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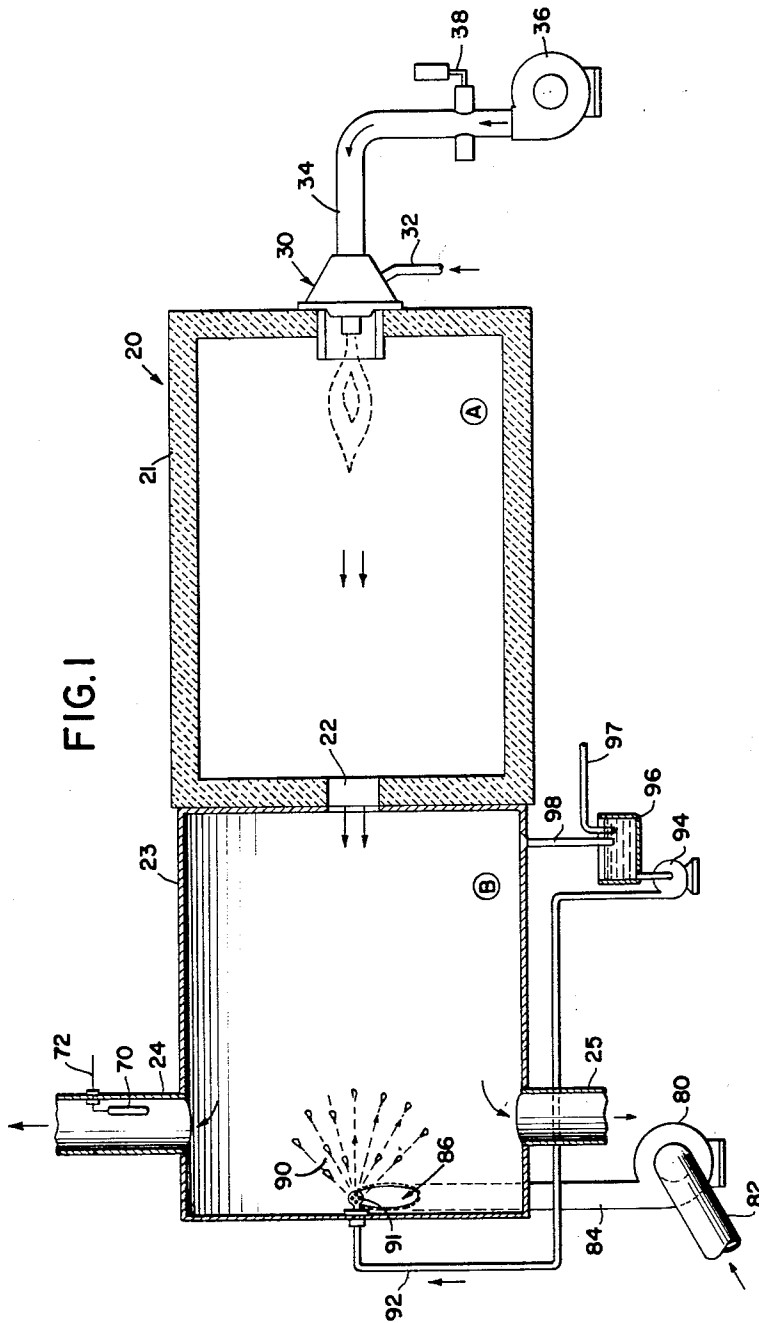
W. L. WELLFORD, JR

