April 27, 1937. R. L. SUTHERLAND 2,078,515

METHOD AND MEANS FOR DRYING MATERIAL

Filed June 29, 1933 6 Sheets-Sheet 1

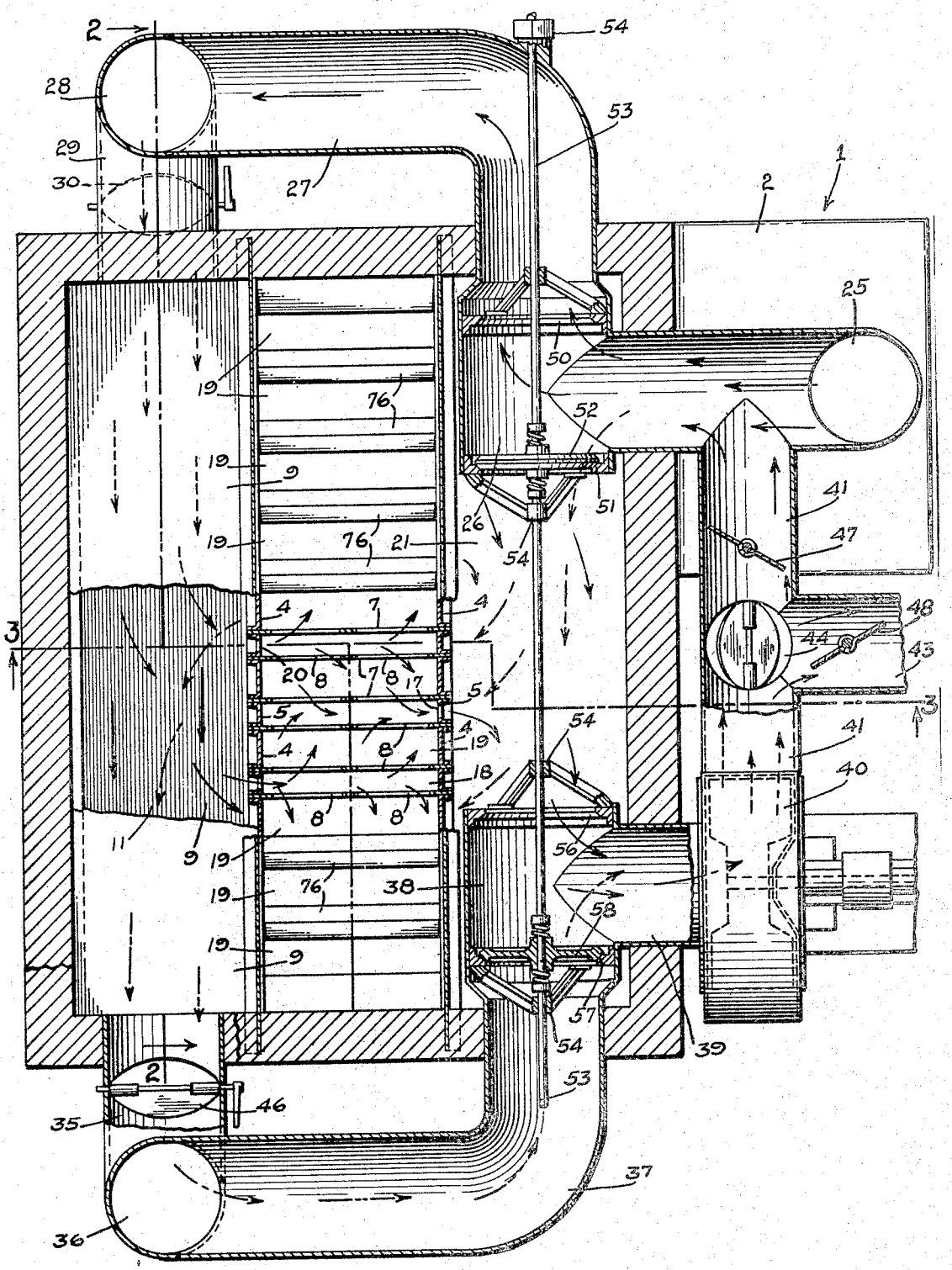


Fig. 1

