inert bed may be fluidized in the drying zone and the entire quantity of coal to be dried swept out by the gas stream. A classification into a main body of coal and a fine fraction is then accomplished in a plurality of cyclones in series.

The fine solids are collected and the necessary amount is supplied to a heat generating station. The heat generating station is another furnace in which there is also a bed of solids being maintained in the fluidized condition. This bed is to be an "inert" bed, that is, it is composed of solid material which does not react with the fluidizing gases and which remains substantially constant, and which is composed of particles whose size is significantly large so as not to be carried out by the upward gas stream but are of such size range that it can be fluidized. These particles will generally be larger than that of the fine particles of material which were recovered from the drying furnace. The inert bed is maintained in a fluidized condition and while in this state, the fine solids previously recovered are supplied to the bed. Air or other oxygen bearing gas is used to fluidize the bed. The fine material being supplied to the bed burns when it contacts the fluidizing air and serves to preheat the air to a high temperature, and also to heat the inert material to a corresponding temperature. The heated inert particles serve as a large heat reservoir in which nearly perfect heat exchange is accomplished. The fine particles thus burn almost instantaneously upon reaching the bed. The inert material also serves to hold the particles for a longer residence time than they would normally have if supplied alone into the gas stream.

An important feature of carrying out the burning process as described in this invention is that this is a process which will operate under a back pressure of 0 to 10 p. s. i. or higher and thus the pressurized hot gases are immediately available for supplying to any unit which requires gases in this condition. At this point, the process is partially distinguished from the usual burner in that in the usual unit, additional compression equipment is needed if a pressurized gas must be supplied.

The thus heated air then is conducted to the previously mentioned drying furnace, where it serves the threefold purpose of drying the coal which is in that furnace, classifying the coal therein so that the fine particles are removed from the larger particles, and finally of fluidizing the materials in this furnace. Finished dry coal is recovered from this drying furnace. If no inert bed is used, the majority will be recovered from the bed directly, with some being recovered from the cyclones or other separation system. If an inert bed is used, the major part will be recovered from the cyclones.

Reverting now to the use of the terms fluidize, fluidized-solids and fluidized bed, it is to be noted that these terms are used interchangeably in the art to designate a type of dense-suspension wherein finely-divided solids particles are dispersed in an upwardly moving stream of gas. When a gas passes upwardly through a mass of finely-divided solids particles three phenomena may occur. At very low space velocities, say of the order of less than 0.5 feet per second, the gas permeates and diffuses up through the solid mass, without imparting any apparent motion to the particles. The gas velocity through the solid mass is always higher than the space velocity but the latter term is used in the art for convenience; it is the velocity the gases would have if they flowed up through an unobstructed passage having a free cross-sectional area equal to that occupied by the solid mass of particles. At very high superficial velocities, e. g. of the order of 50 feet per second, the gas stream picks up the particles and entrains them with the gas stream, thus forming the typical dilute gas-solid suspension or dispersion, as typified by dusty air. At intermediate space velocities, another phenomenon occurs. At space velocities ranging between about 0.5 and 5.0 feet per second, the gas stream suspends the solid particles larger in size than about 250-500 microns as a fluid bed. A fluidized bed is a very dense suspension of solids in a gas; the solids content may vary from 10 pounds to over 100 pounds per cubic foot depending upon the nature of the particles and the gas velocity. The particles in a fluidized bed are in turbulent, zig-zag motion and in appearance the fluidized bed resembles a boiling liquid, it presents a fluid-like level and the particles therein flow under fluistatic head. But more importantly, from the viewpoint of conducting chemical reactions, is the high heat capacity and rapid heat transfer within a fluidized bed. These qualities result in a very high degree of temperature uniformity throughout a fluidized bed; so much so that a fluidized bed may be characterized as thermally-homogeneous.

While the use of fluidized beds has been prominent in the petroleum refining industry, especially in catalytic cracking, they have not been adapted to many other arts and the above description has been incorporated in this specification in order to distinguish a fluidized bed from wet slurries, so-called fixed beds and dilute dispersions or suspensions. The invention employes fluidized beds as an essential feature of the process.

The best embodiment of this invention now known to me is that shown in the figures of the accompanying drawings. These are by no means to be limiting applications of this invention, but its scope is to be determined by the appended claims.

In the drawings,

Figure 1 is an idealized view of a solids-fluidization reactor showing the respective positions of the three essential zones when contained in one reactor.

