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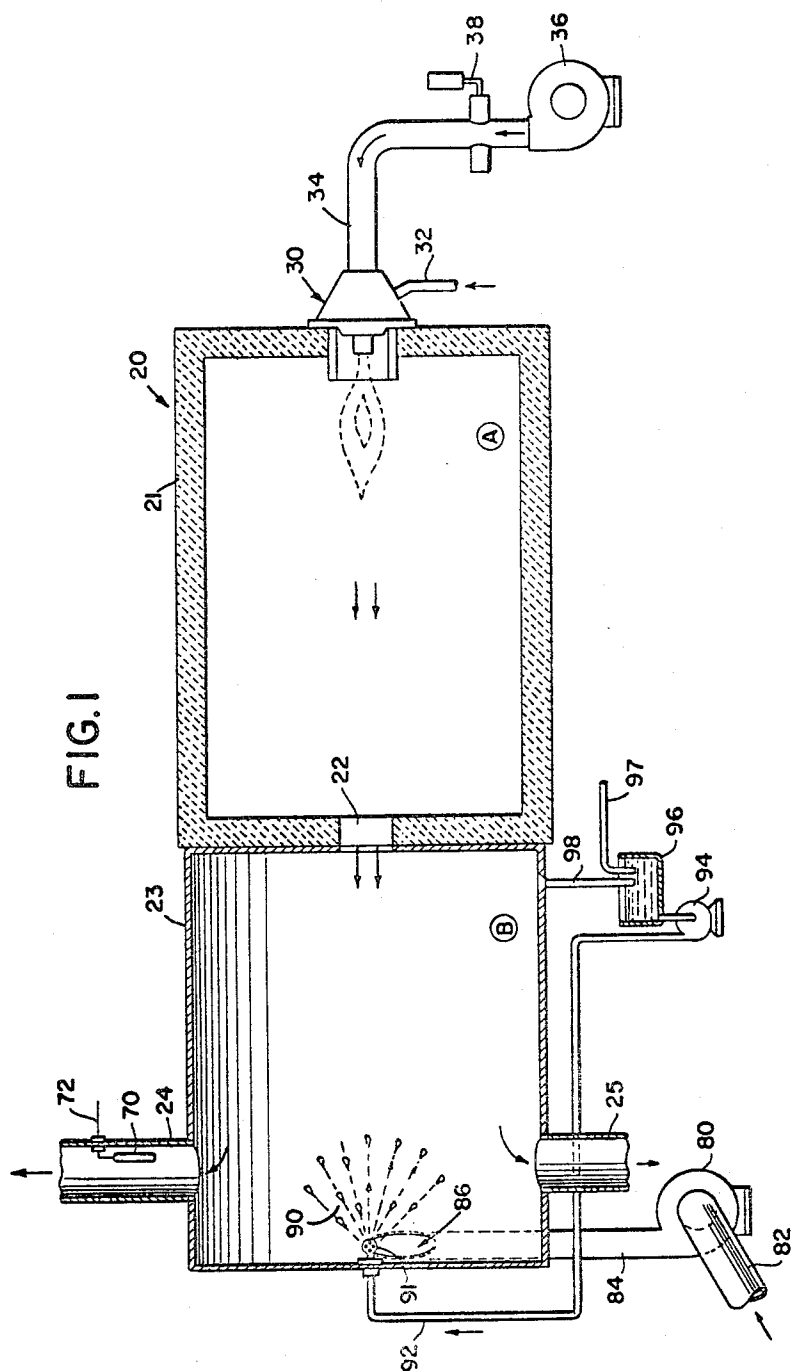
W. L. WELLFORD, JR