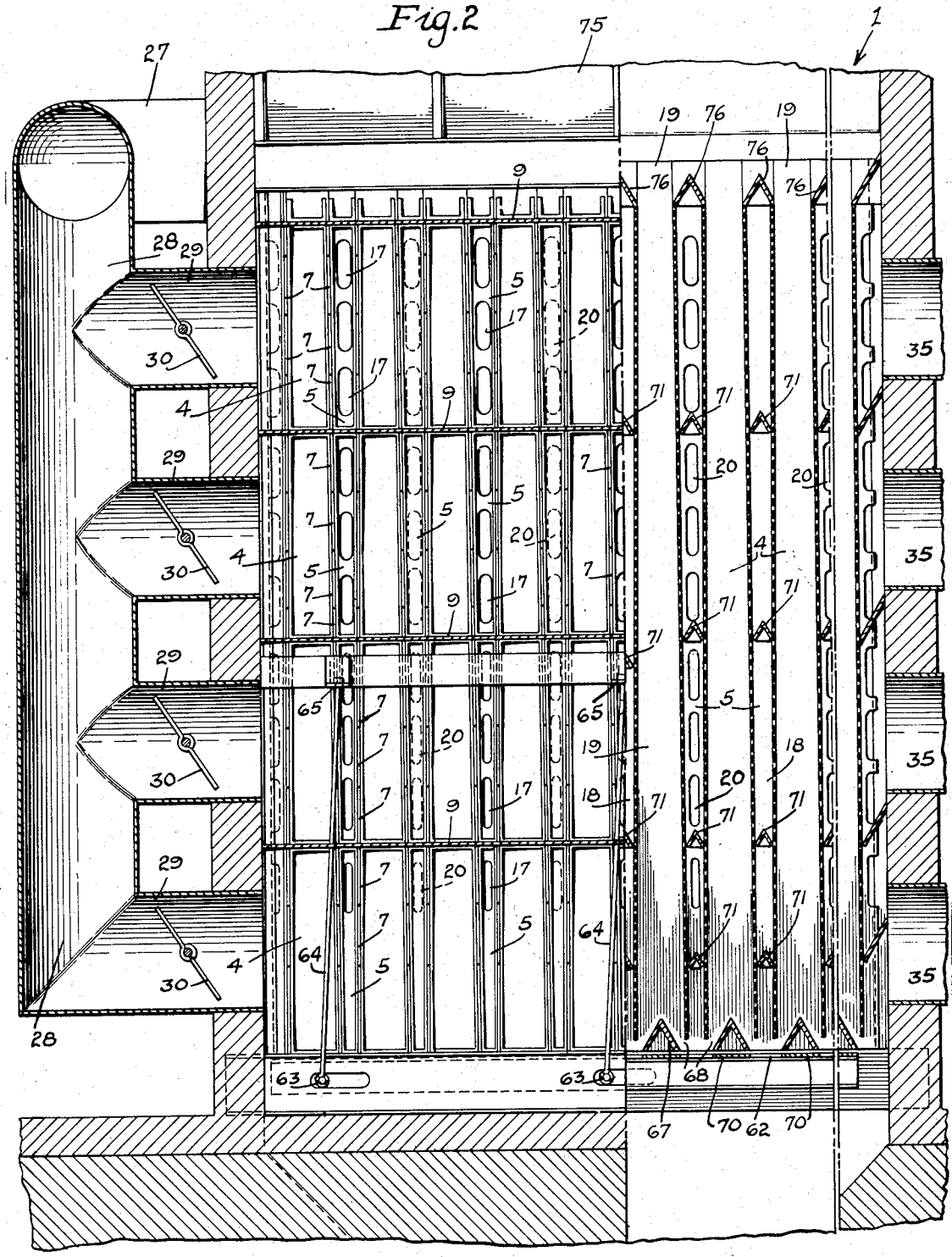
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Fig. 2



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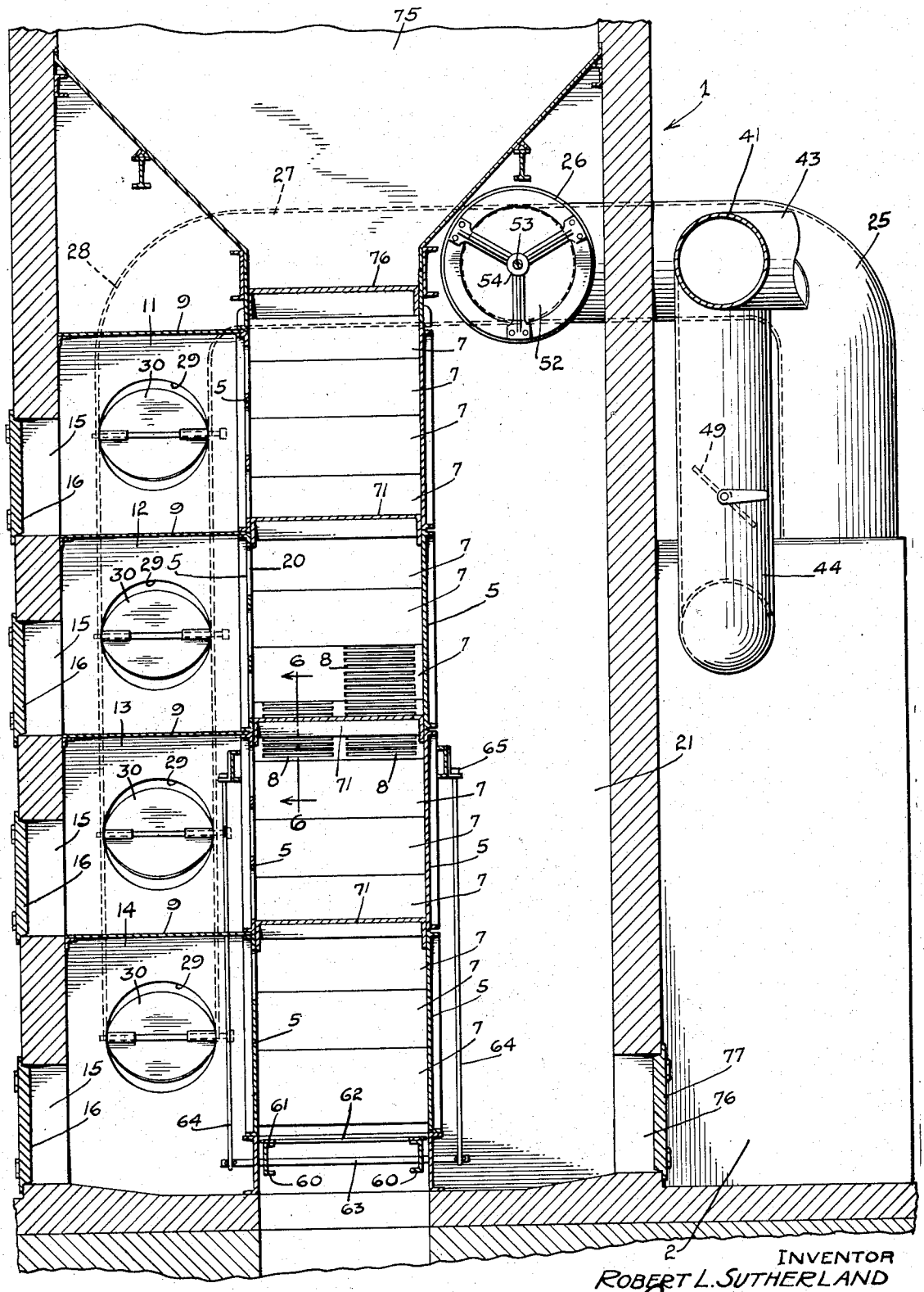