Figure 2 shows a two stage embodiment reactor and all its accompanying units in detail.

Figure 3 is an enlarged view of the drying zone showing the wet coal being supplied and the dry coal being entrained.

More specifically in Figure 2 there is shown reactor collectively designated **20**, comprising top plate **25**, outer shell **34**, and bottom coned plate **50**, and supported by structural members **64**. The reactor in the embodiment shown in these drawings is divided into two zones, namely the heat generating zone A and the drying zone B. The heat generating zone A is lined with insulating brick **39** and firebrick **40** and **41**. At the lower portion of heat producing zone A is located the apertured constriction plate **52** which serves to support the bed of solids to be treated in zone A. This plate has a number of apertures **53**, passing completely therethrough and serving to conduct fluidizing gases through the plate and into bed **43**. Gas for fluidizing the respective beds is introduced through pipe **47** controlled by valve **48**, passes into windbox **51** and thence upwardly through the constriction plate **52**. In the bottom of windbox **51** there is provided a clean-out port **49** from which any fine solids which percolate downwardly through the plate may be removed. Drying zone B in this embodiment is located directly above zone A and is enclosed in the unitary shell **34**. The bed in this zone is supported by constriction plate **71** containing apertures **70**. The heated gas uprising from zone A passes through the constriction plate and into bed **36** of zone B where it serves to dry, classify and fluidize the particles in this bed.

In operating this reactor the wet material to be dried is furnished to hopper **21** which supplies the material to screw-feed means **24** encased in shell **23** and powered by motor **22**. The wet feed is supplied first to the drying zone B where it enters at a point somewhat above the level **72** of bed **36**. In falling downwardly to reach bed **36** the wet feed is first contacted with hot fluidizing gases and is given an opportunity to become partially dried. The location of the feed is not critical, but is helpful. Upon reaching bed **36** it becomes fluidized and dried by the uprising gases. Bed **36** is composed principally of an "inert" material such as ceramics, metals, metal oxides, or a coarse fraction of the materials being dried. This serves as the heat reservoir to which the incoming wet feed is supplied. The velocity of the incoming gases is so adjusted that these inert materials are fluidized while simultaneously the majority of particles contained in the incoming coal are entrained. They are carried upwardly out of bed **36** into freeboard area **73**, from which they pass upwardly into pipe **26** and into primary cyclone separator or settling chamber C. In this separator C, also designated **27**, all but the fines are removed from the gas stream and these so removed particles pass downwardly through pipe **32** controlled by valve **74** into storage hopper **65** where they are now in a finished condition.

The fine materials are carried along through pipe **28** into secondary cyclone separator D, also designated **29**. In this separator the fines are collected and the clean gas passes upwardly through pipe **30** controlled by valve **31** to exhaust. The fines collected in separator **29** pass downwardly through pipe **33** through fitting **61** to hopper **63**. If more fines are collected than is desired, then valve **62** may be closed down, thus diverting the fines and any ash which they might contain through pipe **60** controlled by valve **59** into storage hopper **58**. Thus dry finished fines will be recovered in storage hopper **58** and dry finished coarse materials will be recovered in storage hopper **65**.

The fines which are collected in hopper **63** are used to furnish the necessary heat for conducting the drying operation. These fines are supplied to star feeder **54** empowered by motor **56**. This star feeder supplies the fines to the gas stream passing through conduit **81**, controlled by valve **80**. They are picked up by this gas stream and delivered to bed **43** located in heat generating zone A. By the use of this standpipe feed with compressed air conveying system the danger of flash back is eliminated. This is accomplished by maintaining the carrier air velocity in the coal feed nozzles at rates considerably above the flame propagation rate. The bed in zone A is comprised principally of some fluidized inert material of grain-size considerably coarser than the incoming fines being supplied by star-feeder **54**. The fines are entrapped in this fluidized inert bed for a few moments and they are caused to burn therein by supplying oxygen through constriction plate **52**. Upon burning therein they serve to heat up this incoming gas which then passes upwardly into drying zone B. In order to control the temperature of the now heated uprising gases, an air bleed-in pipe **75** controlled by valve **76** is supplied. To this pipe there may be furnished cool gases which will blend with the hot uprising gases to give a controlled temperature to the gas which is being used for drying material in zone B. It is also possible to control the heated gas temperature and bed temperature to prevent fusion by supplying excess air to the inert combustion bed. Any ash which might build up in zone A and which is not entrained by the gas stream may be removed from zone A by spill pipe **42** and the rate of take-off controlled by valve **77**. This ash will go into storage hopper **45** from whence it is either discarded or subjected to further use beyond the scope of this invention.