3,269,715

KILN FURNACE CONTROLLER

Filed April 2, 1964

3 Sheets-Sheet 1



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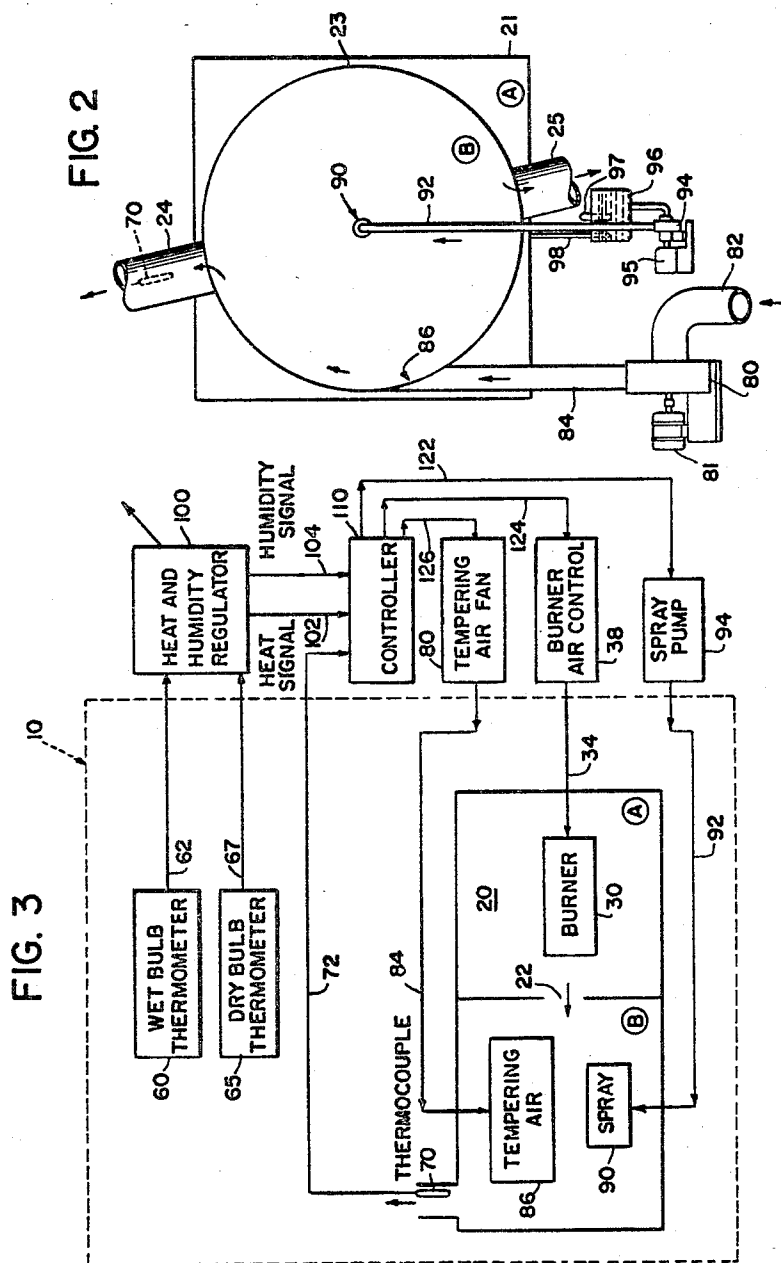
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KILN FURNACE CONTROLLER