Fig. 3

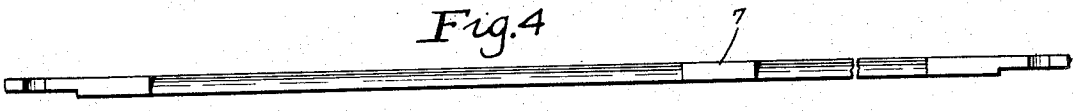
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METHOD AND MEANS FOR DRYING MATERIAL

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Fig.4



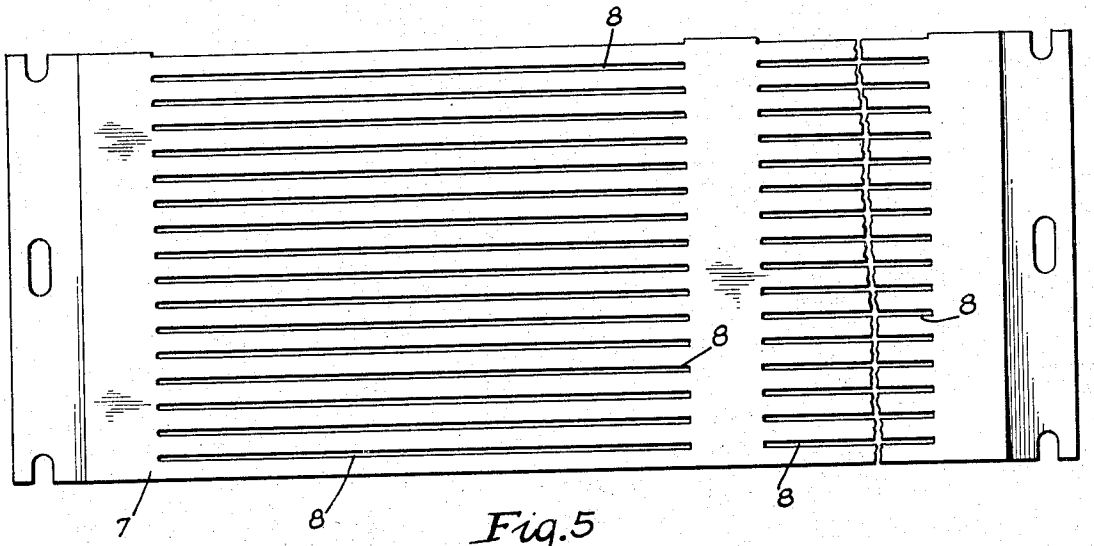


Fig.5

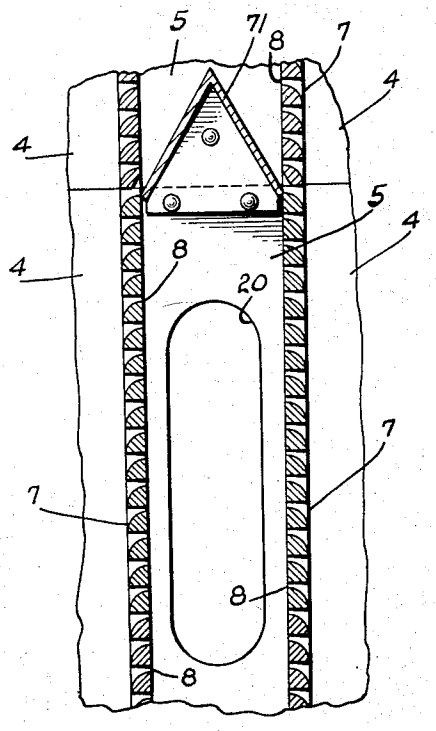


Fig.6

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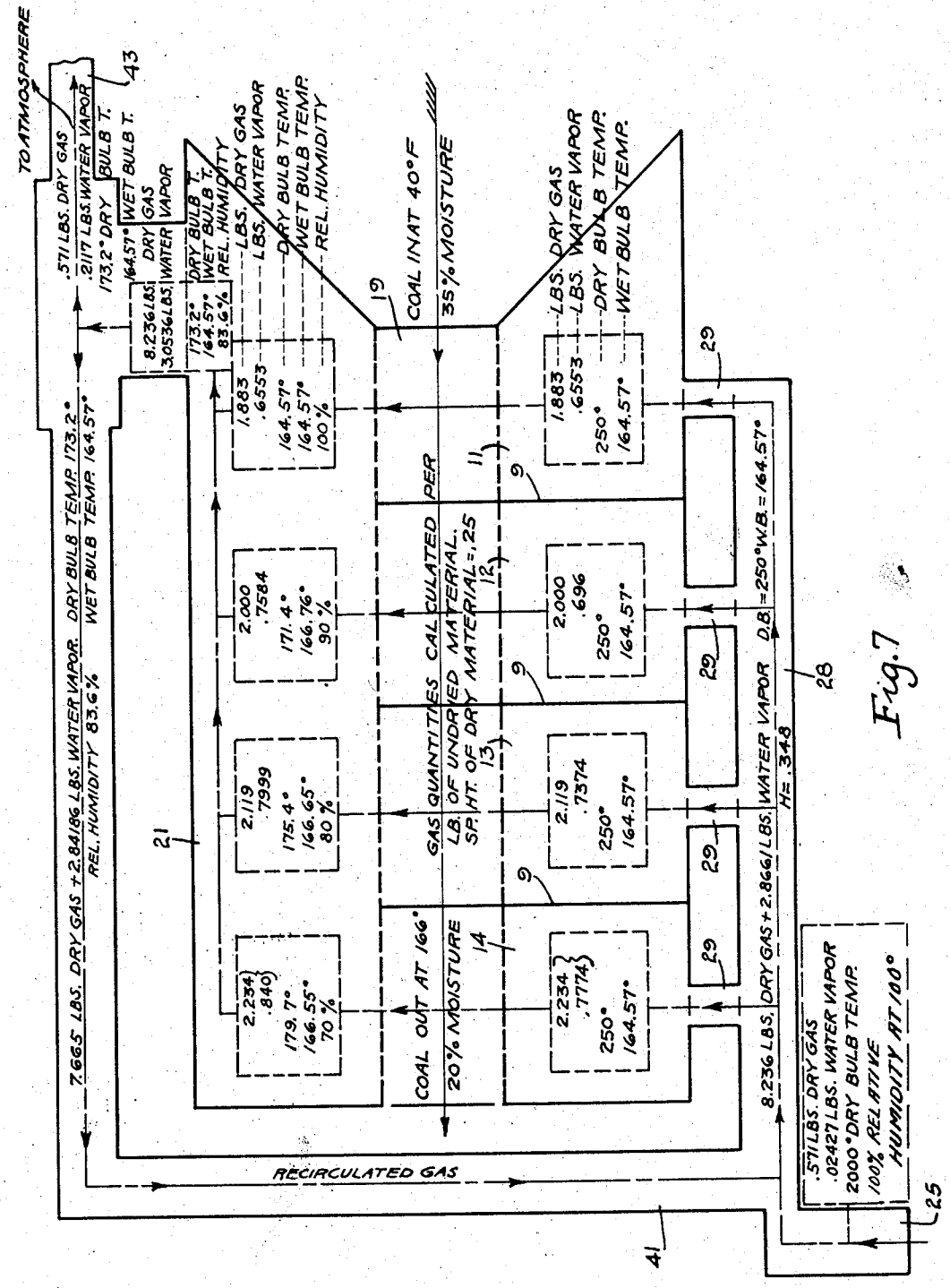


