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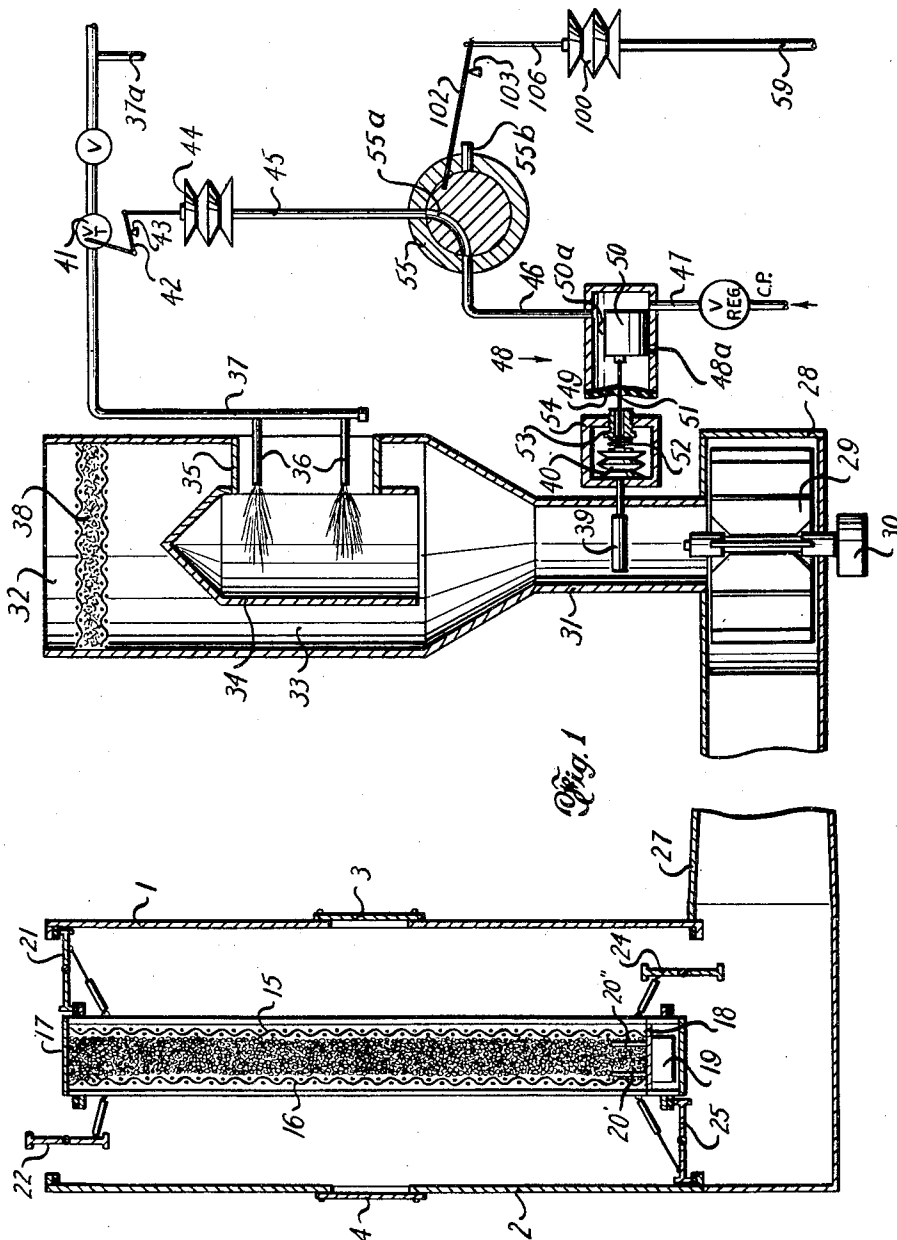
O. A. WRIGHT