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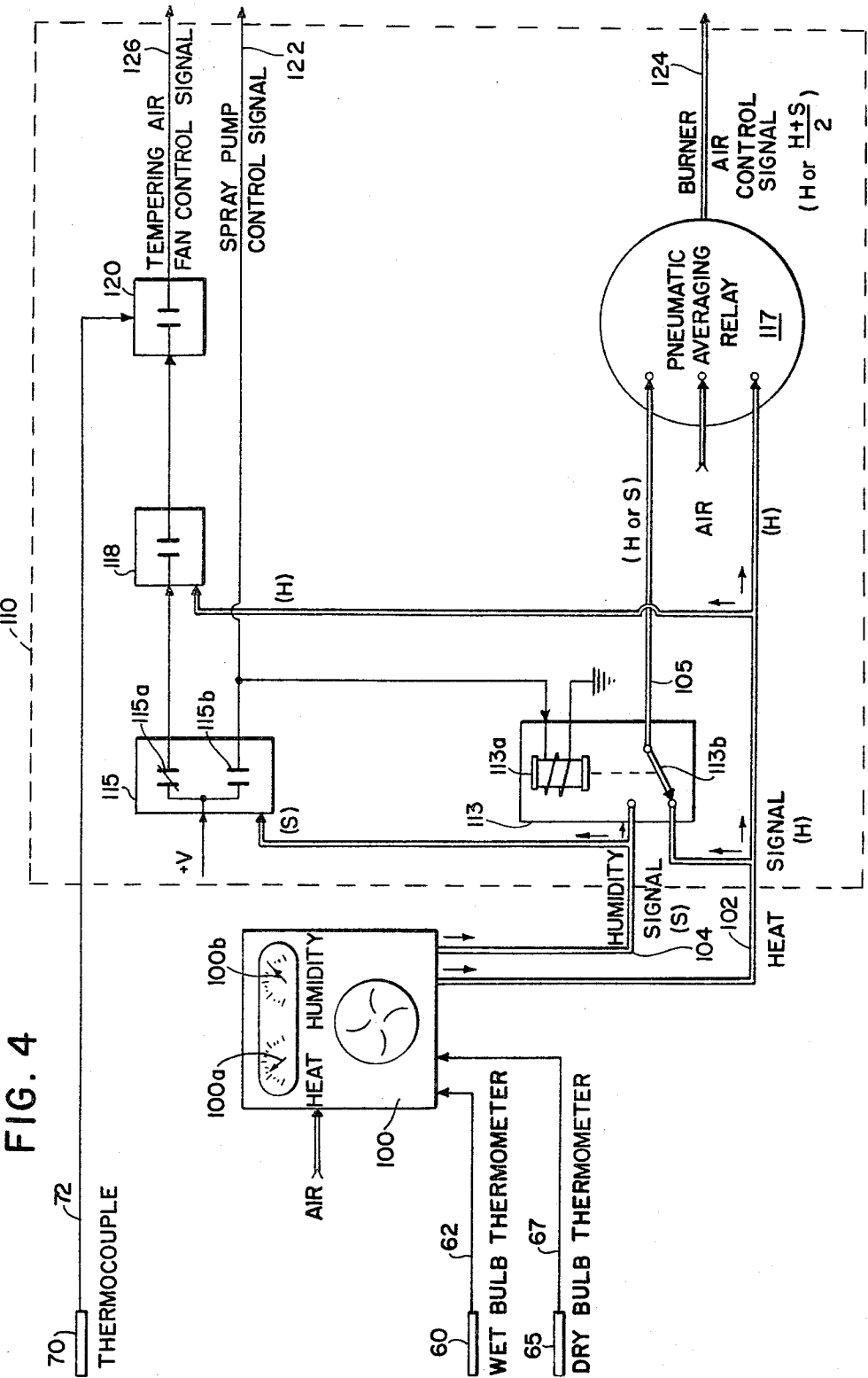
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KILN FURNACE CONTROLLER

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4 Claims. (Cl. 263-19)

This invention relates to certain new and useful improvements in control apparatus for a gas-fired kiln furnace of the type wherein water, as well as heat, are added to the combusted furnace gases to form a heated and moisturized gaseous medium for treating kiln material. More particularly, the invention relates to improved controller means for automatically regulating the operation of the kiln furnace in a more advantageous and efficient manner during those periods in the kiln treatment cycle when increased moisture content is required in the circulating gases, and a large quantity of water in liquid form is introduced for vaporization in the combusted furnace gases. While the control apparatus of the present invention may be advantageously employed in furnace systems supplying a heated and moisturized gaseous medium to kilns for treating various kinds of materials, it is particularly suitable for application in kilns used for the drying and conditioning of lumber. Accordingly, it will be described and illustrated herein as applied to dry kilns of this type.

It is a common practice in the kiln drying of materials such as 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. In addition, the injection of water in the liquid 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.

In a copending United States Patent application, Serial No. 228,366, filed October 4, 1962, now Patent No. 3,151,850, the present applicant disclosed a kiln furnace system of novel design, comprising a two-chambered gas-fired furnace and a furnace controller apparatus, whereby

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large quantities of water, when introduced into the combusted furnace gases in an unheated state, may be rapidly evaporated in the gaseous flow stream with highly satisfactory results.