Fig. 7

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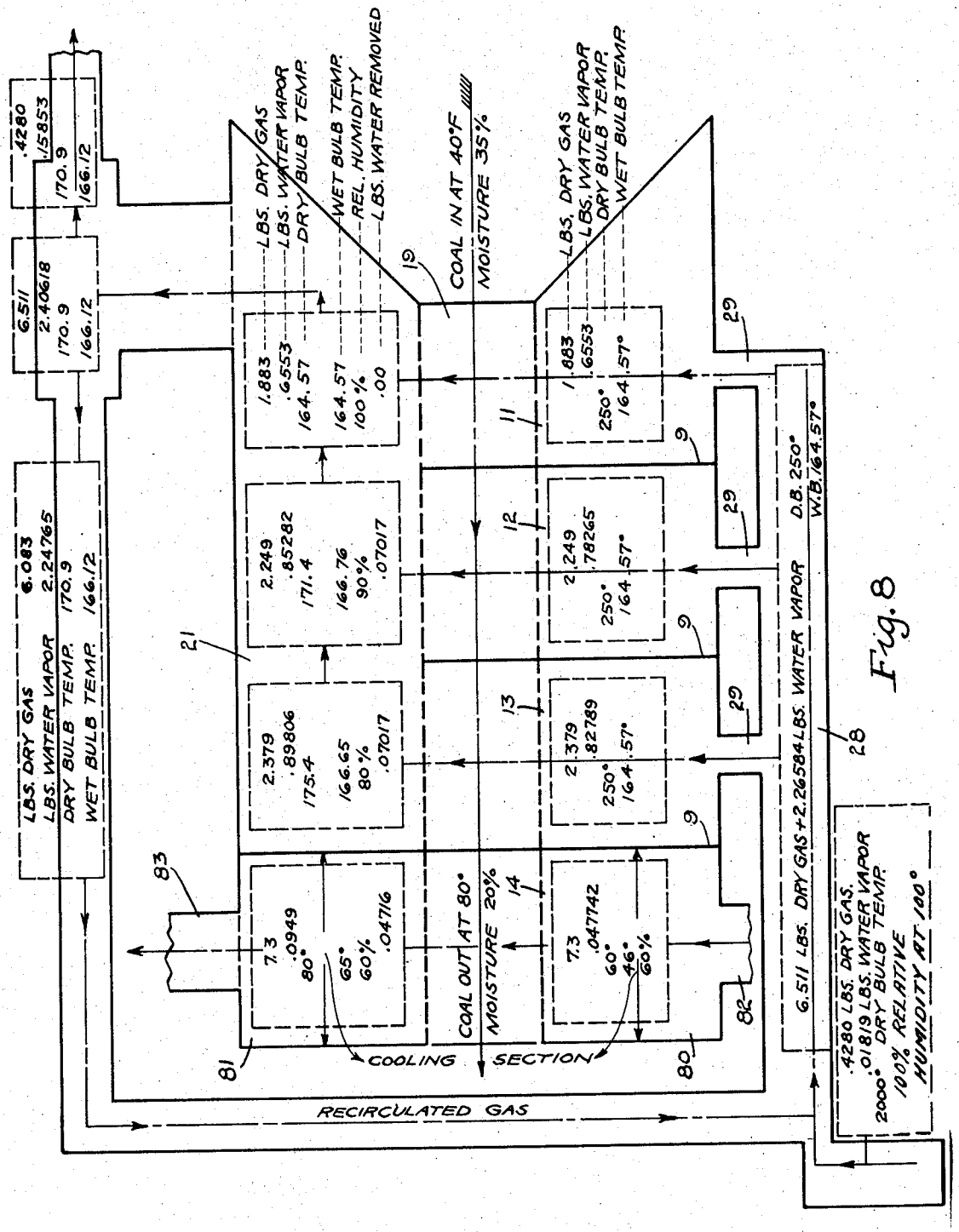


Fig. 8

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UNITED STATES PATENT OFFICE

2,078,515

METHOD AND MEANS FOR DRYING MATERIAL

Robert L. Sutherland, Winnipeg, Manitoba, Canada, assignor to Northern Coal Products Co., Minneapolis, Minn., a corporation of Delaware

Application June 29, 1933, Serial No. 678,151

1 Claim. (Cl. 34—34)

This invention relates to a method and means for drying materials of various kinds, and finds a particularly valuable application in the drying of combustible materials such as coals, including lignite.