2,520,871

METHOD AND APPARATUS FOR DRYING MATERIAL

Filed Aug. 2, 1948

4 Sheets-Sheet 1



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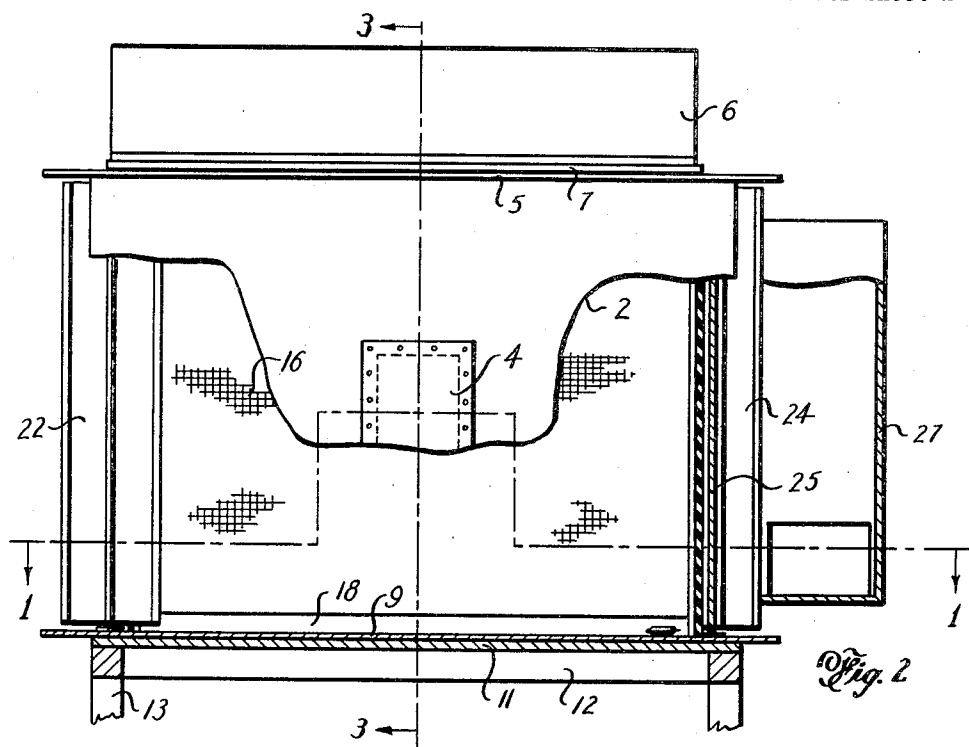
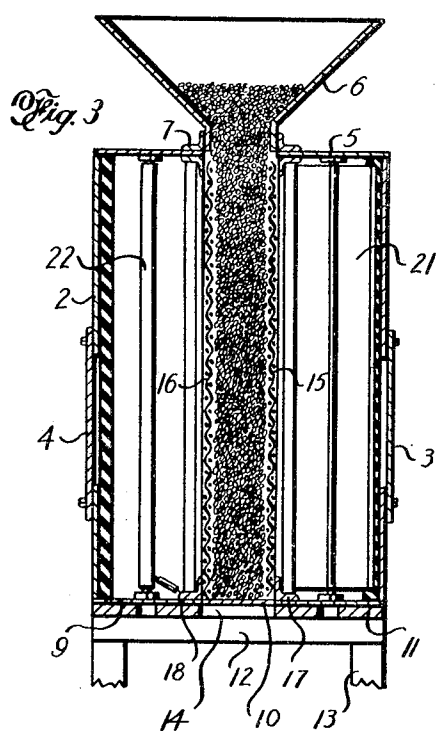
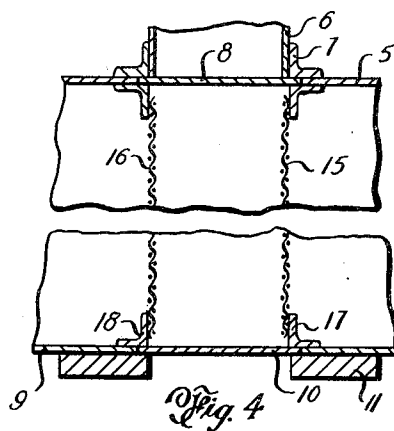
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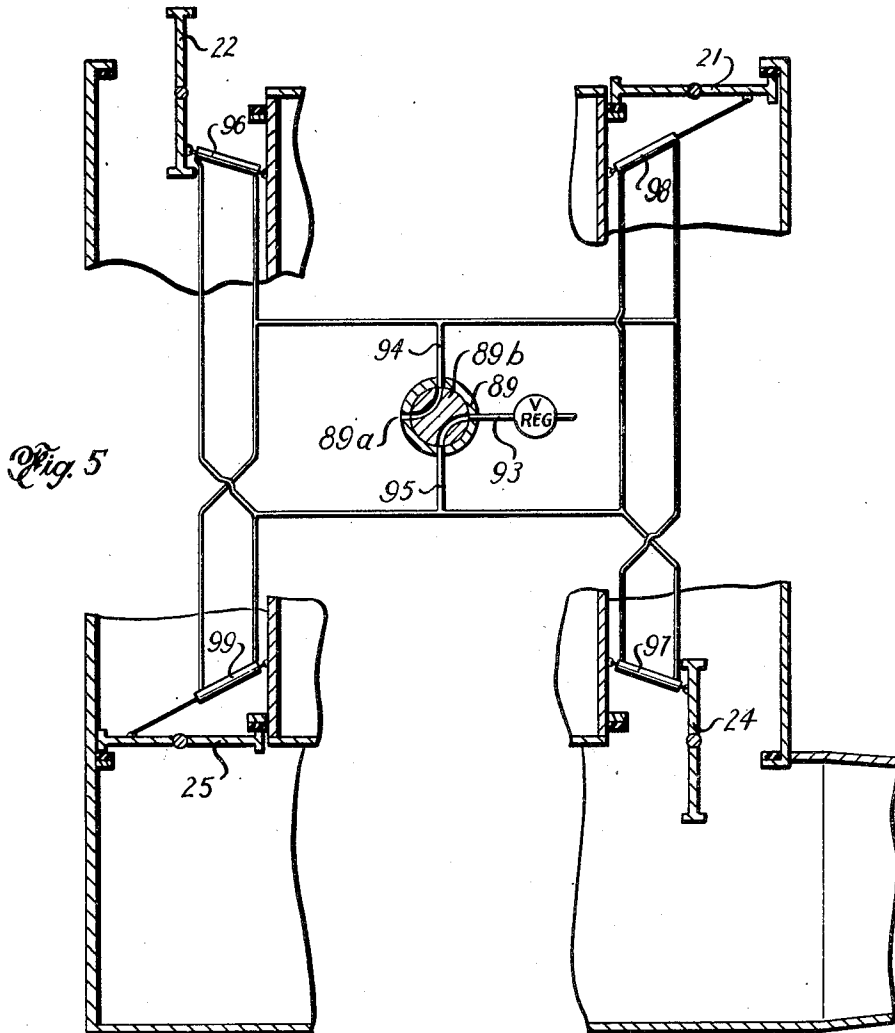
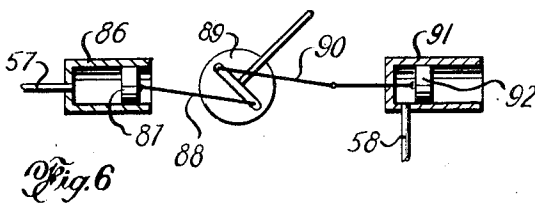
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METHOD AND APPARATUS FOR DRYING MATERIAL

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4 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

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METHOD AND APPARATUS FOR DRYING MATERIAL

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Application August 2, 1948, Serial No. 42,118

14 Claims. (Cl. 34—13)

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This invention relates to improvements in method and apparatus for drying material and refers more particularly to drying materials where it is necessary to maintain the temperature of the entire pack of material to be dried below predetermined maximum temperatures which deleteriously affect the material.