In the exemplary embodiment of the furnace system described in the aforesaid application, the first chamber of the furnace contains a gas burner and functions as a combustion region for heating the gaseous medium which is to be circulated throughout the kiln. The second chamber, which is connected to the first chamber by a passageway, is a vaporizing and tempering region wherein unheated water spray may be introduced into the midst of the heated flow stream prior to its circulation throughout the kiln and wherein return air from the kiln may be intermixed with the combusted furnace gases.

The operation of the kiln furnace is regulated by a control circuit in response to signals received from a pair of wet-bulb and dry-bulb temperature sensors located in the path of the airstream circulating within the kiln. In the control circuit a heat and humidity regulator of conventional type receives the signals from the pair of temperature sensors in the kiln and generates a corresponding pair of output signals, each proportional to the difference in amplitude between the respective input signal and a predetermined temperature or humidity setting on the regulator. These "Heat" and "Humidity" output signals from the regulator are then supplied to a controller means which has a mode selection mechanism whereby either one or the other of the two regulator signals, depending upon their respective amplitudes, is utilized to regulate the operation of the kiln furnace by controlling the combustion rate of its gas burner.

As described in the aforementioned application, S.N. 228,366, now Patent No. 3,151,850, the operation of the kiln furnace is regulated by the mode controller means in the control circuit in such a manner that, during periods of operation when only caloric heat energy is required to be added by the furnace to increase the temperature of the drying medium circulating in the kiln, the gas burner of the furnace is controlled directly in response to the amplitude of the regulator's heat signal in accordance with conventional practice. However, when it is desired to add water to the drying medium to increase its moisture content, regulation of the furnace burner is switched over to an alternate mode of operation and placed under the control of the regulator's Humidity signal rather than its Heat signal.

In this latter mode the furnace apparatus is operated in a manner such that, when an output signal is produced by the regulator, indicating that the relative humidity of the drying medium circulating within the kiln should be increased, means are actuated for injecting a spray of water 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 in accordance with the amplitude of the Humidity signal. As a result of this dual-mode regulatory operation of the furnace burner's combustion rate provided by the controller means, the heated gas medium, during the period when and at the place where water spray is introduced to increase the moisture level of the combusted gases, is continuously maintained at a temperature above the vaporization point, and hence a rapid and substantially complete evaporation of the water spray occurs in the second chamber of the furnace without any appreciable cooling of the heated gases circulating throughout the kiln.

On the other hand, whenever both of the regulator's Heat and Humidity output signals indicate that heat as well as water are required to be added to the drying

medium, and that the additional heat required to raise the kiln temperature is of such substantial magnitude that it can also effect a rapid and thorough evaporation of any water added to the furnace gases by maintaining the temperature in the second chamber of the furnace above the vaporization point, then the circuitry of the mode controller permits the Heat signal from the regulator to override or predominate over its Humidity signal in regulating the combustion rate of the furnace burner.

However, in the operation of a kiln furnace system of the type described in the aforesaid copending application, certain limitations in the control apparatus have been encountered which, while not serious, somewhat limit the effectiveness and overall efficiency of the furnace. In particular, it has been found that the operation of the controller in the control circuit of the kiln furnace, when the operation of the furnace burner is switched away from the regulator's Heat output signal to control by its Humidity signal (i.e., during those periods when water is to be sprayed into the furnace gases and the heat demand in the kiln is low), causes the burner to be turned up to a very high rate of combustion because of the relatively large amplitude of the Humidity signal generated by the regulator when added moisturization is required. Besides being wasteful of gas fuel, such operation requires that great quantities of water spray be added to the furnace gases, beyond that needed merely to increase the moisture content of the gases to the desired level, in order to prevent the dry bulb temperature of the kiln gases from rising beyond the level determined by the "Temperature" setting of the regulator.

In other words, except in those instances when the combustion rate of the furnace burner is left under the control of the regulator's Heat signal (i.e., in those instances in which substantial quantities of caloric heat energy as well as water are called for by the kiln requirements), the existence of a need for an increase in the moisture content of the kiln gases will, with the furnace control apparatus described, convert the burner to regulation by the Humidity output signal of the regulator. In many cases the amplitude of the Humidity signal will be so great at the time that the furnace burner will be turned wide open. This will require that substantial extra quantities of water be drawn for injection into the furnace gases, over and beyond that merely required for moisturization of the gases, in order to cool and remove the excessive caloric heat energy generated by the furnace burner.