Objects of the invention are: to prevent degradation of the material being dried; to dry quickly without firing the material; and to obtain even and thorough drying.

In my experience in drying coals and lignites of higher moisture content, I have learned that the following basic facts must be taken into account:

First.—Practically all coals when mined are saturated with moisture, the normal or inherent moisture content depending on the geological age, chemical composition, and physical structure, the younger coals and lignites containing progressively greater amounts of moisture. Moreover in mining and/or subsequent handling and transportation of the coals, additional or extraneous moisture may adhere to the surface of the coal particles.

Second.—Because of the free moisture on the surface of the coals and lignites, when heated unsaturated gases are brought in contact with the materials, the heat in the gases is practically all used in the evaporation of moisture from the surfaces, and therefore there is little or no penetration of heat into the interior of the lumps. In many solid fuels, surface drying results in greater shrinkage of the surface layers than of the interior, and checking and spalling off of the surface layers takes place.

Third.—When such material is dried to a moisture content below that in which the vapor pressure of the moisture in the material is less than the vapor pressure of the moisture in the surrounding atmosphere, moisture is re-absorbed from the atmosphere, which re-absorption is a heat-generating or exothermic reaction. The amount of heat so generated may be sufficient to raise the temperature of the fuel to the ignition temperature causing spontaneous combustion.

Fourth.—Coals and lignites of higher initial moisture content, are particularly subject to degradation when in contact with atmospheres of low moisture saturation.

Fifth.—Coals and lignites of a higher initial moisture content, when dried, are subject to spontaneous combustion due to the greater reactivity of the combustible elements. This reactivity may be reduced by a treatment with an inert gas or with a gas of low oxygen concentration, during or following the drying process. A feature is the use of such an atmosphere.

Sixth.—Coals and lignites of higher initial moisture content are sensitive to atmospheres containing appreciable amounts of oxygen at higher temperature, the ignition temperature varying from a minimum in pure oxygen, to higher temperatures depending upon the amount of oxygen present.

Briefly, my method includes the first step of heating the material to be dried to the desired temperature of evaporation in a substantially inert atmosphere of high moisture content, to minimize surface drying, and to effect heating of the interior of the lumps, and later maintaining a humidity gradient between the vapor pressures of the moisture in the material, and in the drying atmosphere, as drying proceeds, by controlling the rate of flow of the drying medium through or past the material.

Drying may be effected without including a final cooling operation, or the first stage of drying may be carried out under conditions which will include cooling of the material before discharge from the apparatus.

Objects, features and advantages of the invention will be set forth in the description of the drawings forming a part of this application, and in said drawings—

Figure 1 is a plan section of one form of device by use of which the present method can be carried out;

Figure 2 is a vertical section approximately on line 2—2 of Figure 1, illustrating the manner of controlling the introduction of drying medium, at different points along the line of travel of the bed of material to be dried;

Figure 3 is a vertical section taken approximately on line 3—3 of Figure 1;

Figure 4 is an edge view of one of the slotted passage-forming plates;

Figure 5 is a face view of the plate of Figure 4;

Figure 6 is an enlarged detail vertical section taken approximately on line 6—6 of Figure 3, illustrating one of the dust sheds in relation to the slots of the passage-forming plates;

Figure 7 is a flow chart diagram illustrating the drying-without-cooling method; and

Figure 8 is a flow chart diagram illustrating the drying-with-cooling method, and showing, diagrammatically, a modification of the apparatus to provide for cooling after drying.

Apparatus

The apparatus claimed herein as one means of

carrying out my new method is constructed as follows: Numeral 1 generally designates a vertically elongated structure, the outer walls of which are formed of any suitable material. Adjacent and at the outside of the structure is diagrammatically shown a furnace 2, as means for burning fuel to supply a substantially inert drying medium. Centrally arranged within the structure 1 are a series of vertical passages downwardly through which the material to be dried is moved. This structure includes a series of vertically superposed flanged metal end panels 4—5 forming two opposite vertical walls, of a material-controlling structure. Between the upper and lower edges of these panels are clamped plates 7 having their edges engaged to form vertical walls which define a series of alternate vertically arranged passages 18, 19, respectively for receiving and distributing the drying medium to be circulated, and for confining and guiding the material to be dried as it travels by gravity during the drying operation. The passages 19 for the material are downwardly divergent for causing the bed or body to become thicker as it travels. The purpose of the divergence is to insure flow of the material. It is noted that there is no division of coal bed or body in any passage, that is the arrangement is such that there are no obstructions to flow of the material being dried, except a control valve at the bottom of each column. There are two types of panels respectively indicated at 4—5, see Figures 1 and 2. The flanges of the panels are suitably bolted together to form a solid structure, the bolts not being herein shown. Each plate 7 has two series of horizontal slots 8. The drying medium, introduced into passages 18, passes through these slots into passages 19, thence through the bed of material to corresponding slots at the opposite side of the bed. The panels 4 are horizontally wider than the panels 5.