It has heretofore been proposed to dry certain grains such as rice, maize, flax, oats and the like in drying apparatus wherein the material to be dried is supported between two opposed perforate walls. A heated gas, usually air, is passed through the drying chamber in such manner as to alternately enter the chamber through one of the perforate walls and then through the other perforate wall. The direction of passage of the heated gas through the drying chamber was changed when the temperature of the material lying closely adjacent the perforate wall through which the gas is entering reaches a predetermined maximum temperature. This method of drying materials has been satisfactory to a considerable degree but some difficulty has been experienced in that at the end of the drying treatment there sometimes is a tendency for the material lying adjacent both perforate walls to reach and exceed the maximum temperature.

At the final stage of the drying operation, the moisture content of the material being dried is very low and the cooling effect of evaporation of the moisture content of the material treated is not especially great. Therefore, the flow of gas in any one direction continues for a very limited or short period of time. The material on the downstream side of the pack of material being dried does not always have sufficient time to cool appreciably during this short time interval. In order to correct this it was then proposed to discontinue the passing of the gas through the pack of material to be dried when this condition was encountered. However, this did not work entirely satisfactorily because when the gas flow through the apparatus discontinued the pack of material being dried was very slow to cool.

An object of this invention is to provide a method and apparatus for drying material whereby the temperature of the material to be dried will never exceed a predetermined maximum temperature to which the material treated may safely be heated.

Another object is to provide, in a method and apparatus for drying material supported between two opposed perforate walls wherein gas is first passed through the chamber entering first one perforate wall and continuing in this direction

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until the material lying closely adjacent said perforate wall approaches the predetermined maximum temperature to which the material may be safely heated and then the direction of flow is changed so that the heated gas enters the chamber through the other perforate wall and this is alternately continued, for passing a relatively cool gas through the pack of material to be dried when the material lying adjacent both perforate walls approaches the maximum temperature.

A further object is to provide a method and apparatus for drying material supported in a drying chamber between two opposed perforate walls wherein a relatively cool gas is passed through the pack of material to be dried when the temperature of the material adjacent both perforate walls approaches the maximum temperature to which the material should be heated and wherein this is accomplished automatically.

Still another object of this invention is to provide control apparatus adapted to selectively pressurize two of three stations and to pressurize the third station when the first two stations are simultaneously pressurized.

Other and further objects of this invention will appear from the following description of a preferred embodiment of the invention.

In the accompanying drawings which form a part of the instant specification, are to be read in conjunction therewith, and wherein like reference numerals are employed to designate like parts of the various views:

Fig. 1 is a schematic sectional plan view of apparatus embodying this invention;

Fig. 2 is a side elevational view of the drying housing shown in Fig. 1 with parts broken away for purposes of illustration;

Fig. 3 is a cross-sectional view of the apparatus of Fig. 2;

Fig. 4 is a fragmentary cross-sectional view, on an enlarged scale, similar to Fig. 3 and showing construction details;

Fig. 5 is a schematic view illustrating the control mechanism for actuating the means for directing the flow of drying medium in the apparatus of Fig. 1;

Fig. 6 is a detail upon an enlarged scale of the mechanism for actuating the control valve shown substantially at the center of Fig. 5;

Fig. 7 is a view upon an enlarged scale illustrating the control for energizing the actuating means of Fig. 6 and also the actuating means shown in the right hand portion of Fig. 1 controlling the heating means;

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Fig. 8 is a view taken along the line 8—8 in Fig. 7 in the direction of the arrows; and

Fig. 9 is a modified apparatus for actuating the valve means shown in Fig. 7.

Before describing the drawings in detail it is believed best to point out that in drying certain materials of the character of grain and the like it is desirable to pass a heated gas through the material and preferably the gas should be heated greatly in excess of the temperatures to which the material treated may be safely heated. Usually temperatures in the order of 150° may be employed for this purpose while most grains cannot be heated to this high a temperature and still be usable for certain purposes. These predetermined maximum temperatures to which the grain may be safely heated are well known to those skilled in the art and for example rice for table use may be safely heated to 105° Fahrenheit, maize for the production of glucose to 105° Fahrenheit, maize for germination purposes to 125° Fahrenheit, flax to be used in processing of oil to 100° Fahrenheit, and oats which are to be used as seed oats to 107° Fahrenheit. The apparatus and method of this invention are especially adapted for use in drying materials of this character and the material being dried will never be heated to a temperature to exceed the predetermined selected temperature to which the material may be safely heated for the purpose for which the material is to be used.

Referring now to the drawings more particularly to Fig. 1, a housing having opposite side walls 1 and 2 is provided for the grain or other product to be dried. These side walls are imperforate except for man holes provided therein and closed by covers 3 and 4. These covered man holes provided ready access to the interior of the housing when it is necessary to make repairs, adjustments and the like.

The housing has an upper horizontal wall shown at 5 and mounted upon this wall is a hopper 6 anchored to the wall by a suitable means such as the angle iron 7. The hopper is so arranged that its outlet opening registers with an opening in the upper wall 5 of the housing. A slide 8 is provided for the purpose of closing this opening in the wall 5.

The housing has a bottom 9 which also has an opening of substantially the same size as the opening in the upper wall 5. The openings in the two walls are aligned vertically and the opening in the bottom 9 has a removable slide or closure member 10.

The housing may be supported upon any suitable platform 11 carried on the cross-beams 12 and the upright supports 13. The platform 11 has an opening 14 therein which registers with the opening in bottom 9 of the housing to permit material to pass from the housing to the platform.

A pair of vertical perforate walls 15 and 16 extend vertically within the housing throughout the width of the housing dividing the housing into three separate compartments. These walls 15 and 16 are preferably highly perforate and may be fabricated from screen mesh or the like. Of course, the openings through the screen wall should be sufficiently small to prevent the material to be dried from passing therethrough and at the same time should provide substantially free passage of air or other drying medium through the inner compartment of the housing. This inner compartment provides a drying chamber with a passageway therethrough wherein the perforate

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walls 15 and 16 constitute the termini for the passageway. The two perforate walls 15 and 16 are anchored to the upper and lower walls 5 and 9, respectively, by angle irons 17 and 18 or other suitable means.