3,151,850

KILN FURNACE

Filed Oct. 4, 1962

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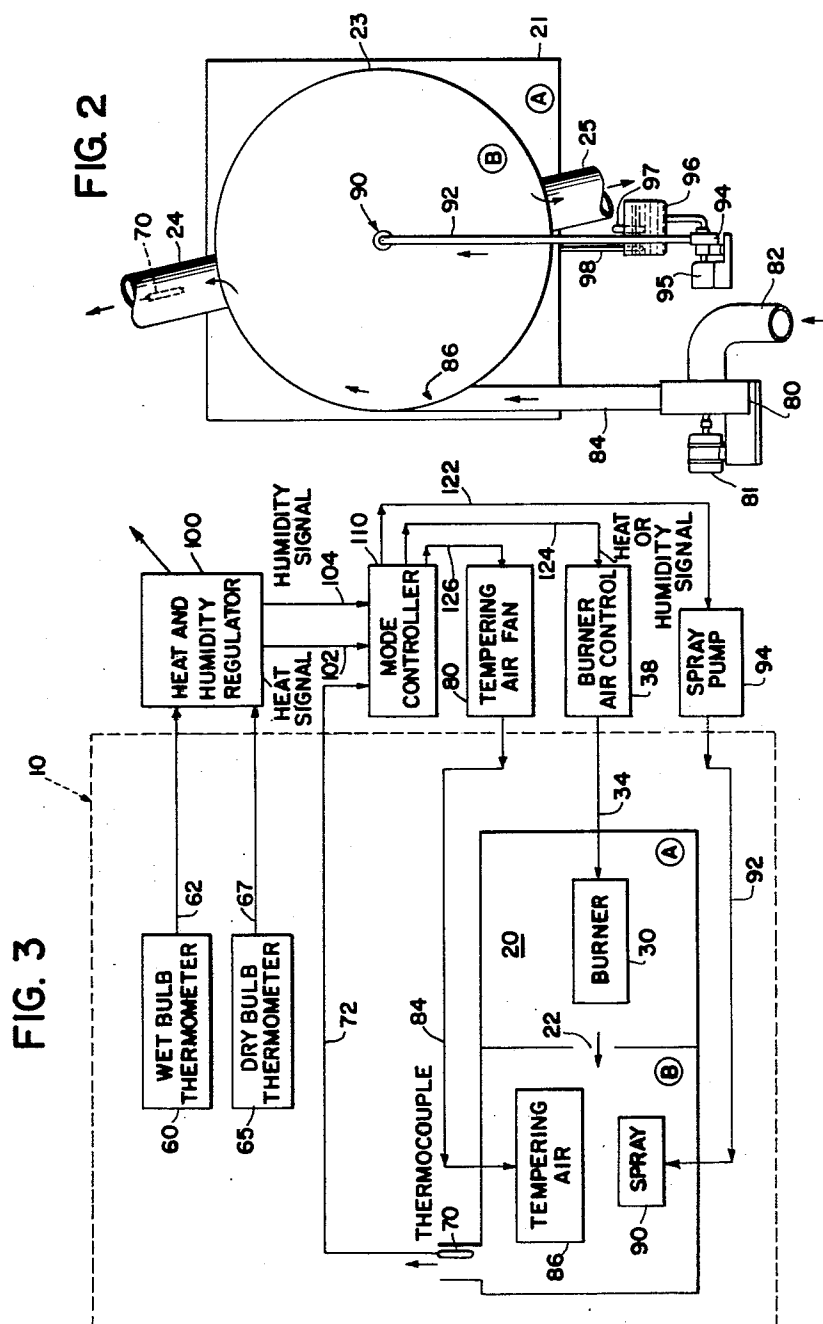
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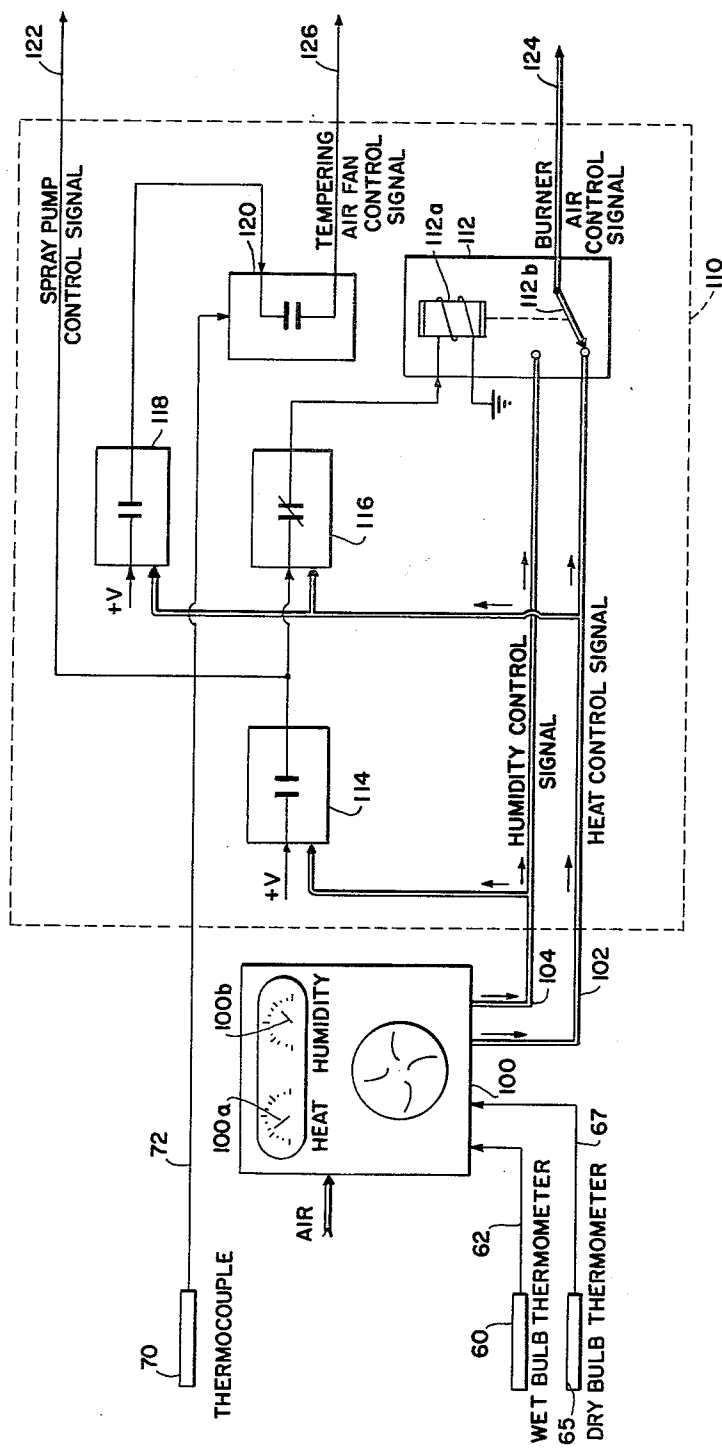
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KILN FURNACE

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FIG. 4



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KILN FURNACE

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5 Claims. (Cl. 263-19)

This invention relates to furnaces for drying and conditioning kilns. While the present invention may be used in the equipment and operation of drying and conditioning kilns used for any specific purpose, it will be described and illustrated herein as applied to kilns employed for drying and conditioning lumber.