The present invention provides a controller apparatus of improved design, for use in an automatic control circuit for regulating the operation of a gas-fired kiln furnace system of the type described, which incorporates all the advantages obtained from a dual-mode furnace controller operation and, in addition, overcomes the above-described limitations which have heretofore limited the effectiveness and efficiency of such kiln furnace systems. To accomplish this desired end, the controller of the present invention provides a dual-mode of operation of the kiln furnace wherein, in a first mode, the combustion rate of the furnace burner is regulated in the conventional manner by the Heat signal from the regulator and, in a second mode, the combustion rate of the furnace burner is regulated by a signal level proportional to the average or mean amplitude of the Heat and Humidity output signals supplied from the regulator.

The second mode of operation ensures that, during those periods when water is sprayed into the second chamber of the furnace in order to increase the moisture content of the kiln gases, the furnace burner will operate at a rate of combustion sufficient to rapidly vaporize all of the injected water spray in a satisfactory manner, but will not operate at so high a rate of combustion that the introduction of additional water will be required to pre-

vent the dry bulb temperature of the kiln gases from rising above the predetermined level set by the regulator. Since the combustion rate of the furnace burner will, in the second mode of operation, be regulated by a control signal which is a function of both the regulator Heat and Humidity signals, rather than the Humidity signal alone as was the case in the controller disclosed previously, the caloric heat energy generated in the furnace during a spraying cycle will be more nearly in accord with that actually needed for rapidly and effectively vaporizing the introduced water, and the generation of superfluous heat energy will be avoided.

As a further improvement in furnace operation, circuit means are also provided in the controller of the present invention to automatically turn off the tempering air fan in the second chamber of the furnace, which intermixes the combusted furnace gases with a return gas flow from the kiln, during those periods in the kiln treatment cycle when increased moisturization of the gas stream is required and water is introduced in the second chamber, in order to further promote a more rapid and efficient vaporization of the water spray into the combusted furnace gases.

It is therefore a principal objective of the present invention to provide an improved controller circuit and control apparatus for a kiln furnace of the type wherein water in liquid form is vaporized into combusted furnace gases to form a heated and moisturized gaseous medium for treating kiln material.

It is another objective of the present invention to provide an improved controller circuit for a kiln furnace of the type described which regulates the operation of the furnace system in a more economical and efficient manner by reducing the quantity of water which must be added to the drying and conditioning medium circulating throughout the kiln in order to satisfy predetermined moisture requirements, and by reducing the amount of caloric heat energy required to rapidly and effectively vaporize such added water.

The foregoing and other objectives, features, and advantages of the present invention will be more readily 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 type of kiln furnace which may be advantageously used with the improved controller apparatus of the present invention.

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

FIG. 3 is a block diagram of a kiln furnace system which employs the improved controller apparatus of the present invention in a control circuit providing automatic operation and regulation of a kiln furnace of the type shown in FIGS. 1 and 2.

FIG. 4 is a schematic diagram of an illustrative embodiment of an improved kiln furnace controller constructed in accordance with the teachings of the present invention.

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) via a pipeline 32 to a gas burner 30 where it is intermixed with a quantity of air forced at high velocity over air line 34 by blower fan 36. The com-

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bustion rate, and hence the temperature of the fired gases, is varied in conventional manner through means of a pneumatically-actuated valve 38 controlling the air-fuel mixture by regulation of 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. 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 a tempering air blower 80 which expels this return air from the kiln into a pipeline 84 connected to chamber B of the furnace 20. Through the air pipeline 84 tempering air 86 is expelled into the chamber through the orifice in the cylindrical side wall of the tank for intermixing with the combusted hot gases from the combustion chamber A.

The drying medium, comprised of the hot gases combusted in chamber A of the furnace 20, together with 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 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 material contained in the kiln.

As set forth in detail in applicant's copending application, the novel construction and principles of operation of the kiln furnace system permit large quantities of water to be effectively and satisfactorily evaporated into the drying medium circulating throughout the kiln without any 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 automatic control apparatus which suitably regulates the combustion rate of the gas burner 30 in the combustion chamber A of the furnace 20 in such a manner that adequate caloric energy is continuously available in the combusted furnace gases to achieve a rapid and complete evaporation of any water spray introduced into the gases in chamber B of the furnace.