The interior of this intermediate compartment between the perforate walls 15 and 16 communicates upwardly with the hopper 6 and downwardly with the opening 14 in the bottom of the housing. Thus grain or other material to be dried may be passed from hopper 6 into the drying chamber and slide 10, when in place, prevents the material from dropping through port or opening 14.

The walls 15 and 16 preferably are substantially parallel so the body of the product to be dried, which is usually referred to as the pack, is of uniform thickness throughout. Preferably sufficient of the product to be dried is provided in the hopper so that the compartment between walls 15 and 16 will be entirely filled even though there should be some shrinkage of the material within the compartment as the drying proceeds. This is desirable in order that there will never be space at the upper end of the pack through which the drying medium might tend to by-pass.

It is necessary to provide means for determining the temperature of the portion of the grain or the other material being treated lying closely adjacent the perforate walls 15 and 16. In this embodiment of the invention a control box shown schematically at 19, which will be hereinafter more fully described, is attached at one end of the heat treating compartment of the housing and has heat sensitive elements 20 projecting into the chamber closely adjacent the perforate walls 15 and 16 and adapted to be embedded into the body of material being treated during the drying operation.

The two compartments at the sides of the drying compartment or chamber are provided at their opposite ends with means for directing flow of the drying medium through the grain. This means includes vertically arranged shutters 21 and 22 at one end of the housing and vertically disposed shutters 24 and 25 at the other end of the housing. A means is provided for actuating these shutters so that the shutter at one end of a given compartment will be open while the shutter at the opposite end of the compartment will be closed. Only one of the shutters 21 and 22 will be open at one time and only one of the shutters 24 and 25 will be open at one time. Each of these shutters 21, 22, 24 and 25 are pivoted about a central vertical shaft and may be opened and closed by mechanism to be hereinafter more fully described.

Communicating with the shuttered openings at one end of each of the outside compartments of the housing is a conduit 27 leading from a blower or compressor 28 in the form of a rotor 29 actuated by a suitable power means connected to pulley 30, the power means is not shown in the drawing. The blower is arranged to force air or other suitable drying medium through the conduit 27 and through one or the other of the shuttered openings controlled by shutters 24 and 25 whichever is open. The drying medium will, of course, then be forced through the drying chamber of the housing and out the shuttered opening at the opposite end of the other compartment.

The drying medium, preferably air intermingled with the products of combustion from the heating unit, is drawn in through the intake conduit 31, this conduit having an open end 32

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at an enlarged diameter portion. The air passes through the annular space 33 about the outside of the burner housing 34 carried by lateral support 35 integral with conduit 31. This support 35 also provides a passageway from the exterior of the conduit into the burner housing. Extending into the burner housing are burners 36 supplied with gas or other suitable fuel through a supply pipe 37. It is to be understood that other suitable heating means may be employed where desirable due to economics or other reasons.

The burner housing 34 is closed at its upstream end to prevent the incoming air from blowing through the burner housing and directly against the flame. Air for supporting combustion enters the burner housing through the interior of support 35 and the downstream end of the burner housing is open so that the products of combustion will flow out through the downstream end of the burner housing into conduit 31 where these products will intermingle with the air. The humidity of the intake air may be adjusted by use of a container 38, filled with suitable material for adjusting the humidity of the air, disposed across the opening 32. This container has perforate walls and does not unduly restrict the flow of intake air into the conduit 31.

In accordance with this invention air may be used as a drying medium even when its relative humidity at atmospheric condition is in the neighborhood of 80%. This is true because the drying medium may have its temperature increased to the order of 150° F. or even higher, even though the maximum temperature to which the material to be treated can be safely raised is in the neighborhood of 100° to 110° F. At this elevated temperature the relative humidity of the air, even containing the products of combustion, will be about 15%.

and to provide at one end of the tube a seal in the material being dried and the change of direction of flow of the drying medium through the drying chamber when the temperature of the material residing closely adjacent the perforate wall 15 or 16 through which the drying medium is entering approaches the maximum temperature to which the material may be safely heated, the temperature of the material in the drying chamber may be maintained within a safe range.

It is desirable to provide a control for the burners 36 dependent upon the temperature of the drying gases before they enter the pack of material to be dried. This control may be readily provided by mounting a heat sensitive device 39 in the restricted portion of conduit 31. This device is then utilized to control a valve or other like mechanism to determine the rate of supply of fuel to the burner housing 34. Where gas or oil is utilized as the fuel, it is preferred to use a gas-filled tube 39 for the heat-sensitive device and to provide at one end of the tube a seal in the form of a bellows 40. This bellows 40 may then be used in conjunction with any suitable valve to control an actuating medium for operating the valve 41 disposed in line 37 supplying fuel to the burners 36.

Referring to the details of this control, throttle valve 41 is connected by linkage 42 pivoted at 43 to bellows 44. When bellows 44 is energized with fluid under pressure, throttle valve 41 is held in open position. As the pressure within bellows 44 is reduced, the throttle valve is moved toward closed position. A means is provided for supplying pressure fluid to bellows 44 at a pressure de-

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pendent upon the temperature of the gases passing by and in contact with heat-sensitive element 39. To accomplish this, bellows 44 is connected through conduits 45, 46, and 47, to a source of pressure fluid. This pressure should be constant and a valve 48 is interposed in the conduits to provide a means for varying the pressure of the fluid supplied to bellows 44.