It is a common practice in the kiln drying of lumber to supply heated air which has been heavily laden with moisture for conditioning the lumber properly during the drying process in order to prevent over-rapid drying of the surface and exterior portions of the lumber. In conventional kilns this drying medium is obtained from air mixed with steam supplied from a steam boiler and then raised to an elevated temperature by heating coils or by a gas-fired furnace. In such prior art arrangements two separate heating sources are frequently employed, one for heating the air to the desired temperature and the other for converting water to steam vapor for rapid evaporation in the air medium. Since the requirement for two separate heating sources greatly increases the expense of construction, operation, and maintenance of a lumber drying kiln, efforts have recently been directed toward the objective of eliminating the steam boiler from the lumber kiln and obtaining the hot moisturized air, utilized as the drying and conditioning medium, with only a single heat source.

Generally, such attempts to obviate the need for a separate steam boiler have been unsuccessful as the periods during the lumber drying process when it is desirable to add moisture to the air medium usually occur at times when the heating source is supplying a relatively small amount of heat since the air circulating within the kiln environment has previously been raised to a high temperature and there is very little heat loss. Accordingly, the introduction of water spray into the path of the circulating gas stream invariably results in a rapid and severe reduction in the air temperature (due to the caloric energy expended for vaporization) and an attendant decrease in the capacity of the gas stream to quickly evaporate the introduced water.

Some prior art devices have attempted, without much success, to overcome this problem by preheating of the water prior to its introduction into the hot air stream in an effort to eliminate the need for an external steam boiler to convert water into steam. It is obvious, however, that merely preheating the water supply to high temperature under pressure (for example, 260° F. at 80 p.s.i.) will now cause the water to be evaporated in significant quantity, when sprayed into the air stream as the pressure is released, because of the substantial additional amount of caloric energy required to supply the latent heat of vaporization. Furthermore, the injection of water in the solid state into the circulating airstream in the kiln produces highly undesirable effects if the water is not vaporized immediately. Water not immediately evaporated settles either on the walls and floor of the kiln, producing scaling and other corrosive effects, or on the lumber itself, leaving undesirable lime deposits when evaporation later takes place.

It is a principal object of the present invention to provide a furnace apparatus of novel design for heating and moisturizing the drying medium in a lumber kiln whereby water, in the unheated state, may be introduced and rapidly evaporated within the medium with highly satisfactory results, thereby obviating the need for an addi-

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tional external heating source. For accomplishing this objective there is provided, in an exemplary embodiment of the present invention, a two-chambered gas-fired furnace whose operation is controlled automatically by signals received from a pair of sensors, measuring temperature and humidity within the kiln wherein drying and conditioning of the lumber is taking place, and from a third sensor monitoring the temperature of the exhaust gases emergent from the furnace.

The first chamber of the furnace contains a gas burner and functions as a combustion region for heating the hot air medium which is to be circulated throughout the lumber kiln. The second chamber, which is connected to the first chamber by a passageway, is a tempering and vaporizing region wherein unheated water spray may be introduced, as desired, into the midst of the heated air stream prior to its circulation throughout the kiln. In this second chamber there is also provided, in addition to means for supplying the water spray, a tempering air blower for intermixing air from the kiln with the heated and moisturized gases from the furnace.

In this exemplary embodiment, a pair of humidity and temperature sensors, which are located in the path of the airstream circulating within the kiln, supply measurement signals to a pair of regulators monitoring the heat temperature and humidity, respectively, within the kiln. Each of these two regulators may be of conventional design and of the type wherein an output signal is derived responsive to the difference between the input signal, corresponding to the measured parameter, and a predetermined setting of temperature or humidity. The respective regulator outputs are, in turn, connected to a mode controller circuit of novel design which regulates the operation of the furnace, in a manner hereinafter described.

As previously mentioned, prior attempts to introduce water, in a form other than steam, into the circulating airstream have been unsuccessful because the gas burner, or other source heating the air medium, is usually supplying insufficient heat at the time to effect rapid and substantial water evaporation. To overcome these difficulties the operation of the present kiln furnace apparatus is controlled by the regulators and the mode controller such that, upon the receipt of signals from the humidity regulator indicating that the relative humidity of the drying medium circulating within the lumber kiln should be increased, a spray of water is introduced into the heated gas stream as it passes through the second of the two furnace chambers, and at the same time the gas burner in the first chamber is immediately turned up to a higher rate of combustion. As the result of the dual-mode regulatory operation of the furnace provided by the controller, the heated air medium, during the period when water spray is being introduced to increase its moisture level, is continuously maintained by the furnace at a temperature above the boiling point of water. Hence a rapid and substantially complete evaporation of the water spray occurs and there is accordingly neither any appreciable reduction in the temperature of the hot airstream emergent from the furnace discharge ducts nor any deposit of unevaporated water within the kiln.