FIG. 3 is a block diagram of a kiln system which may feasibly employ the improved controller apparatus of the present invention in a control circuit providing automatic operation and regulation of a kiln furnace of the type described herein. As has been explained, typically the periods of 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 caloric heat energy in order to maintain the kiln at a predetermined dry bulb temperature. Accordingly, provision is made by the controller means in the control circuit of the furnace system shown in FIG. 3 for switching control of the furnace to another mode of operation when it is desired to add moisture to the kiln drying medium.

In FIG. 3, the gas-fired furnace 20, shown in detail in the embodiment of FIGS. 1 and 2, is illustrated in a

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somewhat schematic representation as juxtaposed next to a kiln 10 of conventional design indicated by the dotted lines. The three blocks contained within the outline representation of the furnace 20 represents 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 86.

A dry bulb thermometer 65 and a wet bulb thermometer 60 are suitably located within the kiln 10 for monitoring, respectively, the temperature and humidity of the drying medium circulating within the 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 dry bulb temperature present within the kiln 10 and the desired temperature (as represented by the setting of the regulator); and the second output is a Humidity Signal, appearing over lead line 104, which similarly represents the difference between the actual and desired wet bulb temperature or moisture content of the drying medium in the kiln. These two signals, together with a third signal which is supplied over lead line 72 by a thermocouple 70 located in an outlet duct of the furnace 20 and which represents the temperature of the furnace's exhaust gases, are supplied to a controller 110 of unique design which selects one of two possible modes of operation for the kiln furnace system.

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 system; that is, the temperature within the 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 Signal 102 is utilized to regulate operation of the furnace. In a second mode of operation, which occurs during those periods in the kiln treatment cycle when water spray is to be added to the combusted furnace gases to increase the moisture content of the kiln drying medium, the furnace operation is regulated by a control signal which is a function of both the Heat Signal 102 and the Humidity Signal 104.

In the illustrative embodiment of the furnace control system, the Heat Signal 102 is in the form of a pneumatic pressure whose amplitude varies in proportion to the difference existing between the actual and desired dry bulb temperature in the kiln. This Heat Signal 102, together with the Humidity Signal 104 which similarly is in the form of a pneumatic pressure proportional to the difference between actual and desired wet bulb temperature, are fed into the controller 110, details of which are shown in the electro-pneumatic schematic diagram of FIG. 4.

Both the Heat Signal 102 and the Humidity Signal 104 are fed to input terminals of an electrically-controlled pneumatic switch 113. In the first mode of operation, corresponding to the "rest" position of the switch arm 113b of the switch, the Heat Signal 102 is connected through to the output line 105; in the second mode of operation, the solenoid 113a of the switch is energized, and the Humidity Signal 104 appears on the output line 105. In either event the signal appearing on the output

line 105 of the pneumatic switch 113 is supplied, together with a separate line containing the Heat Signal 102, as inputs to a pneumatic averaging relay 117 of conventional design, such as Minneapolis-Honeywell Model RP904C, and of the type wherein a pneumatic output signal is generated which represents the average or mean of two pneumatic input signals. The air pressure signal appearing at the output of the averaging relay 117 becomes the Burner Air Control Signal 124 which is supplied to the pneumatically-actuated valve 38 which controls the quantity of air reaching the burner 30, and thus the combustion rate of the furnace.

The Humidity Signal 104 from the regulator is also applied to a pneumatically-controlled contactor element 115. This contactor element is of conventional design and of the single-pole-double-throw type wherein a pneumatic pressure signal of predetermined magnitude, appearing at the input of the element, actuates the mechanism causing the normally-closed electrical contacts 115a to open, and the normally-open electrical contacts 115b to close.