Valve 48 comprises an outer housing, substantially cylindrical, having a flexible diaphragm 49 at its left hand end as viewed in Fig. 1. The housing has a vent 48a and is connected to conduits 46 and 47. Controlling the vent 48a and the opening to conduit 47 is a valve member 50, substantially cylindrical in form with one side 50a cut away. Valve 50 is adapted to slide axially within the housing of the valve and in one position will completely close the opening to conduit 47 and in the other position will completely close the vent opening 48a. The length of valve 50 is such that as the valve is moved from one position to the other, vent 48a will be partially uncovered as the opening to conduit 47 becomes covered. With this arrangement the bellows 44 may be completely vented or pressurized with the maximum pressure. Also, intermediate pressures may be reflected in the bellows.

The position of valve 50 within the valve housing is determined by the pressure in bellows 40, for bellows 40 is connected through link 51 to valve 50. A spring 52 urges bellows 40 toward collapsed position for it abuts the bellows at one end and nut 53 carried by bellows housing 54 at the other end. When the temperature of the drying medium increases, the pressure in bellows 40 increases to urge the valve member 50 toward the position to cover the opening to conduit 47. When the temperature of the drying medium decreases, slide 50 is moved in a reverse direction and throttle valve 41 is moved toward open position.

Conduits 45 and 46 are connected to bellows 44 through a valve 55. The valve 55 has a passage 55a. Passage 55a is adapted in one position of the valve to communicate between conduits 45 and 46 and in the other position to communicate between conduit 45 and vent opening 55b. This provides a means for completely shutting off throttle valve 41 and it is actuated by a mechanism to be hereinafter more fully described, whereby, when the temperature of the material being dried adjacent walls 15 and 16 approaches the maximum temperature to which material may be safely heated, valve 41 will be automatically closed to shut off the fire at burners 36. A suitable pilot, not shown in the drawings, is supplied for burners 36 and has connection with the source of fuel through branch conduit 37a.

It is preferred to provide a control for actuating the means for directing the flow of drying medium through the pack of material to be treated. This control may be manual but it is very difficult to provide adequate control by the manual method, and it is preferred to employ a mechanism which will automatically operate the means for directing flow of drying medium through the pack of material so that the direction of flow of the medium is positively changed when the temperature of the material residing closely adjacent the perforate wall through which the drying medium is entering the heat chamber approaches the maximum temperature that the material may be safely heated to. It is also desirable to automatically cut off the heating means for heating the drying medium when the

temperature of the material adjacent both perforate walls approaches such maximum temperature. While this control may be provided by any suitable means, the control must be very accurate to give the best results and also the control mechanism must be rugged in order to stand up under normal conditions of use.

A pneumatic control system has been devised which gives by far the best results yet obtained and which is very rugged in operation. This pneumatic system is sensitive to within $\frac{1}{2}^{\circ}$ F.

Referring to the details of the preferred embodiment of the control, see Fig. 7, a source of constant fluid pressure, not shown in the drawings, is connected through conduit 56 and intermediate or branch conduits and valves with three pressure stations which may be referred to as station one shown at 57, station two shown at 58, and station three shown at 59. The arrangement is adapted to provide pressure fluid selectively at stations one and two and when both stations are energized to supply pressure fluid at station three.

Conduit 56 is connected through branch conduits 60 and 61 to station one. A three-way valve 62 is interposed between branch line conduits 60 and 61 and has openings communicating with each of the conduits and a third opening 62a providing a vent. The central valve member has a passageway 62b adapted in one position of the valve member to make communication between conduits 60 and 61 and in the other position to vent conduit 61. With passage 62b making conduits 60 and 61 common, pressure fluid is supplied at station one shown at 57. With conduit 61 vented, station one is relieved of pressure.

A means is provided for automatically actuating valve 62 whereby station one is energized when the temperature of the material being dried adjacent one perforate wall of the drying chamber approaches a predetermined maximum. This may be accomplished by lodging one of the heat sensitive devices 20, which will be referred to by the numeral 20', in the drying chamber adjacent wall 16. This heat sensitive device is a gas filled sealed tube, the seal being provided by bellows 63. Bellows 63 is mounted in a housing 64 and has a connecting rod 65 extending through a central passage in nut 66. Coil spring 67 is positioned between nut 66 and the end of the bellows and urges the bellows towards collapsed position. By changing spring 67 or adjusting the axial position of nut 66, the heat-sensitive device may be adjusted to trigger the valve at a selected temperature.

Referring to Fig. 9, there is shown, for purposes of illustrating the principle involved, a schematic arrangement of the actuating linkage between bellows 63 and valve 62.

The rod 65 may be connected directly with the central valve member of valve 62 by a suitable linkage 68 pivoted at 69. The coil spring 70 connected between a suitable support and link 68 causes a toggle arrangement so that the valve 60 will be actuated to place passage 62b in its two operative positions above described. The position of the passage is changed when linkage 68 is moved past center due to axial displacement of rod 65. Thus, when the temperature within heat-sensitive device 20' exceeds a predetermined temperature, the pressure within bellows 63 is great enough to overcome spring 67 and shift rod 65 axially to trip toggle linkage 68 and adjust the position of passage 62b to that shown in Fig. 9 making conduits 60 and 61 common. Pressure

station one, shown at 57, is then energized and will remain energized until the pressure within heat-sensitive device 20' falls below the predetermined maximum. When this occurs, the linkage 68 will be rocked about pivot 69 past center by the axial shifting of rod 65 and the central valve member will be shifted within housing 62 to a position with passage 62b communicating between conduit 61 and vent 62a.

Obviously, the movement of rod 65 due to pressure changes within the heat-sensitive device 20' and bellows 63 is a gradual movement as the pressure increases and decreases due to changes in temperature. No instruments are commercially on the market at this time which answer to the requirements of the mechanism just described. However, there is available commercially a valve which will provide a branch line pressure which varies in magnitude as a function of the temperature of a body of material contacted by a heat-sensitive device. The valve referred to is manufactured by Minneapolis-Honeywell Regulator Company. This particular valve has a rather complicated structure and inasmuch as it is conventional equipment, it is not deemed necessary to show and describe the exact structure and operation of this valve in this application. However, there is shown at 74 and 74' in Fig. 7 of the drawings, two schematic valves which illustrate the principle of operation of the Minneapolis-Honeywell valve. This conventional equipment is employed because of its availability and its sensitivity and because it lends itself well to use in conjunction with this invention.