On the other hand, once the moisture level of the drying air medium again reaches the desired level for lumber conditioning purposes, as determined by the setting of the humidity regulator, the controller switches over the gas burner to an alternative mode of operation wherein its combustion rate is controlled by the heat regulator in response to signals received from the sensor measuring the air temperature within the kiln. If, while the humidity regulator indicates that water spray is required to raise the moisture level of the circulating air medium, the heat regulator monitoring the

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temperature of the airstream in the kiln indicates that the additional heat required at the time from the furnace burner will be sufficient to effect rapid and thorough evaporation of the water spray, then the circuitry of the mode controller permits the output control signal from the heat regulator to override that from the humidity regulator, insofar as regulation of the combustion rate of the gas burner in the first chamber of the furnace is concerned.

In addition to providing dual-mode control of the furnace burner, the mode controller circuit also contains means for actuating the tempering air blowers located in the second chamber of the furnace when the output control signal from the heat regulator exceeds a predetermined threshold, thereby indicating that the temperature of the combusted gases within the kiln furnace has risen sufficiently for the furnace gases to require tempering with return air from the kiln.

The signals from the third sensor, measuring the heat of the exhaust gases in an outlet duct of the furnace, are also supplied, together with output control signals from the heat and humidity regulators, to the mode controller circuit in order to insure that the operation of the furnace is so regulated that the temperature of the airstream in the second chamber of the furnace does not drop below the boiling point of water when evaporation of water spray in the airstream is being effected.

Therefore, since control of the furnace in all modes of operation is such that the hot gas stream is continuously maintained, by automatic regulation of the gas burner and actuation of the tempering air blower at appropriate times, at a temperature in excess of the water boiling point at the situs of the introduction of the water spray (the second chamber of the furnace), rapid and effective evaporation of the water spray is accomplished without any appreciable cooling of the heated air circulating throughout the kiln. And furthermore, there is no need in the furnace apparatus of the present invention for the conventional steam boiler, ordinarily required to accomplish rapid evaporation of water into the airstream circulating within the kiln.

It is therefore a principal objective of the present invention to provide an apparatus for a drying and conditioning kiln having but a single heat source for both combusting hot gases and for effectively evaporating large quantities of water therein to produce a heated and moisturized circulating gas medium.

It is another objective of the present invention to provide a furnace, in a kiln of the type having a drying and conditioning medium of warm, moist air whose moisture level is controlled by periodically evaporating water into the gas stream, wherein there is no requirement for a separate heat source to preheat the water prior to its introduction into the gas stream.

It is still another objective of the present invention to provide a furnace, in a kiln of the type employing a drying and conditioning medium of warm moist gas, which is controlled automatically in two modes of operation in response to the temperature and moisture content, respectively, of the gas medium circulating throughout the kiln.

It is a further objective of the present invention to provide a furnace for a drying kiln having no steam boiler and but a single heat source for combusting hot gases and for vaporizing water into the combusted gases prior to their discharge into the kiln.

And it is yet another objective of the present invention to provide means for automatically regulating the operation of a furnace, in a kiln of the type employing a drying and conditioning medium of warm, moist gas, in response to the temperature and relative humidity, respectively, of the gas medium circulating throughout the kiln.

The foregoing and other objectives, features, and advantages of the present invention will be more readily

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understood upon consideration of the following detailed description of an illustrative embodiment of the invention, taken in conjunction with the accompanying drawings.

FIG. 1 is a front elevational view, partly sectional, of an illustrative embodiment of a lumber kiln furnace constructed in accordance with the present invention.

FIG. 2 is a side elevational view, as seen from the left, of the embodiment of the lumber kiln furnace shown in FIG. 1.

FIG. 3 is a block diagram of a suitable control system for providing automatic operation and regulation of a lumber kiln furnace according to the present invention.

FIG. 4 is a schematic diagram of a mode controller suitable for use in the control system shown in FIG. 3.

Referring now to FIGS. 1 and 2, there is shown a gas-fired lumber kiln furnace, designated generally as 20, provided with two compartments A and B which are linked together by a passageway 22. Compartment A is a combustion chamber, lined with refractory material 21, in which gas fuel is burnt. Compartment B is a tempering and vaporizing chamber, enclosed within a stainless steel tank 23, in which combusted hot gases entering from the first chamber via passageway 22 are moisturized with interjected water spray and are tempered with return gases from the lumber kiln.

In combustion chamber A fuel is supplied from a source (not shown) to a gas burner 30 via a pipeline 32 where it is intermixed with a quantity of air forced at high velocity over air line 34 by blower fan 36. The combustion rate, and hence the temperature of the fired gases, is regulated in conventional manner through variation of the air-fuel mixture. In this exemplary embodiment of the invention this regulation is provided by pneumatically-actuated valve 38 which controls the rate of air flow in the air line 34.