As represented in the diagram of FIG. 4, an electric potential +V is applied to the electrical input or pole arm terminal of the contactor element 115. In the presence of a Humidity Signal 104 from the regulator 100 of sufficiently high amplitude (indicating that water spray should be introduced into the furnace gases to increase their moisture content), the normally-closed contacts 115a will open, and the normally-opened contacts 115b will close. Upon such occurrence, the opening of contacts 115a opens the electrical circuit for the Tempering Air Fan Control Signal 126, the path of which may be traced from the potential source +V, through the normally-open contactor elements 118 and 120 (whose respective functions will be explained subsequently), to the tempering air fan 80. Conversely, the closing of contacts 115b of the contactor element 115, which occurs simultaneously with the disruption of the circuit path for the tempering air fan, completes the circuit for the Spray Pump Control Signal 122 and energizes the motor 95 of the spray pump 94, thereby actuating the mechanism which interjects water spray into the combusted gases in chamber B of the furnace. Hence, through the medium of the circuit operation just described, water spray will be introduced into the combusted hot gases in the furnace whenever the difference (as represented by the Humidity Signal 104) between the actual moisture content of the drying medium circulated within the 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 115.

In order that any quantity of water introduced into 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 combusted furnace gases to supply the latent heat energy required to vaporize all of the water. The improved controller circuit 110 of the present invention is specially designed to handle this situation in a more efficient manner than has previously been the case by converting the furnace to an alternative mode of operation during periods when it is desired to add water to the kiln drying medium.

As shown in the diagram of FIG. 4, when the contacts 115b of contactor element 115 close in response to an actuating Humidity Signal 104 of sufficient amplitude, 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 the solenoid relay coil 113a which actuates pneumatic switch 113. When the solenoid coil 113a is energized, switch arm 113b is drawn upward and the pneumatic pressure signal appearing on the output line 105 is changed over from the Heat Signal 102 to the Humidity Signal 104. Accordingly, the respective input lines to the averaging relay 117 will contain the Humidity Signal

in one and the Heat Signal in the other, and thus the output signal now generated will be the average or arithmetic mean of the two signals, rather than the Heat Signal alone as in the first mode of operation. Therefore the furnace will be converted to a second mode of operation, whenever water spray is to be introduced, wherein regulation of the gas burner 30 is provided by a Burner Air Control Signal 124 which is a function of the amplitudes of both the Heat Signal 102 and the Humidity Signal 104.

Since, in this second mode of operation of the furnace, the average of the respective Heat and Humidity Signal levels 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 in a manner proportional to (1) the quantity of heat required to increase the temperature of the kiln gases to the desired temperature level, plus (2) the amount of additional water required to increase the moisture content of the kiln to the desired humidity level. Accordingly, this alternative mode of operation of the furnace 20 provided by the controller circuit 110 insures that an adequate, but not excessive, quantity of caloric heat energy will be supplied from the gas burner 30 to evaporate the water in an effective manner as rapidly as it is sprayed into the combusted furnace gases. This advantageous and economical result is accomplished by the expedient of having the operation of the burner 30 transferred to regulation by a composite of the Heat and Humidity Signals 102, 104 generated by the regulator 100, whenever the Humidity Signal is of sufficient amplitude to instigate, through activation of contactor 115, the interjection of water spray into the heated furnace gases.

In the first mode of operation, wherein the furnace is regulated directly by the Heat Signal 102 from the regulator and no water is being added to the furnace gases, the furnace controller 110 contains a circuit means for actuating the tempering air fan 80 whenever the furnace exhaust temperature exceeds a predetermined limit. Thus, when the furnace system is in the first mode of operation and contactor element 115 is unactuated, the electric potential +V is applied through the normally-closed contacts 115a to the input of a normally-open contactor 118. In the presence of a Heat Signal 102 from the regulator 100 of sufficiently high amplitude the contacts of the element 118 will close.

Upon such occurrence, the electrical potential +V is then connected, as indicated in the diagram of FIG. 4, to the normally-opened contacts of an electrically-controlled contactor switch 120. An electrical signal from thermocouple 70, which monitors the temperature of the exhaust gases of the furnace 20, is supplied via lead wire 72 to the controller 110 where it is utilized to actuate the switching element of the contactor 120. The pair of contacts will close whenever the electrical signal from thermocouple 70 indicates that the temperature of the exhaust gases has exceeded a predetermined threshold, typically, a level set a few degrees above the vaporization point of water. The happening of such a condition, causing the contact elements of contactor 120 to close, completes an electrical circuit path and generates a Tempering Air Fan Control Signal 126 which in turn actuates the tempering air fan 80.