Referring to the embodiment of the control shown in Fig. 7 which employs valve 74 and 74', a bellows 71, separate from the bellows which provides the seal for the heat-sensitive device 20', is employed together with valve means 74 for selectively supplying an actuating power to operate the valve 62. The bellows 71 has a rod 72 which is connected with the linkage 68 and serves to shift the central valve member to its Fig. 7 position when the bellows 71 is energized to a predetermined pressure. The spring 70 and the adjustable linkage 68 provides a means for adjusting the sensitivity of the control of the valve 62 when the pressure within said bellows 71 falls below a predetermined limit, the passage 62b will make connection between conduits 61 and vent 62a. Bellows 71 is connected to a source of constant or regulated fluid pressure through conduits 73, 73a, 60 and 56 and valve 74 controlling flow through these conduits. The valve 74 is disposed between conduits 73 and 73a. Valve 74 has a diaphragm which is secured to rod 65. The rod 65 is secured at one end to bellows 63 and at the other end to valve member 76 within the housing of valve 74. The valve member 76 is adapted to control the vent 75 and the connection between the valve housing and conduit 73a. Valve member 76 is long enough to close both the vent and the connection with conduit 73a, when in an intermediate position, and when in extreme positions within the housing provides communication between the interior of the housing and either the vent 75 or the conduit 73a, dependent upon which extreme position the valve member is in.

When the heat sensitive device 20' is cold, valve member 76 is in a raised position with the valve housing vented. As the temperature of the material about device 20' raises sufficiently to overcome spring 67, valve member 76 is pushed

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downwardly and closes vent 75. A further increase in temperature about device 20' will effect further lowering of valve member 76, cracking the opening between conduit 73a and the interior of the valve housing. This will permit pressure from the constant pressure source to enter the housing and also conduit 73 and bellows 71. This is a closed system and as the pressure within the housing builds up, the pressure acting on the underside of the housing diaphragm will raise the diaphragm to shut off conduit 73a. In operation the pressure within housing of valve 74 will reach a value for any given temperature of the material surrounding device 20' such that the valve member 76 will maintain the vent and the opening to conduit 73a both closed. As the temperature about device 20' decreases, valve member 76 will rise slightly to permit partial venting of the pressure within the valve housing and then the valve member will again close the vent. As the temperature about device 20' increases, valve member 76 will be forced downwardly to uncover the opening to conduit 73a until the pressure within the valve housing increases sufficiently so that the force against the diaphragm will move the valve member upwardly to close the conduit opening.

It is believed obvious that the pressure within conduit 73 and bellows 71, as well as the interior of valve 74 will always be a function of the temperature to which the heat sensitive device 20' is subjected. This pressure controls the actuation of valve 62.

In practice, it is recommended that the source of constant pressure be fifteen pounds gauge and that the pressure within bellows 71 which will effect actuation of valve 62 to place the passage 62b in its Fig. 7 position be in the order of seven pounds.

One advantage of the use of the control apparatus as detailed in Fig. 7 is that the pressure within conduit 73 may be employed to control other operations when desirable. Another advantage is that the bellows 71 may be selected to have the proper degree of extensibility due to pressure variations within a selected range of low pressures.

In rice drying operations, it is usually desirable to change the direction of flow of drying medium through the rice pack when the temperature adjacent the perforate wall through which the drying medium is entering the drying chamber reaches 105° F. With the flow direction changed, the temperature of the material on the downstream side of the rice pack will fall, and it is desirable that the arrangement of the valve 74, bellows 71, and valve 62 be such that the valve 62 will be vented when the temperature drop is in the order of 1° F.

Station two, shown at 58, is energized or de-energized substantially in the same manner as station one, shown at 57, but in response to heat sensitive device 20''. This station communicates with the source of constant pressure through branch line conduit 77 and 78 with a valve 62 therebetween. This station is energized and de-energized by the same type equipment and in a similar manner to that just described in connection with station one and in the interest of simplicity, further discussion of the apparatus and method of operation will be dispensed with, like parts in the apparatus have been given like numerals with the prime differentiating them from the apparatus controlling station one.

Station three shown at 59 is connected with the

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main conduit 56 downstream from branches 60 and 77 by conduits 79, 80 and 81. Two three-way valves 82, designated generally as 83 and 84, respectively, are interposed in this communication line. One of the valves is operated by the bellows 71'', connected to station one by conduit 82 and operates valve 83 by linkage 68. The connection and operation of this valve is exactly the same as the apparatus and operation thereof of the other valves 62, and in the interest of simplicity the parts are given the same numbers and a discussion thereof and the operation thereof is dispensed with. However, it is pointed out that with station one energized, bellows 71'' is energized to make communication between conduits 79 and 80 and with station one vented, conduits 79 and 80 are not common. A similar arrangement is provided between conduits 80 and 81 in the form of valve 84 actuated by a bellows 71''' to which it is operatively connected by linkage 68. This bellows 71''' has a connection through conduit 85 with station two and is energized upon the energization of this station and is vented upon venting of this station.

It is believed apparent that with stations one and two energized, station three will be energized, while if either stations one or two are vented, station three will always be vented. Station three is connected to the fire control shown in Fig. 1 and heretofore described.

Referring to Fig. 6, station one, indicated by numeral 57, is seen to connect with a pneumatic actuator mechanism including cylinder 86 with piston 87 reciprocally mounted therein. The piston is connected by link 88 to the actuator valve for manipulating the shutters 21, 22, 24 and 25. This valve 89 is a four-way valve and has another actuating connection by means of linkage 90 with an actuator connected to station two indicated by the numeral 58. The conduit 58 supplies pressure to the interior of housing or cylinder 91 to the left of piston 92, when the station is energized, to force the piston to the right, as shown in the drawings. Thus, when stations one or two are actuated, they serve to shift valve 89 whereby a pneumatic pressure is supplied, through an independent system, to actuating means for the shutters 21, 22, 24 and 25.