Within the chamber 1, see Figures 2 and 3, and at the outer side of one of the panel-formed walls, there are arranged horizontal partition plates 9, to provide vertically superposed chambers respectively designated 11, 12, 13 and 14, from which drying medium is delivered to the material to be dried. These division plates are held between the flanges of the panels as best shown in Figure 3. The wall 1 is provided, see Figure 3, with cleaning openings 15 each closed by a door 16, an opening for each chamber 11, 12, 13 and 14. The panels 5 are provided with openings 17 through which drying medium enters the gas passages 18. Referring to Figure 2, it is noted that only every other one of the panels 5 of this side are provided with the openings 17. The gases pass through the openings 17 into the chambers 18, through the slots 8 in the plates 7, through the material in the chambers 19, through the slots of the plates at the opposite side of the chambers and thence through vertically elongated openings 20 of the panels 5 of the opposite side. Thus, see Figure 3, the gas is forced to take a tortuous course through the material. After passage through the openings 20, the cooled drying medium from all levels is discharged into a common chamber 21, from which the mixed products are removed by a suitable fan.

The substantially inert gases which are products of combustion of furnace 2, are, see Figure 1, delivered to the various chambers 11, 12, 13 and 14 through pipes 25, see Figure 1, valve seat casing 26, pipe 27, vertical manifold pipe 28 and from the manifold through separate pipes 29 to respective chambers 11, 12, 13 and 14. Each manifold branch pipe 29 is provided with a damper 30 for regulating the rate of flow or volume of the drying medium to the chambers 11, 12, 13 and 14.

The chambers 11, 12, 13 and 14 extend the full longitudinal length of the structure 1, see Figure 1, and each chamber has leading therefrom at that end opposite pipes 29, a passage or pipe 35 communicating with another vertically disposed manifold 36 connected by pipe 37 with valve seat casing 38 in turn connected by suction pipe 39 with suction fan 40 which, in this embodiment, is the sole means for circulating and re-circulating the drying medium, and mixture of drying medium and moisture from the material being dried.

The fan 40 delivers into pipe 41 which, in turn, delivers into pipe 25. Pipe 41 has a branch pipe 43 leading to the atmosphere, and also has a branch pipe 44 leading into the furnace 2, as best shown in Figure 3. Each pipe 35 is provided with a suitable damper 46, for the same purpose as dampers 30. Pipe 41 is provided with a damper 47 located between pipe 25 and pipes 43 and 44. Pipe 43 is provided with a suitable damper 48 and pipe 44 is provided with a suitable damper 49.

The purpose of damper 47 is to control the amount of effluent drying medium being returned to the affluent medium of the system. Damper 48 in pipe 43 controls the amount or proportion of effluent medium discharged to the atmosphere. Damper 49 controls the amount of effluent medium discharged into the furnace 2, to regulate its temperature. By means of the double connection through pipes 41 and 44 it is possible to control the temperature in the combustion chamber of furnace 2.

Referring to Figure 1, means is provided for reversing the direction of flow of the drying material through the various columns or beds of the material to be dried, to obtain even drying at both sides of the beds. Valve seat casings 26 and 38 are provided with valve means so arranged that reversing circulation can be obtained. The valve casing 26 has axially spaced valve seats 50—51 alternately engageable by valve 52 carried by rod 53 slidably held in bearings 54. Valve casing 38 is provided with axially spaced valve seats 56—57 alternately engageable by valve 58 also carried by rod 53.

As shown in Figure 1, the valves 52 and 58 are so positioned as to obtain circulation of the products in the direction of the full line arrows. When the valves 52 and 58 are respectively seated at 50—56 the flow takes the direction of the dotted line arrows, that is from the pipe 25 through casing 26, seat 51, across chamber 21, first through openings 20, then through passages 18, through the bed of material in the passages 19, then through passages 17, thence through pipes 35, manifold 36, pipe 37, seat 57, casing 38 to fan 40. In this case, the fan is rotating in the same direction as when the valves are in the full line position shown in Figure 1. The delivery velocities and amounts of gases can be readily varied and controlled by properly adjusting the dampers 30 and 35, etc., and recirculation can be controlled by dampers 47, 48, etc.

The rate of motion of the material to be dried, is controlled by a valve mechanism, see Figures 2 and 3, comprising a pair of beams 60 connected by a plate 61 slotted as at 62. The plate

is disposed below the bottoms of the passages 19. The beams are carried on rods 63 each supported at opposite ends by links 64 swingably attached as at 65 to channels. As shown in Figure 2, the slots 62 are positioned to permit feeding of the material to be dried. Centrally arranged at the lower end of each passage 19, is an inverted V-shaped element 67 forming with the lower ends of the partition plates 7, passages 68. When the valve is moved the proper distance, the portions 70 of the plate 61 are brought into opposition to passages 68, to stop the flow, each slot 62 at this time assuming a position in opposition to a corresponding V-shaped element.

Inverted V-shaped shed-plates 71, see Figures 2 and 6 are arranged in the vertical gas passages 18 for the purpose of preventing the collection of dust. Their surfaces are so arranged with relation to the slots 8 of the plates 7 that dust passes outwardly through these slots into the passages 19, see Figure 6.

There is of course provided a hopper 75, for delivering the material to be dried into the vertical passages 19. The tops of passages 18 are closed by V-shaped caps 76. A suitable clean-out opening 76 with door 77 is provided for the mixing chamber 21.

The apparatus as above described is a feature of the invention and is closely related to the method in that it represents one form of device by which the new method can be carried out.

Drying method without cooling

First referring to flow diagram, Figure 7, the quantitative data of the diagram are only given as an example, without intentional limitation, and for the purpose of more clearly illustrating the practice of the method. The quantities of gas and air shown for each zone refer to one specific case only. The fluid temperatures and humidities indicated substantially represent an average condition. In winter, more gas will be required for warming the coal. The calculations are made on the assumption that no heat is lost by radiation. The calculations of the gas quantities refer to one pound of coal with its original moisture content.