Thus, in the first mode of operation, 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 pre-

scribed limit without any need for tempering the furnace gases with return air from the lumber kiln.

However, as previously explained, whenever the furnace system is changed over to the second mode of operation, wherein water spray is introduced into the combusted furnace gases, the energizing circuit for the tempering air fan 80 is opened by actuation of the contactor element 115, and thus no tempering of the furnace gases with return air from the kiln occurs at such times. This "inhibit" feature of the controller 110 promotes the over-all efficiency of the kiln furnace system by reducing the total amount of heat energy required from the furnace burner to rapidly and effectively vaporize the introduced water while maintaining kiln temperature.

It will be readily understood, of course, that a complete controller apparatus and control circuit for the kiln furnace system described above might typically comprise circuitry and apparatus for providing a pre-purge or post-purge cycle in the kiln furnace operation through the actuation of venting means, as well as such additional regulatory and overload devices as are conventional in kiln furnace operation. With this in mind, the drawings and accompanying description have been directed at illustrating only those elements of the controller system of the present invention which, in combination, interact in novel fashion to provide the improved dual-mode operation of the 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 chamber for drying and conditioning material,
 - (b) a kiln furnace of the type having a first region containing a gas burner for combusting hot gases, and a second region containing means for spraying water into said combusted gases prior to circulation through said kiln chamber,
 - (c) a first sensor located in said kiln for measuring the dry bulb temperature of circulating kiln gases,
 - (d) a second sensor located in said kiln for measuring the wet bulb temperature of said kiln gases,
 - (e) a regulator means connected to receive signals from said first and second sensors and generating a pair of "heat" and "humidity" output signals indicating, respectively, the instantaneous heat and humidity requirements of said circulating kiln gases as determined by comparison of said sensor signals with predetermined settings of said regulator, and
 - (f) a controller connected to said regulator containing means which, in a first mode of operation, regulates the combustion rate of said furnace burner in response to the "heat" signal received from said regulator, and, in a second mode of operation, actuates said furnace spray means and regulates the combustion rate of said furnace burner in response to a sig-

nal which is a composite of the amplitudes of the respective "heat" and "humidity" signals received from said regulator.

2. The combination set forth in claim 1 wherein said controller contains means for switching from said first to said second mode of operation whenever the "humidity" signal from said regulator exceeds a predetermined level.

3. The combination set forth in claim 1 wherein said composite signal regulating the combustion rate of said furnace burner during said second mode of operation is formed by means in said controller generating an output signal which is the arithmetic average of the respective amplitudes of the "heat" and "humidity" signals from said regulator.

4. In a kiln system, the combination comprising

- (a) a kiln chamber for drying and conditioning material,
- (b) a kiln furnace of the type having a first region containing a gas burner for combusting hot gases, and a second region containing means for spraying water into said combusted gases prior to circulation through said kiln chamber as well as means for tempering said combusted gases with return air from said kiln chamber,
- (c) a first sensor located in said kiln for measuring the dry bulb temperature of circulating kiln gases,
- (d) a second sensor located in said kiln for measuring the wet bulb temperature of said kiln gases,
- (e) a third sensor for measuring the temperature of combusted gases emergent from said furnace,
- (f) a regulator means connected to receive signals from said first and second sensors and generating a pair of "heat" and "humidity" output signals indicating, respectively, the instantaneous heat and humidity requirements of said circulating kiln gases as determined by comparison of said sensor signals with predetermined settings of said regulator, and
- (g) a controller connected to said regulator containing means which, in a first mode of operation, regulates the combustion rate of said furnace burner in response to the "heat" signal received from said regulator and actuates said tempering air means when the temperature of said emergent furnace gases exceed a predetermined level, and, in a second mode of operation, actuates said furnace spray means, inhibits the actuation of said tempering air means irrespective of the temperature of said emergent furnace gases, and regulates the combustion rate of said furnace burner in response to a signal which is a composite of the amplitudes of the respective "heat" and "humidity" signals received from said regulator.

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