The hot gases, fired by the gas burner 30 in combustion chamber A of the furnace 20, then flow out through the passageway 22 into chamber B of the furnace where tempering and vaporization takes place, as needed. It is here, in chamber B, that controllable amounts of water spray 90 are introduced into the hot gases to increase the moisture content of the drying medium prior to its circulation throughout the lumber kiln. Water, supplied from a source (not shown) via conduit 97 to a sump tank 96, is withdrawn from the sump by spray pump 94 and then impelled at high pressure over water line 92 to nozzle 91 which disperses the water into a spray 90 of fine droplets. The water spray is directed within the chamber B so as to intermix with the combusted hot gases emergent from the combustion chamber A through the passageway 22. In an illustrative embodiment of the invention, the tempering and vaporizing chamber B is a tank-like enclosure of cylindrical design, and the spray nozzle 91 and the connecting passageway 22 are disposed generally along the longitudinal axis of the cylindrical chamber, so as to insure good intermixture of the injected water spray with the combusted gases. The small amount of water spray which is not immediately vaporized by the heat of the combusted gases falls to the bottom of the chamber B where it is withdrawn by drain 98 and returned to the sump tank 96 for recirculation.

Air circulating within the lumber kiln is drawn therefrom by suitably located ducts (not shown) and directed via an inlet line 82 to an air blower 80 which expels this return air from the kiln into a pipeline 84 connected to chamber B of the furnace 20. The air pipeline 84 is preferably arranged so as to approach tangentially the cylindrical surface of the tank-like enclosure for chamber B, in order that tempering air 86, expelled into the chamber through the orifice in the cylindrical side wall of the tank, will intermix well with the hot gases from the combustion chamber A.

The lumber drying medium, comprised of the hot gases combusted in chamber A of the furnace 20, together with

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the water vapor 90 and return kiln air 86 which has been added in chamber B, is then discharged from the furnace through a pair of outlet ducts 24, 25 in the lumber kiln. These ducts are provided along their length with suitable baffles and openings (not shown) for directing and circulating the heated and moisturized drying medium throughout the mass of lumber contained in the kiln.

As previously mentioned, the novel construction and principles of operation of the present invention permit large quantities of water to be effectively and satisfactorily evaporated into the drying medium circulating throughout the lumber kiln without the need for providing a separate external steam boiler for vaporizing the water prior to its introduction into the drying medium. This advantageous result is accomplished by suitably regulating the combustion rate of the gas burner 30 in the combustion chamber A of the furnace 20 such that adequate caloric energy is continuously available in the heated gases to achieve the desired rapid and complete evaporation of the water spray introduced into the gases in chamber B of the furnace.

FIGURE 3 is a block diagram of a suitable control system for providing the automatic operation and regulation of a lumber kiln furnace, of the construction described herein, in order to accomplish the above and other objectives of the present invention. As has been explained, typically the periods of lumber kiln operation during which it is desirable to add water to the drying medium to increase the moisture content thereof usually occur when the furnace is required to supply relatively little heat in order to maintain the temperature of the drying medium in the kiln at some predetermined value. Accordingly, provision is made in the control system shown in FIG. 3 for switching-over control of the furnace to another mode of operation when it is desired to add moisture to the drying medium during those periods when relatively little heat energy is required from the furnace to maintain the desired temperature in the lumber kiln.

In FIG. 3, the gas-fired furnace 20, shown in detail in the embodiment of FIGS. 1 and 2, is illustrated in a somewhat schematic representation as located within a lumber kiln 10 of conventional design indicated by the dotted lines. The three blocks contained within the outline representation of the furnace 20 represent the three variable elements of the furnace whose operation may be regulated automatically by the control system; namely, the combustion rate of the burner 30, the actuation of the water spray 90, and the introduction of tempering air 85.

A dry bulb thermometer 65 and a wet bulb thermometer 60 are suitably located within the lumber kiln 10 for monitoring, respectively, the temperature and humidity of the drying medium circulating within the lumber kiln. The signal indications from the dry and wet bulb thermometers are supplied over respective lead wires 67, 62, to a heat and humidity regulator 100. As more particularly shown in FIG. 4, the heat and humidity regulator 100 may be of conventional design, such as a Foxboro Vacuum Pneumatic Temperature-Humidity Recording Controller, of the type wherein an output signal (e.g., a pneumatic air pressure) is derived responsive to the difference between the input signal, corresponding to the measured parameter, and a predetermined setting of temperature or humidity. Thus, as indicated in FIG. 3, two outputs are derived from the regulator 100; the first is a heat signal, appearing on lead line 102, which represents the difference between the temperature present within the lumber kiln 10 and the desired temperature in the kiln (as represented by the setting of the regulator); and the second output is a humidity signal, appearing over lead line 104, which represents the difference between the actual and desired moisture content of the drying medium in the lumber kiln. These two signals, together with a third signal supplied over lead line 72 by a thermocouple 70 located in an outlet duct of the furnace 20 and represent-

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ing the temperature of the furnace's exhaust gases, are supplied to a mode controller circuit 110 of unique design which selects one of two possible modes of operation for the furnace. Details of the mode controller 110 are shown in FIG. 4 which is a composite electropneumatic schematic diagram of its construction and circuit configuration.