Now referring to Figures 1 to 4, and 7: Assuming normal operating conditions to have been established, substantially inert gas, produced for example by burning fuel in furnace 2, is introduced into conduit 25, see Figures 1 and 3. As shown in the example, see flow diagram, Figure 7, this gas may have a dry bulb temperature of 2000° F., and a moisture content corresponding to saturation at 100° F. Ths fluid is mixed with that amount of recirculated fluid from pipe 41 necessary to produce a mixture of fluid having the required dry and wet bulb temperatures. The material to be dried, before introduction into the drier may have for example a temperature of 40° F., and a thirty-five per cent moisture content. Temperatures and humidities shown in Figure 7 represent the normal conditions of operation after an equilibrium between quantities of initially introduced fluid, and recirculated fluid has been established.

This gas is delivered through the conduits 25, 26, 27, to vertical or manifold conduit 28, see Figure 2. From manifold 28 the gas enters pipes 29 each controlled by a damper 30. Although these dampers are shown in the drawings as having the same adjustment, it will be understood that in practice, each is adjusted in accordance with the requirements for velocity or volume of the entering drying medium in the different zones.

See Figure 7 for data concerning amounts and temperatures of the drying medium, before passage through the bed of material in the different zones. The gas now enters chambers 11, 12, 13, 14. By reference to Figure 7, it is seen that the dry and wet bulb temperature of the gas in chambers 11, 12, 13, 14 is the same, and that the amount of drying medium is successively increased from chamber 11 to chamber 14.

The drying medium now passes through the openings 17 into passages 18, through slots 8 and through the various columns of moving material, thence through the openings 20 of the opposing plates and into the main chamber 21, see Figure 1. In this chamber, the drying medium and moisture of the material from the various zones is mixed, and moved by fan 40 through valve seat casing 38 into conduit 41. Referring to Diagram 7, it is noted that as the operation proceeds, the relative humidity of the effluent fluid decreases from above downwardly, being 100, 90, 80 and 70 per cent, leaving chambers 11, 12, 13 and 14 respectively. After mixing, the relative humidity is 83.6. Fluids from all zones are mixed in chamber 21.

In this instance, the single fan 40 provides the power for circulating the drying medium. From conduit 41 part of the mixture is discharged to the atmosphere through pipe 43 past damper 48, and part is returned through pipe 41 past damper 47 to conduit 25, where it is mixed with initial incoming hotter and drier fluids from furnace 2. Figure 7 shows the temperatures and amounts of dry fluid and water vapor in that portion which flows to the atmosphere and also in that portion which is returned to conduit 25 for mixing with initial incoming fluids. The fluid discharged to the atmosphere has a higher dry bulb temperature, and is less completely saturated with water vapor than the fluid leaving the upper or warming compartment. This condition obtains when only one fan is used for circulating a drying medium. By the use of a second fan and a separate compartment for receiving any portion of the fluid which passes from the chamber 11 through the upper part of the chamber 19, it would be possible to discharge the portion of drying fluid to the atmosphere at a lower dry bulb temperature and complete saturation. The material, after drying, may pass out of the drier at a temperature of 166°, and may contain about twenty per cent of moisture.

It will be noted that there has not been substantial drying of the material as a result of the passage of the drying medium through that portion of the material in the first zone. A differential has thereafter been maintained between the vapor pressures in the material and the drying medium, which has resulted in a controlled rate of flow of the moisture in the material to the drying medium. The temperature at which evaporation of moisture from the material takes place is determined by the initial dry bulb temperature and saturation of the drying medium, after the material has been heated to the temperature of evaporation.

Mixing of fluids (in which the temperature has been reduced and the humidity increased by contact with the material to be dried) with the initial fluids, in any proportion, does not substantially affect the temperature at which evaporation takes place. I am able from this fact to reduce the temperature of the fluids (initially

at a temperature which would cause degradation or ignition of the material) to a temperature below the danger point, and to control the humidity differential between the material and the drying medium by regulating the flow of fluids through the material.

If desired, the humidity differential can be further controlled by supplying regulated amounts of fluid at different temperature and/or humidity, to be mixed with the principal source of supply of fluid and applied to the material at different stages in the drying process. A novel feature includes the application of a drying medium (preferably substantially inert fluid) at a temperature below which there is danger of degradation or ignition of the material being dried, and at a humidity or saturation which, at the desired temperature, will provide the desired temperature of evaporation and the control of the humidity differential throughout the drying process by progressively changing the quantity of the drying medium applied to the material as drying progresses, either by varying the thickness of the bed to change the resistance to the flow of fluid supplied at constant pressure, or by changing the pressure of the fluid supplied to a bed of constant thickness.

A modification includes the admixing of gas of other initial temperature and/or humidity and applying in the different zones of the bed as desired, to maintain or aid in maintaining the desired humidity differential, or to reduce the final temperature of the product to the desired point.

Drying with cooling

In case the dried material, such as lignite or other fuel, is to be passed directly to a stoker or pulverizer, cooling as part of the drying process is not necessary. However, in cases where the drier is operated at a mine or source of material, it is desirable to cool the material after drying and before storing, or before loading on cars for transportation to point of consumption. In this instance, the last compartment, see flow chart diagram, Figure 8, may be used to supply cooling gas to reduce the temperature of the dried material. Any number of such compartments can be used. The medium may be air at atmospheric temperature or mixtures of air and furnace gases in such proportions as to provide the desired temperature and humidity to effect cooling. The thermal efficiency is higher when the cooling medium is at or near the same temperature as the material to be cooled, providing the humidity of the drying medium is low.

Figure 8 is a diagram or flow sheet showing the manner of operating when it is desired to bring the material to a lower final temperature than that heretofore indicated. The general operation previously described applies here but a slight modification is made in the apparatus. This modification is only shown in the diagram and consists in connecting the lower compartment **80** with a separate exhaust fan (not shown) which may also serve as a forced draft fan for the fire box, which supplies hot gas to the upper zones. No means is shown for reversal of the flow of the drying medium in the cooling zone, but it is obvious from my disclosure that this could be done, and that more than one cooling zone could be used. It is noted that in this form of the invention, the lowermost chamber **80** delivers across the bed into a receiving chamber **81**, which is separate from mixing chamber **21**. The cooling medium enters at **82** and leaves at **83**. In this instance, as in the first, the moisture in the fluid may be utilized to control humidity, and the desired balance of relative humidity can be obtained by introducing fluid from the furnace **2** or from any other source or sources, and it is intended that the cooling medium, whatever its source, may or may not be re-circulated.