Any particles in zone B which are too large to be fluidized by the uprising gas may be intermittently or continuously withdrawn, as conditions require, through spill pipe **37** controlled by valve **38**. These particles represent dry finished product and are hence blended with the coarse dried product in storage hopper **65**.

EXAMPLE 1

This unit has been found useful in drying Pennsylvania anthracite coal containing 25% to 30% moisture. Since completely dry coal dusts severely, drying operations are usually controlled to leave a residual moisture content of 3% to 5%. It has been found however that it is possi-

ble to reduce the moisture content to 0%, if desired.

The screen analysis of the constituents which were used is as follows.

Coal used as inert bed in drying compartment

Mesh	Percent Cum.+
6	37.3
8	54.6
10	72.1
14	84.1
20	92.3
28	98.7
35	99.5
48	99.8
65	99.9

Pennsylvania anthracite coal to be dried

Mesh	Percent Cum.+
10	0.1
14	1.2
20	5.6
28	14.4
35	25.7
48	40.0
65	53.7
100	65.9
150	77.1
200	83.3
325	90.4

Sand used as the inert bed in the coal burner

Mesh	Percent Cum.+
20	5
28	25
35	94
48	99.9

Fine coal burned in combustion chamber

SAMPLE A

Mesh	Percent Cum.+
65	0
100	27.9
150	51.0
200	68.9
325	90.7

SAMPLE B

Mesh	Percent Cum.+
150	0
200	25.7
325	56.9

The reactor was operated at a feed rate of 50 tons of the above wet feed per hour and at this rate, under the conditions which I shall describe, 36 tons of fines were required to be supplied per day to the heat generating zone A in order to accomplish the necessary drying. The reactor was operated with the heat generating zone at a temperature of 1850° F. and the drying zone was operated at a temperature of 200° F. The stack gas coming from the drying zone was 200° F.

Another advantage of this inert bed coal burner is the high burning efficiency. The use of the inert bed system eliminates the loss of fuel due to sifting through the conventional grates. My tests have indicated that practically no unburnt coal is carried out by the stack gases leaving the zone A. Tests indicated combustion efficiency of 95–100% in the inert bed. The hot gases from the pressurized burning operation may also be used for low temperature calcination operations such as decomposition of trona, dehydration of hydroxides, etc., in addition to drying wet materials.

EXAMPLE 2

A further use of this invention is the drying of any combustible materials from which it is possible to separate the fines and burn them independent of the drying of the main body of material.

An example of such material, in addition to coal, would be pyritic materials which have come from a flotation cell. These materials are not only wet but contain flotation agents as a contaminant. If it is desired to dry the pyritic concentrates before shipping them to a smelter or for other treatment, or if it is desired to partially heat the pyritic concentrates in order to decompose the flotation agents, then the process of this invention is useful. The pyritic fines are separated, passed into the combustion bed and burned. The heated gases then pass into the drying bed to dry the main body of the ore.

In employing the apparatus of this invention, the source of the fine materials is not necessarily to be confined to those which are recovered from the drying zone but may also include any fine materials which are combustible, so as to supply heat for drying. In commercial applications, this will frequently include stockpiled fine material.

It is also within the ambit of this invention that it be carried out in a plurality of reactors which need not be located one above the other or contained within the same shell. Thus any operations above outlined which are currently using oil etc. as a source of heat, can be adapted to this process by installing a separate heat generating unit to consume the fine combustible materials and supply hot gas to the drying unit, or for other operations.

In the description of the drawings, a unit was shown in which the drying is performed using an inert bed and collecting the dried material from the cyclones, or other separating means. This operation can be carried out equally as well, although not as economically, by fluidizing the material to be dried directly in bed **36**, and using a gas velocity low enough so that the solid entrainment is kept to a minimum. This will be determined by the material being treated or dried and by the screen analysis of this material.