Referring to Fig. 5, a schematic actuating mechanism for the shutters is shown. Valve 89 has a connection 93 with a source of constant pressure and has a vent opening 89a. The valve also has connections 94 and 95. Conduit or connection 94 and conduit or connection 95 are each connected through a series of conduits to the pneumatic actuators for the shutters 21, 22, 24 and 25. The pistons within cylinders 96 and 97 are connected to shutters 22 and 24, respectively, by suitable rods. Pressure is supplied to each of these actuators so as to simultaneously swing shutters 22 and 24 to an open position while the pressure is supplied to actuators 98 and 99, connected respectively to shutters 21 and 25, so as to maintain these shutters closed. In other words, when the connection 95, as shown in Fig. 2, is made common with connection 93, the connection 95 supplies power fluid to the pistons within actuators 96 and 97 on the side of the pistons to cause the rods connected to the shutters to telescope within the piston and to swing shutters 22 and 24 open. At the same time, this connection 95 supplies power fluid to cylinders 98 and 99 on the side of the pistons therein to cause the rods connected to the shutters to be extended and to close shutters 21 and 25. At this time the

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connection 94 is vented, thus venting the spent power fluid from the sides of the pistons opposite to those energized by the connection 95. When the temperature of the material residing adjacent the wall 15 approaches the maximum temperature to which the material should be heated, the control mechanism will shift the valve member 89b of valve 89 if the material adjacent the other perforate wall has sufficiently cooled, whereby conduit 94 will be connected with conduit 93 to supply pressure fluid to the cylinders 96, 97, 98 and 99, to cause shutters 22 and 24 to be swung closed and shutters 21 and 25 to be swung open. The connection 95 will at the same time be vented permitting exhaust of the expended or spent power fluid from these cylinders.

Referring now to station three, indicated at 59 in the drawings, and referring to Fig. 1, it will be seen that the station is connected to a bellows 100, and that the bellows has a link 101 connected to rod 102 pivoted at 103, and adapted to control the position of the central valve member of valve 55. Thus, when station three is energized, bellows 100 will be extended to cause the central valve member of valve 55 to be rotated, making connection between conduit 45 and vent 55b. When station three is then de-energized, bellows 100 will collapse and the valve member will be swung to the position that conduit 45 is made common with conduit 46 and valve 41 is then controlled solely in response to the temperature of the drying medium passing by heat sensitive device 39.

In operation, material to be treated is loaded into the heat chamber by pouring it into hopper 6. The material is then subjected to the heat treatment due to fan 29 blowing the drying medium, which is heated by burners 36, into one of the outer compartments of the housing for the material to be dried. The opposite end of the other outer compartment is open and the drying medium will be forced through the material to be dried, entering through one of the perforate walls 15 and 16 and departing from the chamber through the other. Inasmuch as the heat sensitive devices 20' and 20'' reside closely adjacent the perforate walls 16 and 15, respectively, when the material adjacent the wall through which the drying medium enters reaches or approaches a predetermined maximum temperature to which the material may be heated for the purpose to which the material is to be used, the control shown schematically at 19 and detailed in Fig. 7 causes a shifting of shutters 21, 22, 24 and 25 so as to cause the drying medium to pass through the drying chamber from the opposite direction. If in this operation the material adjacent both perforate walls falls within a limit closely approaching the maximum temperature at which the material should be heated, station three of the control will be energized, causing butterfly valve 41 to be completely closed, discontinuing the energization of the heating means. Cool air is then passed by fan 29 through the pack of material to be treated and will always continue to enter through the same perforate wall through which the heated drying medium was passed at the time the butterfly valve was closed. Immediately upon the de-energization of either station one or two, due to the temperature of the material adjacent either perforate wall falling below the temperature at which the stations one or two will be energized, station three will be de-energized and butterfly valve 41 will be opened in response to the collapse of bellows 100.

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During the drying operation, the temperature of the drying medium will be controlled by the heat sensitive device 39 disposed in the restricted portion of conduit 31 and kept within selected limits.

When the heat treatment or drying operation has been completed, the dried material may be withdrawn from the drying apparatus by removing bottom or slide 10. After removal of the dried material, slide 10 may be reinserted and the heat treatment chamber may then be refilled for another operation.

From the foregoing, it will be seen that this invention is one well adapted to attain all of the ends and objects hereinabove set forth, together with other advantages which are obvious and which are inherent to the structure.

It will be understood that certain features and sub-combinations are of utility and may be employed without reference to other features and sub-combinations. This is contemplated by and is within the scope of the claims.

As many possible embodiments may be made of the invention without departing from the scope thereof, it is to be understood that all matter herein set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

Having described the invention, what is claimed is:

1. Apparatus for drying material comprising two opposed perforate walls providing a drying chamber; means for heating a gaseous drying medium and forcing the medium through the chamber to selectively enter the chamber through either perforate wall and leave the chamber through the other perforate wall; two heat sensitive devices within the chamber, with one of said devices closely adjacent one perforate wall and the other closely adjacent the other perforate wall, said devices adapted to be embedded in the material to be dried; and a flow and heat control system for the drying medium including means responsive to the heat sensitive devices for shifting the direction of flow of drying medium through the drying chamber when the temperature of the material being dried, adjacent the perforate wall through which the drying medium is entering the chamber, approaches the maximum temperature to which the material may be safely heated for the purpose to which the material is to be used and for shutting off the heating means in the event the material being dried adjacent both heating devices approaches said maximum temperature.

2. The method of drying materials supported in a chamber having two opposed perforate walls comprising the steps of heating a gas and passing the heated gas through first one perforate wall and out the other and then through the latter perforate wall and out the first, determining the temperature of the material being dried which lies closely adjacent the perforate walls, and reversing the direction of flow of heated gas when the temperature of the material adjacent the perforate wall through which the gas is entering the chamber approaches a maximum temperature to which the material being treated may be safely heated and passing a relatively cool gas through the drying chamber when the material adjacent both perforate walls approaches that maximum temperature.