In a first mode of operation, the operation of the furnace is regulated in a manner somewhat similar to that employed with conventional furnace control systems; that is, the temperature within the lumber kiln 10 is sensed by dry bulb thermometer 65, converted to an appropriate electrical or pneumatic signal and supplied to regulator 100 where it is compared with a predetermined "Heat" setting 100a, and the resulting difference or error signal appearing at an output of the regulator as a Heat Control Signal 102 is utilized to regulate operation of the furnace. In the embodiment of the control system illustrated in FIGS. 3 and 4, the Heat Control Signal 102 is in the form of a pneumatic pressure whose magnitude varies in proportion to the difference existing between the actual and desired heat temperatures in the kiln. This Heat Control Signal is fed into the mode controller 110 and, in a first mode of operation of the system, is directed through an electrically-controlled pneumatic switch 112 to become the Burner Air Control Signal 124. The air pressure signal appearing in line 124 is supplied to the pneumatically-actuated valve 38 which controls the quantity of air reaching the burner 30. Thus the combustion rate of the gas burner 30 is automatically regulated, in the first mode, by the temperature of air circulating within the lumber kiln.

The Heat Control Signal 102 from the regulator is also applied to two pneumatically-controlled contactors 116 and 118 in the mode controller circuit 110. These contactor elements are of conventional design and of the type wherein a pneumatic pressure of predetermined magnitude, appearing at the input of the element, actuates the mechanism. Contactor 116 contains a pair of normally-closed electrical contacts (whose function will be explained subsequently) and contactor 118 contains a pair of normally-open contacts.

As represented in the diagram of FIG. 4, an electric potential +V is applied to the electrical circuit of the normally-open contactor 118. In the presence of a Heat Control Signal 102 from the regulator 100 of sufficiently high pneumatic pressure the contacts of the element 118 will close. Upon such occurrence, the electrical potential +V is then connected, as indicated, to a pair of contacts of an electrically-controlled contactor switch 120. Electrical signals from thermocouple 70 which monitors the temperature of the exhaust gases of the furnace 20, are supplied via lead wire 72 to the mode controller 110 where they are utilized to actuate the switching element of the contactor 120. Contactor element 120 contains a pair of normally-open contacts which close when the electrical signals from thermocouple 70 indicate that the temperature of the exhaust gases has exceeded a predetermined threshold, typically, a few degrees above the vaporization point for water. The happening of such a condition, causing the switch element of the contactor to close, completes an electrical circuit thus generating a Tempering Air Fan Control Signal 126 which actuates the tempering air fan 80. Thus tempering of the furnace is initiated and nominally controlled by the temperature of its exhaust gases, subject, however, to an overriding control provided by the normally-open contactor 118 which holds the energizing circuit for the tempering air fan 80 open during those long periods of time in the drying process when the heat demand from the burner is relatively low. The primary function of contactor 118 is to economize on the operation of the tempering air blower 80 so that it will not be repetitively actuated in short spurts when the gas burner 30 is firing at such a low level

of combustion that the temperature of the exhaust gases will remain well within the prescribed limit without any need for tempering the furnace gases with return air from the lumber kiln.

The Humidity Control Signal 104 from the regulator 100 is supplied to the mode controller 110 where it is utilized to regulate operation of the pump 94 which causes water to be introduced into the combusted hot gases in chamber B of the furnace 20. In the first mode of operation of the furnace, as shown in the diagram of FIG. 4, the Humidity Control Signal 104 which is fed to one of the two input terminals of the pneumatic switch 112 is not connected through to the output line of the switch on which the Burner Air Control Signal 124 appears. Thus, in the first mode of operation corresponding to the "rest" position of the switch arm 112b of the electrically-controlled pneumatic switch 112, the air supply for the gas burner 30 is regulated in response to the Heat Control Signal 102 appearing at the output of the regulator 100.

The Humidity Control Signal 104, although not connected to the circuit regulating the operation of the furnace burner 30, is also applied, however, to a third contactor 114 of the mode controller circuit 110. Contactor element 114 is actuated by a pneumatic signal in a manner similar to that previously described in connection with contactor elements 116 and 118. Upon the application of a pneumatic pressure signal of sufficient magnitude to the input of contactor element 114, its pair of normally-open switch contacts close, and a circuit path for an electrical potential +V is completed through the element. Thus an electrical signal will appear at the output of the contactor element 114 when it is actuated by a pneumatic Humidity Control Signal 104 which exceeds a predetermined threshold value. This electrical signal is utilized as a Spray Pump Control Signal 122 to energize the motor 95 of the spray pump 94 and thereby to actuate the mechanism which interjects water spray into the combusted gases in chamber B of the furnace to raise their moisture content. Hence, through the medium of the circuit apparatus just described, water spray will be introduced into the combusted hot gases in the furnace when the difference (as represented by the Humidity Control Signal 104) between the actual moisture content of the drying medium circulated within the lumber kiln (as measured by the wet bulb thermometer 60) and the desired value (as represented by the "Humidity" setting 100b of the regulator 100) is sufficiently great to actuate contactor element 114.

In order that any quantity of water introduced into the chamber B of the furnace be evaporated satisfactorily, it is necessary to insure that there is adequate caloric energy present in the heat of the hot gases combusted within the furnace to supply the latent heat required to vaporize all of the water. The mode controller circuit 110 of the present invention is specially designed to handle this situation effectively by converting the furnace to an alternative mode of operation when it is desired to add water to the lumber drying medium during periods when only a small amount of heat energy is being required from the furnace to maintain a desired kiln temperature.