It is far more advantageous to use an inert bed because the coarse inert material serves to break up any lumps of wet material which are fed to the reactor. By the use of an inert bed a much higher space velocity of fluidizing gas is permitted which produces a violent agitating action in the dryer. As an example, in the drying of −14 mesh anthracite coal, if no inert bed was used, and employing a space rate of 1 ft./sec., the maximum moisture content that could be tolerated without causing defluidization difficulties was about 7%. However, with the use of an inert bed and increasing the space rate to 12 ft./sec., it is possible to treat coal with 35% moisture.

The inert bed also permits an increase in the unit capacity of the unit several fold. One unit which was tested was increased in capacity from 2.5 tons/sq. ft./24 hrs. using no inert bed to a capacity of 25.0 tons/sq. ft./24 hours, when using an inert bed.

I claim:

1. The continuous process of heat treating finely divided solid combustible materials which comprises establishing and maintaining a heat treating zone containing an inert material as a bed therein in a fluidized condition, supplying material to be treated to the heat treating zone, supplying fluidizing gas to the zone at a velocity sufficient to fluidize the inert material in the bed and entrain the materials being treated but insufficient to entrain the inert material, separating entrained coarse materials and entrained fine materials from the entraining gas at a point functionally remote from the heat treating zone and functionally remote from each other, establishing and maintaining a heat generating zone containing an inert material as a bed therein in a fluidized condition, supplying an oxygen bearing gas to said zone at fluidizing velocities, supplying said separated entrained fine particles to the inert fluidized bed in said zone, burning the fine particles to yield a heated gas, supplying the heated gas to the heat treating zone and discharging treated combustible material from the heat treating zone.

2. The process according to claim 1, wherein the temperature of the drying zone is maintained in the range between 165° F. and 250° F.

3. The process according to claim 1, wherein the temperature of the heat generating zone is maintained in the range between 1500° F. and 2100° F.

4. The process according to claim 1, wherein the inert material of the bed in the heat treating zone is one of the group comprising coal, ceramic balls, gravel and sand.

5. The process according to claim 1, wherein the inert material of the bed in the heat generating zone is one of the group comprising sand, ceramic balls, gravel, pulverized cinders and metal oxides.

6. The continuous process for drying finely-divided combustible solids which comprises the steps of establishing and maintaining a bed of such solids in a drying zone by feeding such solids thereto and removing them therefrom, maintaining solids of the bed as a turbulently mobilized fluidized bed by passing therethrough, at a velocity sufficient to both entrain fine solids and fluidize larger solids but insufficient to entrain such larger solids, an uprising stream of fluidizing gas initially having a sensible heat content sufficient to maintain solids of the bed at solids drying temperatures, drying solids in the bed, discharging gases containing entrained fine solids from the zone whereby dried fine solids are separated from larger solids and removed from the zone, and discharging dried larger solids from the zone; characterized in that the drying zone is maintained at solids drying temperatures by establishing and maintaining in a combustion zone a bed of finely-divided non-combustible solids, maintaining such solids as a turbulently mobilized fluidized bed by passing therethrough an uprising stream of free oxygen bearing gas at fluidizing velocities, supplying dried fine combustible solids to the fluidized bed to pass therethrough, combusting such fine solids during their passage through the fluidized bed to produce a sensible-heat carrying gas, and supplying such heated carrying gas uprisingly through the solids of the drying zone to maintain drying temperatures therein as well as to serve as a quantity of the fluidizing gas supplied to the drying zone.

7. The process according to claim 6 wherein the combustible materials as initially supplied to

the bed of the drying zone comprise wet coal.

8. The process according to claim 6 wherein the combustible materials as initially supplied to the bed of the drying zone comprise wet pyritic materials.

WALFRED W. JUKKOLA.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
Re. 21,526	Odell	Aug. 6, 1940
1,296,906	Batchelor	Mar. 11, 1919
1,680,183	Szikla et al.	Aug. 7, 1928
1,697,268	Evesmith	Jan. 1, 1929
2,465,410	White	Mar. 29, 1949
2,465,464	Meyer	Mar. 29, 1949
2,528,098	White	Oct. 31, 1950
2,534,728	Nelson et al.	Dec. 19, 1950
2,567,959	Munday	Sept. 18, 1951
2,573,906	Huff	Nov. 6, 1951

FOREIGN PATENTS

Number	Country	Date
286,404	Great Britain	Mar. 8, 1928

OTHER REFERENCES

Fluid-Solid Air Sizer and Dryer, by C. S. Wall and W. J. Ash; Ind. and Eng. Chemistry, vol. 41, No. 6, June 1949, pages 1247 to 1249.