Although I have herein, for purposes of illustration, shown a form of drying apparatus usable for coal or lignite, and have illustrated my drying method by reference to the drying of a combustible material such as coal or lignite, and although this particular application of my method is claimed, there is no intention to be entirely limited to the application of the method to combustible substances. It is evident that the principle can be applied to obtain thorough drying of any non-combustible moisture-containing material, and to the drying of any material in a manner to prevent or minimize checking or spalling, and to obtain more uniform drying clear to the middle of a lump, or piece of such material of any shape.

I have shown that the fluid at its highest temperature and lowest relative humidity is introduced into the upper chamber and comes in contact with the entering material when that material is at its lowest temperature and has a maximum moisture content. As drying proceeds, the material being dried is warmed and dried and the drying fluid is cooled and becomes more highly saturated with moisture. The release of moisture from the material is gradual, and the heating and humidity can be so relatively controlled that moisture is driven from the innermost portion or core of the material at any desired velocity. The final temperature of the entering fluid is determined by the number of re-circulations. In the present method, wet or cooled, partly or completely saturated fluid is mixed with initial hot furnace fluids.

The fluids entering the various boxes have the same dry bulb temperature and humidity; the amount of drying effected is controlled by the rate of flow or by the amount of fluid traveling through the various sections of the bed. Thus, by changing the velocity and volume of the fluid passing through the material, more or less drying can be obtained at will. The velocity of the fluid through the fuel bed in any zone must be sufficient to produce the desired humidity of the fluids after passage through that zone. For lignite, the humidity is controlled solely by mixing wet or cooled saturated fluid with the initial hot furnace fluid. The mixing is accomplished in a single chamber **21**, rather than in a series of chambers.

In the first section of the bed in which the material enters the apparatus cold and substantially saturated with moisture, it is desirable to have the drying medium applied of sufficient total humidity that after cooling in contact with the material, it will be in a substantially saturated condition in order that there may be substantially no flow of moisture from the material to the drying medium. The function of the drying medium in this section of the apparatus is to preheat the material to the desired temperature of evaporation without removal of moisture.

In succeeding sections of the bed, such differential between the vapor pressures of the moisture in the drying medium and in the material as is required to cause flow of moisture from the material to the drying medium must be

maintained. The differentials between the vapor pressures in successive sections of the bed may be increased or decreased in successive sections of the bed, as desired. Such differentials will be maintained between the vapor pressures in the drying medium and in each succeeding section of the bed as will result in the maximum drying rate with minimum degradation of the material. Obviously, the greater the differential in any section, the more rapid the flow of moisture from the material to the drying medium.

During the operation, when the temperature of the material has reached the desired evaporating temperature, which will ordinarily be below the boiling point of water for certain materials, the heat given up by the drying fluid will be used in evaporating moisture. This is accomplished by reducing the vapor pressure of the moisture in the drying fluid below the vapor pressure of the moisture in the material, as before stated. In this way, a gradual flow of moisture from material to drying medium can be accomplished. Again it is noted that the vapor pressure differential in any section of the bed is determined by the difference between the dry bulb and the wet bulb temperature of the gas, and by the temperature and moisture content of the material. It is therefore evident that the vapor pressure differential may increase or decrease in successive sections of the bed as drying proceeds, the gradient or rate of change being determined by controlling the rate of flow, and therefore time of contact of the drying fluids with the material. As the rate of flow is reduced, the final dry bulb temperature will be reduced, and the wet bulb temperature increased.

There are two ways of operating with the present method. One is to introduce the drying medium at a dry bulb temperature approximately the temperature of the material and at a wet bulb temperature substantially lower than the temperature of the material. In this case, part of the heat of the fluid is used in evaporating moisture with a consequent reduction in the temperature of the material. The dry bulb temperature will be reduced and the wet bulb temperature increased.

Another way is by using a drying medium at substantially lower dry and wet bulb temperatures than the temperature of the material in which case a part of the heat in the material will be used in warming the medium passing therethrough, and a part in evaporating moisture. In either case, the temperature of the material will be reduced, the reduction in temperature depending upon the quantity of the fluid used and the time of contact.

In practical application the drying medium is supplied at a temperature such that it will bring the material to be dried up to the desired drying temperature. The material is maintained at this desired drying temperature by adding heat to the circulating medium, and the rate of drying is regulated by regulating the humidity and quantity of the drying medium. Heat is added to the circulating medium both for the purpose of maintaining the temperature of the material and for the purpose of maintaining the humidity of the drying medium. The moisture absorbed by the circulating medium is removed by allowing part of the effluent fluid to escape to the atmosphere, and replacing it with an equal weight dry hot fluid from the furnace, which is accompanied by an amount of water vapor depending upon the type of fuel and conditions under which it is burned. It is noted that for success in drying lignite and materials of like characteristics, it is necessary to operate so that the temperatures of drying can be controlled, with the ability to increase the humidity gradient during successive stages of the drying operation.

I claim as my invention:

A method for drying combustible material consisting in applying an inert drying medium to the material to be dried, said medium being at a temperature below the point at which there is danger of degradation or of ignition of said material and having a degree of humidity which at the desired dry bulb temperature will provide the desired temperature of evaporation, and controlling the vapor pressure differential between moistures in the material and in the drying medium throughout the drying process by progressively changing the quantity of the applied drying medium as drying progresses, by varying the thickness of a bed of the material to correspondingly vary the degree of resistance to flow of drying medium supplied at constant pressure.

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