As shown in the diagram of FIG. 4, when the contacts of contactor element 114 close in response to an actuating Humidity Control Signal 104 of sufficient magnitude, the electrical signal appearing at its output, besides serving as a Spray Pump Control Signal 122 to activate the water spraying process in chamber B of the furnace, is also applied to normally-closed contactor 116, whose actuation is controlled pneumatically by the Heat Control Signal 102 from the regulator 100. The output from contactor element 116 is in turn applied to the solenoid relay coil 112a which actuates pneumatic switch 112.

When a closed path is presented for an electrical potential +V through the circuit comprised of normally-

open contactor 114 and normally-closed contactor 116, then the solenoid coil 112a will be energized and switch arm 112b drawn upward, converting the gas burner 30 of the furnace to a second mode of operation wherein regulation is provided by the Humidity Control Signal 104, rather than by the Heat Control Signal 102. Upon such occurrence, the pneumatic air pressure appearing as the Humidity Control Signal output 104 of the regulator 100 is applied to the pneumatically-controlled valve 38 which regulates, through control of the air supply to the burner 30, the combustion rate of the gases fired in chamber A of the furnace 20.

Since, in this second mode of operation of the furnace, the Humidity Control Signal 104 directly regulates the operation of the gas burner 30, the combustion rate and temperature of the gas fuel fired by the burner 30 in chamber A of the furnace will increase directly proportional to the amount of water spray 90 introduced into the combusted gases in chamber B of the furnace, irrespective of the fact that the temperature of the drying medium circulating within the lumber kiln 10 corresponds closely to the "Heat" setting 100a of the regulator 100. Accordingly, this alternative mode of operation of the furnace 20 provided by the mode controller circuit 110 insures that adequate heat energy will be supplied from the gas burner 30 to evaporate effective amounts of water as rapidly as it is sprayed into the hot gases to increase their moisture content. This advantageous result is accomplished by the expedient of having the solenoid coil 112a of the pneumatic switch 112 energized, so as to transfer operation of the burner 30 to regulation by the Humidity Control Signal 104 generated by the regulator 100, whenever this signal is of sufficient magnitude to instigate, through activation of contactor 114, the interjection of water spray into the heated gases in the furnace.

The presence of normally-closed contactor 116 in the mode controller circuit 110 permits the first mode of furnace operation to override the second whenever the heat energy, then instantaneously being required from the furnace to raise or maintain the temperature of the drying medium circulating in the lumber kiln (as indicated by the pressure level of the Heat Control Signal 102 generated by the regulator 100), will also be adequate to satisfactorily evaporate any water spray which may be added to the hot gases at that time to raise their moisture content. Thus, for example, if the Heat Control Signal should be of sufficiently large amplitude, at the same time that the Humidity Control Signal from the regulator is of sufficient amplitude to actuate the water spray apparatus, then the contacts of normally-closed contactor element 116 will be actuated into the open position, this breaking the energizing circuit for the solenoid coil 112a. This sequence of events causes switch arm 112b to return to the rest position and restores the burner 30 to control by the Heat Control Signal output of the humidity regulator 100 (i.e., the first mode of operation).

In sum, therefore, the operation of the furnace apparatus of the present invention is regulated by an automatic control system in such a manner that, during periods of operation when substantially only caloric heat energy is required to be added by the furnace to increase the temperature of the drying medium circulating in the lumber kiln, the gas burner is controlled directly in response to signals from a dry bulb thermometer responsive to the temperature of the drying medium. On the other hand, when it is desired to add substantially only water to the drying medium to increase the moisture content thereof, regulation of the burner of the furnace is provided by signals from a wet bulb thermometer in the lumber kiln responsive to the moisture content of the drying medium. Finally, whenever the temperature and humidity sensors in the lumber kiln indicate that both heat and water are to be added to the drying medium in substantial quantities, the gas burner of the furnace is regulated in response to signals from the dry bulb thermometer in the

kiln so long as the indicated heat required will be adequate to evaporate in a satisfactory manner the water added to the furnace gases. Thus, automatic regulation of the furnace's operation is provided by a control system which is responsive to the value of the particular parameter of the drying medium, whether it be temperature, humidity, or both, which it is desired to vary, as determined by the appropriate settings of a heat and humidity regulator. This is a unique feature of the control system of the present invention and, when combined with the novel two-chambered furnace construction described herein, permits heating and moisturizing of the drying medium in a lumber kiln to be achieved in a highly satisfactory and efficient manner without the necessity for a separate external steam boiler for vaporizing the water prior to its introduction into the drying medium.

It will be readily understood, of course, that a complete automatic control system for the lumber kiln furnace described above might typically comprise such additional regulatory and overload devices, e.g., a high-limit temperature cut-off switch, as are conventional in furnace operation. With this in mind, the diagram of FIG. 4, and the accompanying description, has been directed at illustrating only those elements of the control system of the present invention which interact in novel fashion to provide the dual-mode operation of the lumber kiln furnace.

The terms and expressions which have been employed here are used as terms of description and not of limitation, and there is no intention, in the use of such terms and expressions, of excluding equivalents of the features shown and described, or portions thereof, it being recognized that various modifications are possible within the scope of the invention claimed.