3. The method of claim 2 wherein the material is rice and the maximum temperature is 105° Fahrenheit.

4. The method of drying material supported in a chamber having opposed perforate walls comprising the steps of heating a gas and passing the heated gas through first one perforate wall and out the other and then through the latter perforate wall and out the first, determining the temperature of the material being dried which lies closely adjacent to the perforate walls and reversing the direction of flow of heated gas when the temperature of the material adjacent the perforate wall through which the gas is entering the chamber approaches the maximum temperature to which the material being treated may be safely heated and discontinuing the heating of the gas and passing the unheated gas through the drying chamber when the material adjacent both perforate walls approaches said maximum temperature.

5. In the method of drying material retained between two opposed perforate walls wherein a gas is heated and passed through the chamber alternately entering the chamber first through one perforate wall and then through the other perforate wall, the temperature of the material closely adjacent to two walls is continuously measured and the direction of gas flow through the chamber is changed when the temperature of the material adjacent the walls in which the gas is entering approaches the maximum temperature to which the material may be safely raised for the purpose to which the material is to be used, the improvement which resides in the combination therewith of the steps of discontinuing heating of the gas when the material adjacent to both perforate walls approaches said maximum temperature and passing relatively cool gas through the material for sufficient time to cool the material adjacent at least one of the perforate walls substantially below said maximum temperature.

6. The method of claim 5 wherein the material to be dried is rice and the maximum temperature is 105° Fahrenheit.

7. In the method of drying material retained between two opposed perforate walls wherein a gas is heated and passed through the chamber alternately entering the chamber first through one perforate wall and then through the other perforate wall, the temperature of the material closely adjacent the two walls is continuously measured and the direction of flow of gas is changed when the temperature of the material adjacent the walls through which the gas is entering approaches the maximum temperature to which the material may be safely raised for the purpose to which the material is to be used, the improvement which resides in the combination therewith of the steps of automatically discontinuing heating of the gas in direct response to said measurements when the material adjacent both perforate walls approaches said maximum temperature, and passing relatively cool gas through the material for sufficient time to cool the material adjacent at least one of the perforate walls substantially below said maximum temperature.

8. An apparatus for drying material including a drying chamber defined in part by two opposed perforate walls, means for forcing gas through the drying chamber, means for directing the flow of gas so as to enter the chamber selectively through either perforate wall and pass therefrom through the other perforate wall, means for heating the gas before it enters the chamber, two heat sensitive devices within the

chamber, one disposed closely adjacent each of the perforate walls, means responsive to the heat sensitive devices to control the means for directing flow of gas through the chamber and to control the means for heating the gas.

9. An apparatus for drying material including a drying chamber defined in part by two opposed perforate walls, means for forcing gas through the drying chamber, means for directing the flow of gas so as to enter the chamber selectively through either perforate wall and pass therefrom through the other perforate wall, means for heating the gas before it enters the chamber, two heat sensitive devices within the chamber, one disposed closely adjacent each of the perforate walls, pneumatic means responsive to the heat sensitive devices to control the means for directing flow of gas through the chamber and to control the means for heating the gas.

10. An apparatus for drying material including a drying chamber defined in part by two opposed perforate walls, means for forcing gas through the drying chamber, means for directing the flow of gas so as to enter the chamber selectively through either perforate wall and pass therefrom through the other perforate wall, means for heating the gas before it enters the chamber, heat sensitive devices responsive to the temperature of the material to be dried and lying closely adjacent each perforate wall, means responsive to the heat sensitive devices to control the means for directing flow of gas through the chamber and to control a means for heating the gas.

11. An apparatus for drying material including a drying chamber defined in part by two opposed perforate walls, means for forcing gas through the drying chamber, means for directing the flow of gas so as to enter the chamber selectively through either perforate wall and pass therefrom through the other perforate wall, means for heating the gas before it enters the chamber, two heat sensitive devices within the chamber, one disposed closely adjacent each of the perforate walls, means responsive to the heat sensitive devices to control the means for directing flow of gas through the chamber and to shut off the means for heating the gas when the temperature of the material being dried and lying closely adjacent the two perforate walls exceeds a predetermined value.

12. Drying apparatus comprising a drying chamber with a gas flow passageway there-through, shutter means adapted to direct flow of the gas through the drying chamber selectively in both directions, actuator means for operating the shutter means, adjustable means for heating the gas before it passes into the drying chamber, two heat sensitive devices one adapted to be disposed in the material being dried closely adjacent both termini of the flow passage through the drying chamber, pneumatic means responsive to said devices for operating the shutter means to reverse the direction of gas flow through the drying chamber when the temperature of the material about the heat sensitive device at the entrance terminal of the passageway is greater than a predetermined value and the temperature at the other terminal of the passageway is less than said value, said pneumatic means adapted to shut off the heating means when the temperature of the material at both heating devices is above said maximum value.

13. A pneumatic control adapted to selectively supply control pressure fluid to three stations

comprising a main conduit connectable to a source of pressure fluid, three branch conduits communicating with the main conduit and stations one, two and three, respectively, valve means controlling the branch lines communicating with stations one and two adapted to selectively and independently connect the first two stations with the main conduit and to vent the stations, two heat sensitive devices one corresponding to each of the stations one and two and connected with the valve means to control same, valve means controlling the branch conduit to station three, means responsive to pressure at stations one and two to control the latter valve means, the latter valve means adapted to make communication between station three and the main conduit only when stations one and two are both pressurized and to vent station three when either of stations one and two is vented.

14. A control as in claim 13 wherein means responsive to the heat sensitive devices to control pressure fluid from the main conduit and

this controlled pressure fluid is utilized to actuate the valve means in the branch conduits leading to stations one and two.

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