What is claimed is:

1. In a kiln system, the combination comprising
 - (a) a kiln for drying and conditioning material,
 - (b) a kiln furnace having a first chamber containing a burner for combusting hot gases and a second chamber connected to said first chamber for receiving said combusted hot gases, said second chamber containing means for spraying water in a solid state into said combusted hot gases prior to their circulating through said kiln,
 - (c) a first sensor located in said kiln for measuring the dry bulb temperature of said circulating kiln gases,
 - (d) a second sensor located in said kiln for measuring the wet bulb temperature of said circulating kiln gases, and
 - (e) a control apparatus connected to receive signals from said first and second sensors and comprising, a regulator means for comparing the respective dry and wet bulb signals with predetermined temperature and humidity levels for said circulating kiln gases and generating output signals representative of instantaneous temperature and humidity requirements in said kiln, and a controller means, connected to receive said regulator output signals, for actuating said spray means when increased humidity is needed and for regulating the combustion rate of said burner in a manner whereby hot gases in said second chamber are continuously maintained throughout the period of said spraying at a sufficiently high temperature to effect a rapid and substantially complete evaporation of said water spray in said gases.
2. The combination set forth in claim 1 wherein said regulator means generates a pair of "heat" and "humidity" output signals indicating, respectively, the instantaneous temperature and humidity requirements for said circulating kiln gases as determined by comparison of said dry and wet bulb sensor signals with predetermined settings of said regulator, and said controller means, in a first mode of operation, regulates the combustion rate of said burner in response to the "heat" signal received from said regulator, and, in a second mode of operation, actuates said spray means and regulates the combustion

rate of said burner in response to the "humidity" signal received from said regulator.

3. The combination set forth in claim 2 wherein said controller means includes a mode-determining means permitting said first mode of operation to predominate over said second mode in regulating the combustion rate of said burner when the "heat" signal received from said regulator exceeds a predetermined level, thereby indicating that the caloric heat energy demanded from said burner to raise the temperature of the circulating kiln gases will also be adequate to satisfactorily evaporate any water introduced into said combusted hot gases by said spray means.

4. In a kiln system, the combination comprising

- (a) a kiln chamber for drying and conditioning material,
- (b) a kiln furnace containing a burner for combusting hot gases,
- (c) a duct in said furnace for permitting said combusted hot gases to emerge from said furnace for circulation throughout said kiln chamber,
- (d) a first blower means providing forced circulation of said combusted hot gases through said furnace, said duct and said kiln chamber,
- (e) a sensor located in said duct for measuring the temperature of said emergent furnace gases,
- (f) a second blower means for cooling said combusted hot gases in said furnace by tempering them with return gases from said kiln chamber, and
- (g) a control means responsive to the signal received from said temperature sensor in said duct for automatically actuating said second blower means to provide tempering of the combusted hot gases in said furnace when said emergent furnace gases exceed a predetermined temperature.

5. In a kiln system, the combination comprising

- (a) a kiln for drying and conditioning material,
- (b) a kiln furnace having a first chamber containing a burner for combustion hot gases and a second chamber connected to said first chamber for receiving said combusted hot gases, said second chamber containing means for spraying water in a solid state into said combusted hot gases prior to their circulating through said kiln,
- (c) a duct in said furnace for permitting said combusted hot gases to emerge from said furnace for circulation throughout said kiln,
- (d) a first blower means providing forced circulation of said combusted hot gases through said furnace, said duct and said kiln,
- (e) a first sensor located in said kiln for measuring the dry bulb temperature of said circulating kiln gases,
- (f) a second sensor located in said kiln for measuring the wet bulb temperature of said circulating kiln gases,
- (g) a third sensor located in said duct for measuring the temperature of said emergent furnace gases,
- (h) a tempering air blower means for cooling said combusted hot gases in said second chamber of said furnace by intermixing them with return gases from said kiln, and
- (i) a control apparatus connected to said first, second and third sensors, said control apparatus comprising a regulator means for comparing dry and wet bulb signals received from said first and second sensors with predetermined temperature and humidity levels for said circulating kiln gases and generating output signals representative of instantaneous temperature and humidity requirements in said kiln, and a controller means, connected to receive said regulator output signals and said third sensor signals, (1) for actuating said spray means when increased humidity is needed, (2) for regulating the combustion rate of said burner in a manner whereby hot gases in said second chamber are continuously main-

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tained throughout the period of said spraying at a sufficiently high temperature to effect a rapid and substantially complete evaporation of said water spray in said gases, and (3) for actuating said tempering air blower means in response to signals received from said third sensor indicating that said emergent furnace gases have exceeded a predetermined temperature level.

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2,606,372	Foulder et al. -----	Aug. 12, 1952
2,725,224	Pierce -----	Nov. 29, 1955

**UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION**

Patent No. 3,151,850

October 6, 1964

Walker L. Wellford, Jr.

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

Column 1, line 23, for "tempearture" read -- temperature --; line 54, after "will" insert -- not --; column 2, line 17, for "filn" read -- kiln --; column 4, line 70, for "temperaing" read -- tempering --; column 7, line 9, for "furnase" read -- furnace --; column 9, line 5, for "patricular" read -- particular --; column 10, line 39, for "combustion" read -- combust: --; column 12, line 6, for "2,488,144" read -- 2,448,144 --.

Signed and sealed this 19th day of January 1965.

(SEAL)

Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents