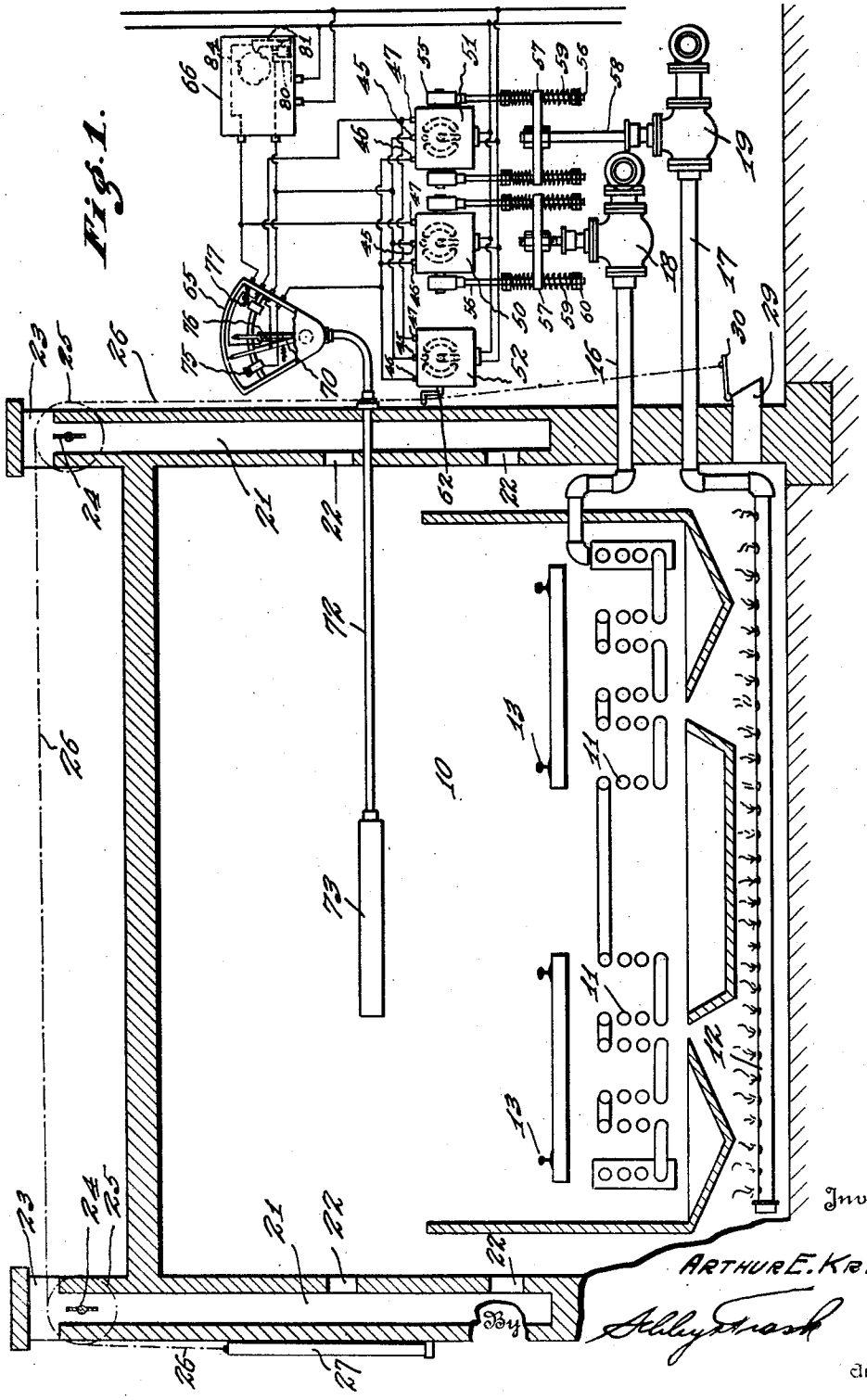
April 16, 1935. A. E. KRICK 1,997,826

PROCESS FOR DRYING CONTROL

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Fig. 1.



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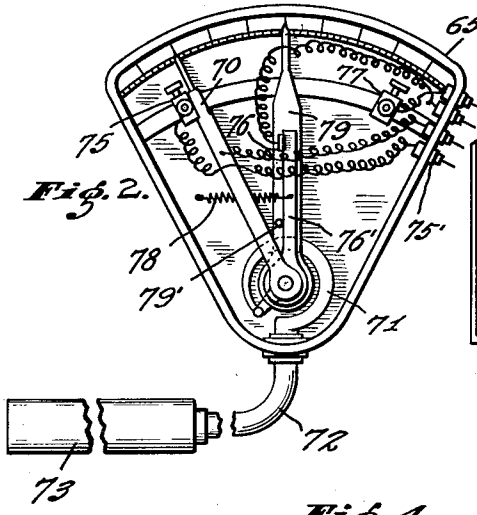


Fig. 2.

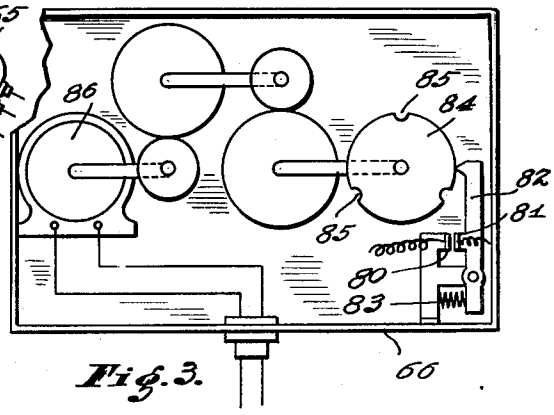


Fig. 3.

Fig. 4.

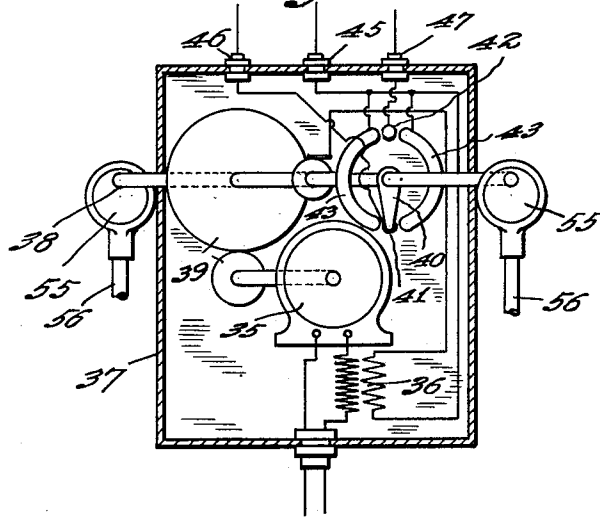


Fig. 5.

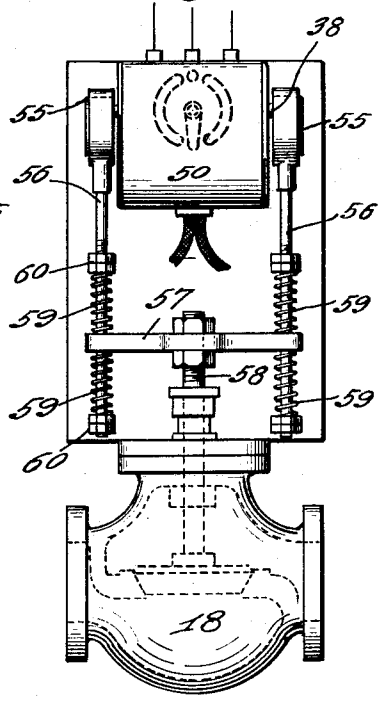
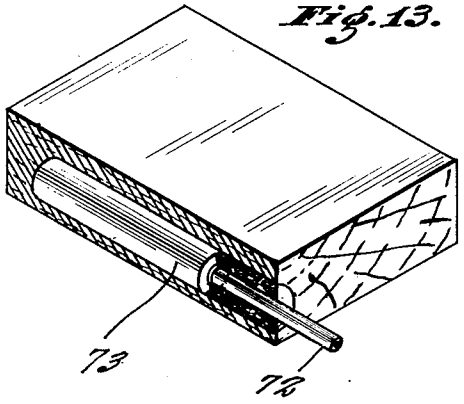


Fig. 13.



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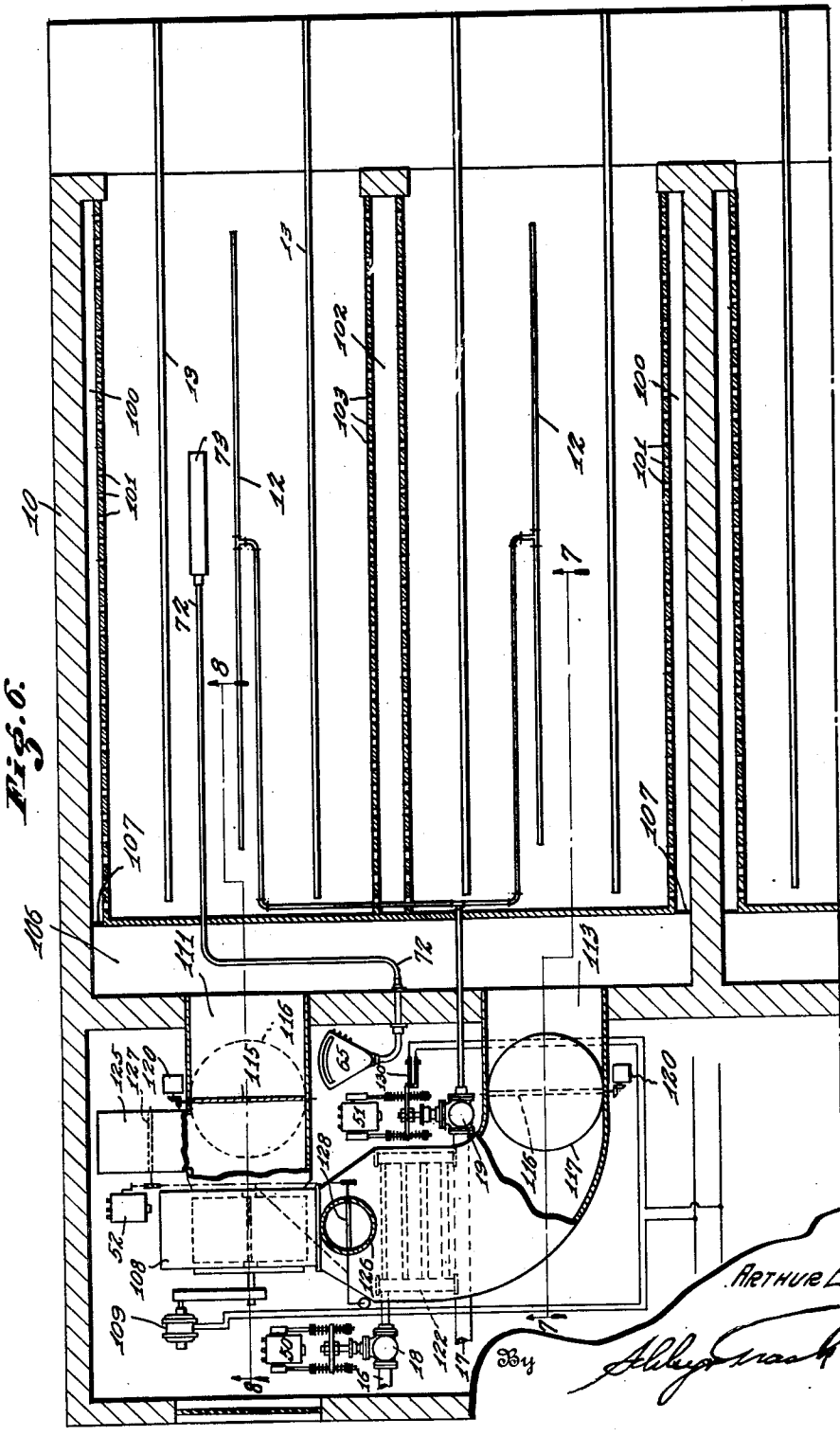


Fig. 6.

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Fig. 7.

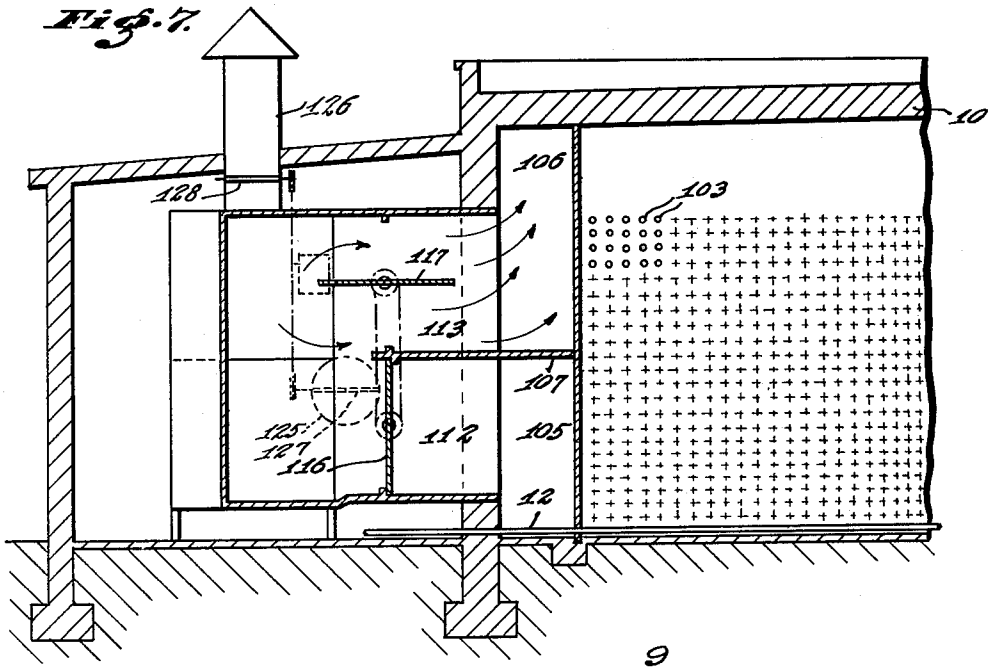
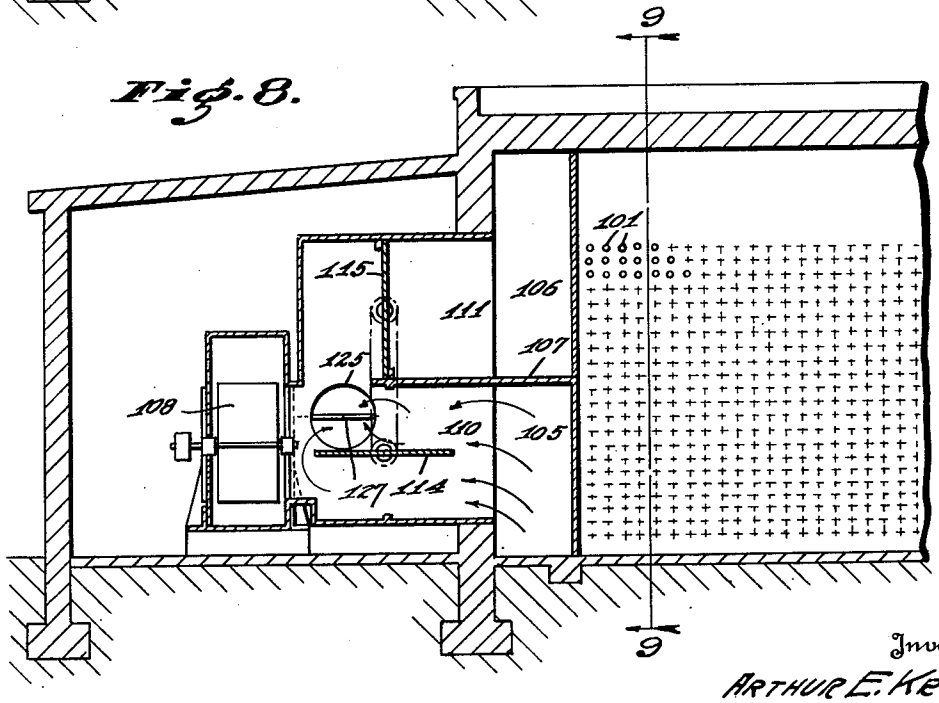


Fig. 8.



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Fig. 9.

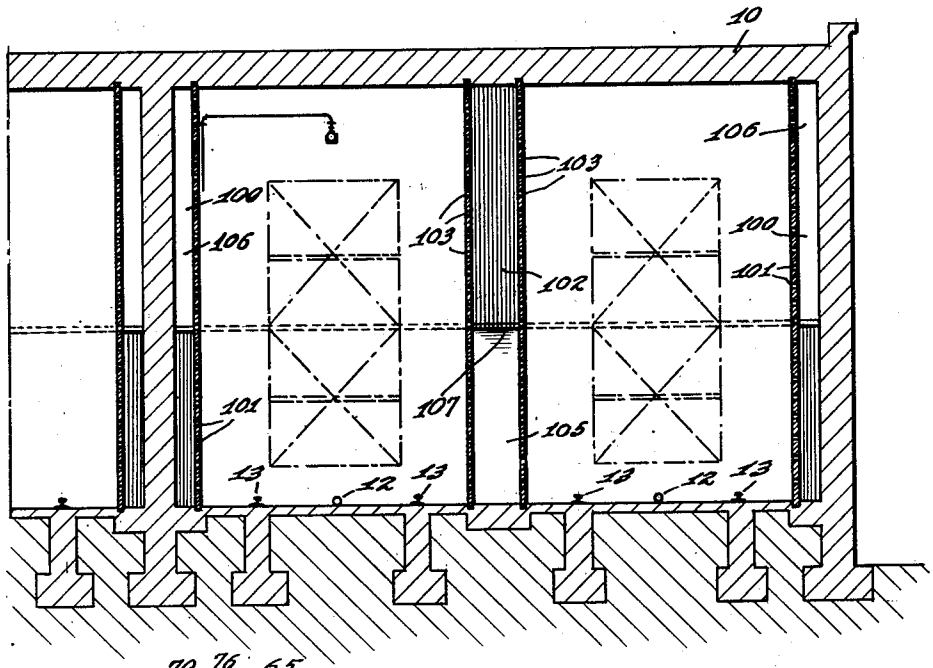


Fig. 10.

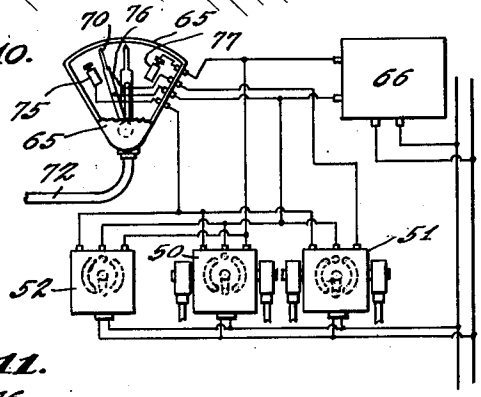
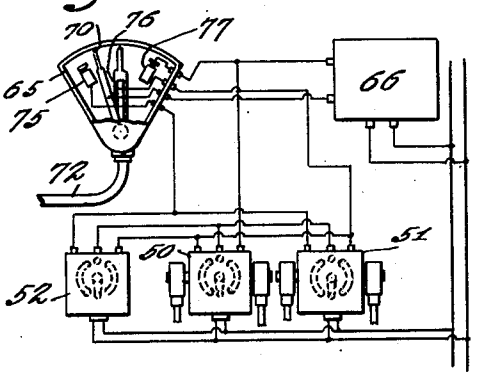


Fig. 11.



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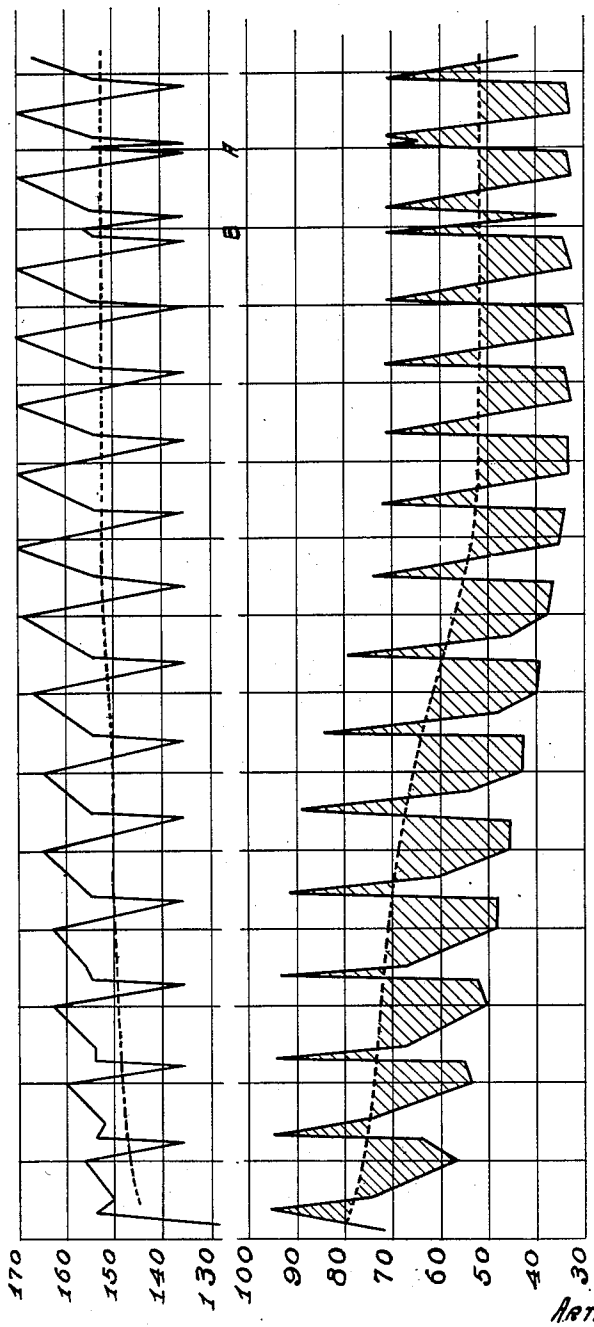


Fig. 12.

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Patented Apr. 16, 1935 1,997,826

UNITED STATES PATENT OFFICE

1,997,826

PROCESS FOR DRYING CONTROL

Arthur E. Krick, Indianapolis, Ind.

Application October 14, 1929, Serial No. 399,466

11 Claims. (Cl. 34—24)

My invention is concerned with a process and apparatus for carrying out kiln drying, particularly the kiln drying of lumber; and it is my object to improve, accelerate, and lower the cost of kiln drying of lumber, and to provide a simple apparatus for controlling the drying process.

It has long been recognized that the proper kiln drying of lumber necessitates the control of both humidity and temperature of the air within the kiln. In my prior Patents No. 1,490,569, issued April 15, 1924, and No. 1,513,727, issued October 28, 1924, I disclosed a process and apparatus by the use of which lumber could be dried more satisfactorily and in less time than by the use of previously known processes. The process contemplated in my two prior patents embodied the repeated raising and lowering of the relative humidity between wide limits, the lower limits being below the value which would be safe for the material if continued. Each cycle of the process embodied two steps: First, a gradual decrease in relative humidity; and second, an increase, desirably relatively abrupt. The preferred apparatus contemplated in my two prior patents included wet-bulb and dry-bulb thermometers. The relative humidity was controlled on one of three ways—i. e., by means controlled jointly by wet-bulb and dry-bulb temperatures, by means responsive to wet-bulb temperatures alone, or by means responsive to dry-bulb temperatures alone. In any of these modifications, the mean dry-bulb temperature might be increased and relative humidity decreased as the drying process proceeded.

That process, together with the apparatus by means of which it was carried out, had the advantages noted in my prior patents. It accelerated the drying and largely eliminated from the lumber dried such defects as cracking, splitting, and case-hardening. The repeated lowering of the relative humidity to a point which would be dangerous if continued was most effective in removing moisture from the wood and more particularly from the surface of the wood, while the repeated raising of the relative humidity softened the surface of the wood and kept the surface in condition to permit the passage of moisture from the interior to the outer portions of the lumber.

I have now found that the process described in my prior patents can be improved, that the apparatus necessary for the control of the drying process can be simplified, and that the total time required for drying may be materially lowered by modifying the process disclosed in my prior patents. My improved process comprises subjecting the lumber to repetitions of a three-step cycle instead of, although including, the simple two-step cycle shown in my prior patents. My new process involves the following steps:

1. Raising the temperature and the relative humidity;

2. Lowering the relative humidity by producing a further rise in temperature, this step continuing either for a predetermined time or until a predetermined temperature is reached;

3. Permitting the temperature to drop; and repeating this cycle until the lumber is dry.

My process can be carried out by different types of apparatus among which may be manually controlled apparatus, time-controlled apparatus, automatic apparatus controlled by temperature-responsive means, or by the combination of time and temperature-responsive means. I prefer the last.

The accompanying drawings illustrate apparatus by means of which my process can be effectually carried out: Fig. 1 is a transverse section through a lumber-drying kiln, the control apparatus being illustrated diagrammatically; Fig. 2 is an illustration of one form of a thermostatically controlled switch suitable for incorporation with the control apparatus; Fig. 3 is a somewhat diagrammatic illustration of a time-controlled switch also embodied in the control apparatus; Fig. 4 is a somewhat diagrammatic illustration of one of several motor units which are employed in operating the valves that control the supply of steam to the kiln; Fig. 5 is an elevation of one of such steam-control valves illustrating the manner in which it is connected to the motor unit; Fig. 6 is a horizontal section through a forced-draft type of kiln showing my control apparatus arranged to control temperature and humidity conditions within such kiln; Figs. 7 and 8 are vertical sections on the lines 7—7 and 8—8 respectively of Fig. 6; Fig. 9 is a vertical section on the line 9—9 of Fig. 8; Figs. 10 and 11 are diagrammatic illustrations of modified arrangements of electrical connections of the control apparatus; Fig. 12 is a chart in which curves of somewhat idealized form are used to illustrate the variations in dry-bulb temperature and relative humidity during the drying process; and Fig. 13 is an illustration showing the motor member of the thermostatically-controlled switch located within a sample of the wood to be dried in the kiln.

In Fig. 1, the kiln 10 may be of any desired construction, and embodies heating means 11 and air-humidifying means 12. I may provide also some

suitable means such as the tracks 13 for supporting trucks carrying the lumber or other material which is to be dried. The nature of the heating means and the air-humidifying means, and also the precise arrangement of these elements relative to the kiln 10 and tracks 13, is immaterial. I prefer, however, to provide heating means in the form of steam coils and to locate such heating means below the tracks 13. I prefer also that the humidifying means 12 consist of steam-spray pipes. The steam for the heating coils 11 and for the air-humidifying means is conveniently supplied from two pipes 16 and 17 which lead respectively to the heating coils and the air-humidifying means. In the pipes 16 and 17, I provide automatically controlled valves 18 and 19 respectively, which will be described in detail hereinafter.

Although it is not essential, I may provide the kiln with ventilating means. As illustrated in the drawings, this means takes the form of vertical ducts 21 located in the walls of the kiln and provided with openings 22 through which they communicate with the interior of the kiln. Near their upper ends, the ducts 21 are provided with outlet openings 23. Air-flow through the ducts is controlled by valves or dampers 24 which may take any desired form. As illustrated in the drawings, the dampers 24 are in the form of butterfly valves each of which carries a pulley or sprocket 25. A chain or other flexible element 26 passes over the sprockets 25, and may be moved in one direction by a weight 27 which tends to maintain the dampers 24 in open position. The dampers may be closed by moving the chain 26 to raise the weight 27. One or more air-inlet openings 29 may be provided near the bottom of the kiln, these openings being conveniently controlled by dampers 30 arranged to be operated simultaneously with the outlet dampers 24.

Desirably, the dampers are controlled automatically along with the valve 18 which controls the supply of heating steam and the valve 19 which controls the supply of humidifying steam.

My invention is not limited to any particular form of control apparatus, as many different kinds of control apparatus may be used. In its broader aspects, my invention is not even limited to the use of automatic control apparatus as my process may be carried out under manual control.

In the automatic control apparatus illustrated in the drawings, I employ electric motor units of the well-known Honeywell type. One of such units is illustrated somewhat diagrammatically in Fig. 4. It comprises an electric motor 35 adapted to be connected through the primary of a transformer 36 to a source of alternating current. The motor 35 may be mounted in a casing 37 through which there extends a shaft 38 operatively connected with the motor 35 through some form of speed-reducing gearing. Within the casing 37, the shaft 38 has mounted for rotation with it a contact arm 40 which co-operates with a stationary commutator having two diametrically opposite control contacts 41 and 42 and two holding-circuit contacts 43. One end of the secondary of the transformer 36 is connected to the contact arm 40, and the other end is connected to the two holding-contacts 43 and to a terminal 45. The two control contacts 41 and 42 are connected respectively to two other terminals 46 and 47.

Normally, the shaft 38 is at rest with the contact-arm 40 engaging one of the control contacts 41 or 42, there is no electrical connection between the terminal 45 and either of the terminals 46 and 47, and the secondary circuit of the transformer 36 is therefore open. Since no current flows through the transformer-secondary, the primary acts as a choke coil and prevents a supply of current to the motor 35. As shown in Fig. 4, the contact arm 40 is in engagement with the control contact 41, and it will remain in this position until a circuit is completed between the terminals 45 and 46. Thereupon, the secondary of the transformer 36 will be short-circuited through the contact arm 40, contact 41, and the terminals 46 and 45. This short-circuiting of the transformer secondary permits the flow of current to the motor 35, which begins to rotate the shaft 38. As the shaft 38 rotates, the contact arm 40 passes into engagement with one of the holding-circuit contacts 43, and the secondary of the transformer 36 remains short-circuited through such contact 43 and the contact arm 40 until the contact arm passes out of engagement with such holding-circuit contact and into engagement with the control contact 42. Unless a circuit is completed between the terminals 45 and 47, the secondary of the transformer 36 is thus open-circuited and the motor 35 stops. When a circuit is completed between the terminals 45 and 47, the transformer-secondary is again short-circuited, and the shaft 38 makes another half-revolution to return the contact arm 40 into engagement with the control contact 41.

In the arrangement of control apparatus illustrated in Fig. 1 there are three of the motor units such as have just been described. One of these, here indicated as 50, operates the steam valve 18 which controls the supply of steam to the heating coils 11. Another unit, here indicated as 51, operates the valve 19 which controls the supply of steam to the humidifying pipes 12. The third motor unit 52 controls the ventilating dampers 24 and 30. It will be evident that if the kiln is not provided with dampers there will be no necessity for the third motor unit 52.

One arrangement by which the motor units 50 and 51 control the valves 18 and 19 is illustrated in detail in Figs. 4 and 5. As shown, the shaft 38 projects outwardly beyond the sides of the casing 37 and has mounted for rotation with it two eccentrics 55. Eccentric rods 56 are connected to these two eccentrics and extend downward through a cross-head 57 carried by the stem 58 of the valve 18, which may be an ordinary globe valve. The rods 56 are loosely received within holes in the cross-head 57, and compression springs 59 act oppositely between the cross-head and spring-abutments 60 on each of the rods 56. When the two eccentrics 55 are in their lowermost position, the valve 18 is held closed, the upper springs 59 being compressed. When the shaft 38 rotates through one-half revolution, however, the eccentrics 55 will raise the cross-head 57 and the valve stem 58 to open the valve. The lower pair of springs 59 are provided to prevent any injury which might result should the valve stem or cross-head encounter any obstruction to upward movement before the eccentrics 55 have reached their uppermost position.

In the motor unit 52, which controls the dampers 24, I may mount on the projecting end of the shaft 38 a crank 62 to the end of which the chain 26 is connected. During one half

revolution of the crank 62, it will move the chain 26 to close the dampers 24 and 30 and raise the weight 27; and during the next half-revolution, the crank will permit the weight 27 to drop and open the dampers.

The three motor units 50, 51, and 52 are under the joint control of a thermostatic switch 65 and a time-controlled switch 66. These switches operate to open and close circuits between the terminal 45 and the terminals 46 and 47 of each of the motor units, and thereby control the position of the shafts 38 of the motor units.

One form of temperature-responsive switch 65 which is suitable for use in carrying out my invention is illustrated in Fig. 2. It comprises a pivotally mounted contact finger 70 adapted to be swung about its axis under the control of a Bourdon tube 71 which is connected through a tube 72 with a fluid-pressure bulb 73 located within the kiln.

Co-operating with the contact arm 70 are three adjustable but normally stationary contacts 75, 76, and 77. As shown in Fig. 2, the contact arm 70 is at the leftward limit of its movement and in engagement with the contact 75. As the temperature within the kiln increases, the contact arm is moved to the right to engage first the contact 76, and then the contact 77. In the particular form of switch 65 illustrated in the drawings, the intermediate contact 76 is mounted upon a pivoted arm 76' biased toward the left as by means of a spring 78. For the purpose of limiting leftward movement of the arm 76', there is provided an adjusting arm 79 which carries an abutment 79' that engages the arm 76' and limits its movement under the influence of the spring 78. Upon a decrease in kiln temperature, the contact finger moves toward the left, the contact-bearing arm 76' moving with it until the abutment 79' is engaged, whereupon leftward movement of the contact 76 and its supporting arm 76' ceases, and the contact arm 70 continues on toward the low-temperature contact 75.

The time-controlled switch 66 may be of any desired construction, Fig. 3 being merely a diagrammatic illustration of one form of suitable switch. This switch comprises a fixed contact 80 and a movable contact 81, the latter being mounted on an arm 82 which is movable to cause engagement and disengagement of the two contacts. The arm 82 is biased, as by means of a spring 83, toward a position in which the contacts 80 and 81 will engage. Normally, the arm 82 is held away from this position by means of a rotatable disk 84, the periphery of which is engaged by the end of the arm 82. At suitable angular intervals, the periphery of the disk 84 is notched as at 85 in such a manner that the arm 82 will be permitted to carry the contact 81 into engagement with the contact 80 whenever one of the notches 85 comes into alinement with the end of the arm 82.

Any convenient means may be employed for rotating the disk 84 at the desired speed. As illustrated in Fig. 3 this means comprises a synchronous motor 86 adapted to be connected to a source of alternating current and arranged to drive the disk 84 through suitable speed-reducing gearing.

The electrical connections between the motor units 50, 51, and 52 and the switches 65 and 66 are illustrated in Fig. 1. The three terminals 45 of the motor units are connected together and to the contact arm 70 of the switch 65. The three contacts 46 of the motor units are also connected together and to the low-temperature contact 75 of the switch 65. The terminal 47 of the motor unit 50 is connected to the high temperature contact 77 of the temperature-controlled switch, and the terminals 47 of the two motor units 51 and 52 are connected together and to the intermediate-temperature contact 76 of the switch 65. In addition, the time-controlled switch 66 is connected between the terminals 45 and 47 of the motor unit 50, and is thus in parallel with the contact arm 70 and contact 77 of the thermostatic switch 65.

In Fig. 1, the various parts of the control apparatus are illustrated in the positions they occupy during the cooling period. The valve 18 controlling the heating system and the valve 19 controlling the humidifying steam are both closed, and the dampers 24 are open. During this period, the temperature within the kiln is gradually dropping, and the contact arm 70 of the thermostatically controlled switch 65 is moving to the left toward the contact 75. When it reaches this contact, the cooling period is terminated and the humidifying period begun.

The engagement of the contact arm 70 with the contact 75 short-circuits the secondaries of the transformers in each of the motor units 50 and 51, and also 52 if ventilation control is provided, thus causing all the shafts 38 to make a one-half revolution. This operation of the motor units opens the valves 18 and 19 and closes the dampers 24 and 30. The resultant supply of steam to the heating coils 11 and to the spray pipes 12 rapidly increases the temperature and relative humidity within the kiln; and as a result of the rise in the kiln temperature, the contact arm 70 of the temperature-responsive switch moves to the right toward the intermediate contact 76.

When the contact arm 70 engages the contact 76, the secondary of the transformer associated with the motor unit 51 is short-circuited to cause the shaft 38 of such motor unit to make a one-half revolution to close the steam-spray valve 19. At the same time, if damper control is provided, the secondary of the transformer associated with the motor 52 is also short-circuited; and the resultant one-half revolution of the crank 62 opens the dampers 24 and 30, and provides for the circulation of air through the kiln.

The operations which have just been described terminate the spraying period and initiate the heating period, as the valve 18, which controls the supply of steam to the heating coils 11, remains open. Due to the rise in temperature, and the ventilation desirably provided by the opening of the dampers 24 and 30, if they are used, the relative humidity of the air in the kiln gradually decreases as the heating period progresses. The heating period continues until terminated either by the thermostatic switch 65 or by the time-controlled switch 66. If the heating period is terminated by the thermostatic switch, the steam-supply valve 18 remains open until the contact arm 70 engages the contact 77 as a result of the continued rise of temperature in the kiln. When this occurs, the motor unit 50 is energized to close the valve 18. In certain instances, however, the time-controlled switch 66 may close the secondary circuit of the transformer in the motor unit 50 before the temperature of the kiln has risen sufficiently to cause the contact arm 70 to engage the high-temperature contact 77. In such an event, the closing of the time-controlled switch results in the closing of the steam-supply valve 18. In either event, the supply of heating steam to the kiln is cut off,

and the kiln temperature gradually drops, the various parts of the control apparatus during the cooling period occupying the positions illustrated in Fig. 1. When the temperature has dropped sufficiently to bring the contact arm **70** into engagement with the low-temperature contact **75**, a new cycle is initiated.

My process and control apparatus are not limited to use in connection with the more common type of dry kiln illustrated in Fig. 1, as they may also be employed in a forced-draft kiln, a particular type of which is illustrated in Figs. 6 to 9 inclusive. The forced-draft kiln shown in Figs. 6 to 9 is a reversible circulation kiln, but the reversible circulation feature, per se is not my invention. This type of kiln is known and need be but briefly described here.

In such a kiln, the walls are provided with air ducts **100** which communicate with the interior of the kiln through a multiplicity of openings **101** well distributed over the inner face of the wall. Extending longitudinally of the kiln near the center thereof is a partition which has a similar duct **102** extending through it, this duct also communicates with the interior of the kiln through openings **103** similar to the openings **101**.

At the end of the kiln there are two transversely extending chambers **105** and **106** separated by a horizontal partition **107**. The upper chamber **106** communicates with the two ducts **100** in the side walls of the kiln, while the lower chamber **105** communicates with the duct **102** in the central kiln-partition.

The circulation of air through the kiln is obtained by means of a fan or blower **108** (Figs. 6 and 8) driven by any suitable means such as the electric motor **109**. The blower **108** has a branched air-inlet, the two branches **110** and **111** of which communicate respectively with the two chambers **105** and **106**. The discharge conduit of the fan is also branched, the two discharge branches **112** and **113** also communicating respectively with the chambers **105** and **106**. Air flow through the four branches is controlled respectively by means of dampers **114**, **115**, **116**, and **117**. The two dampers **114** and **115** are desirably mechanically interconnected in such a way that when one of them is opened the other is closed. The two dampers **115** and **117** are similarly arranged; and in addition the damper **114** is arranged to be open when the damper **116** is closed. In practice, the positions of each of the four dampers is periodically reversed, as by means of electric motors **120** which may be time-controlled.

With the dampers arranged as in Figs. 7 and 8, air is drawn out of the kiln through the central kiln-partition conduit **102**, the chamber **105**, and the branch **110** of the inlet conduit. The air discharged from the fan passes through the branch **113** of the discharge conduit into the chamber **106**, and thence into the ducts **100** in the side walls of the kiln. Upon a reversal in the positions of the four dampers **114**, **115**, **116**, and **117**, the direction of air flow in the kiln is reversed, the air passing out from the kiln through the side-wall ducts **100**, through the fan, and back to the kiln through the duct **102**.

In such a kiln, the relative humidity may be increased by means of steam-spray pipes **12**, as in the kiln illustrated in Fig. 1. The heating means, however, is not located directly in the kiln, but instead comprises a series of steam coils **122** located in the discharge conduit of the fan **108** and adapted to heat the air discharged from such fan before it enters the kiln.

In the inlet and the discharge conduits of the fan **107**, there are respectively located ventilation conduits **125** and **126**, air-flow through which is controlled respectively by dampers **127** and **128**. During the spraying period, these dampers are closed, and they preferably remain closed through the heating period also. When they are closed, no fresh air is admitted to the kiln itself or to the inlet or discharge conduit of the fan **108**. When the dampers **127** and **128** are open, however, some fresh air is drawn into the fan and displaces some of the air in the circulating system, the displaced air escaping through the conduit **126**.

The control apparatus employed in automatically controlling temperature and humidity conditions in the kiln shown in Figs. 6 to 9 inclusive may be substantially the same as that illustrated in connection with the common type of kiln shown in Fig. 1. The motor unit **50** operates the valve **18** which controls the supply of steam to the heating coils **122**; the motor unit **51** operates the steam-spray valve **19**, and the motor unit **52** controls the ventilating dampers **127** and **128**.

In addition, I prefer to provide a control for the fan motor **109** in order that the fan may be rendered inoperative during the spraying period. This control may conveniently take the form of a switch **130** which is associated with the steam-spray valve **19** or the motor unit **51** and which opens the supply circuit to the fan motor when the steam-spray valve **19** is opened and which closes the motor supply circuit when the valve **19** is closed.

The control apparatus illustrated in Fig. 6 operates in a manner analogous to that of the control apparatus associated with the kiln shown in Fig. 1. During the cooling period, the valves **18** and **19** are closed, the dampers **127** and **128** open, and the fan is running. Upon the termination of the cooling period, the valves **18** and **19** are opened and the dampers **127** and **128** closed to initiate the spraying period. Due to the opening of the valve **19**, the switch **130** is opened and the fan **108** is stopped, and there is no circulation of air through the kiln. When the temperature within the kiln has reached a value sufficient to terminate the spraying period under the control of the switch **65**, the steam-spray valve **19** is closed. This operation of the valve **19** also closes the switch **130**, and the fan **108** is started to institute the heating period, which continues until terminated either by the switch **65** or by the time-controlled switch **66**. Upon the termination of the heating period, the valve **18** is closed, the fan **108** continues to operate, and the temperature within the kiln gradually drops until it reaches the value at which the thermostatic switch **65** institutes a new spraying period.

The dampers **127** and **128** may be controlled in a manner analogous to the dampers **24** and **30** shown in Fig. 1—i. e., they may be closed during the spraying period and open during the heating and cooling periods. I prefer, however, to operate them in such a manner that they will be closed during the spraying and heating periods and open only during the cooling period. This result is easily accomplished by rearranging the connections of the motor units as shown in Fig. 10. The terminal **47** of the motor unit **52** is disconnected from the corresponding terminal of the motor unit **51** and connected to the terminal **47** of the motor unit **50**. If this is done, the dampers **127** and **128** will operate with the steam valve **18**, being closed when such valve is open and open when such valve is closed.

In both forms of kiln which have been illustrated and described, it will be noted that steam is supplied to the heating coils during the spraying period. While I regard this as desirable, it is not essential, however, as I may delay the opening of the valve 18 until the termination of the spraying period. The electrical connections between the motor units 50, 51, and 52 may be changed as indictated in Fig. 11 to accomplish this mode of operation. In Fig. 11, the connections are the same as those shown in Fig. 1 except that the terminal 47 of the motor unit 50, which terminal controls the opening of the heating-steam valve 18, is connected to the intermediate contact 76 of the switch 65 instead of to the low-temperature contact 75. As a result, the valve is not opened until the spraying period is terminated.

As stated above, the heating period may be terminated either by the temperature-responsive switch 65 or by the time-controlled switch 66 which is closed for a short time at definite intervals. The intervals between successive closings of the switch 66 may vary with the kind and size of lumber being dried, but I have found a four-hour interval satisfactory for most lumber. This places a maximum time limit of four hours on each heating period during the drying process; and except in rare instances limits the duration of the whole cycle to four hours.

The apparatus which has been described is but one example of a control means by which my process may be carried out. The drying process can be practiced by manual control or by any form of automatic control which provides repetitions of the three-step cycle comprising a humidifying period, a heating period, and a cooling period.

As an example of dry-bulb temperatures at which the three steps of the drying cycle can be begun or terminated, I may note here one set of kiln temperatures which have been satisfactorily utilized in the drying of two-inch maple lumber. When such lumber is being dried, I may set the low-temperature contact 75 of the temperature-controlled switch 65 so that it is engaged by the contact arm 70 when the dry-bulb temperature within the kiln is approximately 135° F; I set the intermediate contact 76 in such a position that it will be engaged by the contact arm 70 when the dry-bulb temperature within the kiln is approximately 154° F.; and the high-temperature contact 77 is arranged to be engaged by the contact arm 70 when a dry-bulb temperature of 170° F. exists in the kiln. The time-controlled switch 66 closes momentarily at four-hour intervals.

With the apparatus described, with the electrical connections arranged as in Fig. 1 whereby both the steam-spray valve 19 and the heating-steam valve 18 open at the termination of a cooling period, and with the contacts 75, 76, and 77 of the temperature-controlled switch 65 adjusted as just set forth, the normal cycle comprises the following steps, beginning with a kiln temperature of approximately 135° F.:

1. The valves 18 and 19 open, the steam supplied to the kiln in the form of a spray causes a rapid rise in relative humidity, and such steam, supplemented by the steam supplied to the heating coils, causes a rise of temperature to 154° F.

2. Following the closing of the steam-spray valve 19, a gradual lowering of the relative humidity and a gradual increase in dry-bulb temperature occur, until the heating period is terminated either by the action of the thermostatic switch 65 or by that of the time-controlled switch 66.

3. Upon the termination of the heating period, the temperature within the kiln gradually drops to 135° F., whereupon the cooling period is terminated and a new cycle instituted. The relative humidity during the cooling period depends upon ventilation and the condition of the outside atmosphere, and any change in relative humidity during the cooling period is usually relatively slight.

Should the electrical connections be arranged as shown in Fig. 10, whereby the heating system is not turned on until the spraying period is terminated, the cycle will be substantially the same except that the spraying period may be slightly longer; for under such circumstances the rise in kiln temperature from 135° to 154° F. is caused solely by the steam spray without the aid of any heating steam in the coils 11.

In my prior patents, I contemplated that the average relative humidity during the drying process might be gradually lowered as the drying process proceeded, and I also contemplated that the maximum dry-bulb temperatures might be gradually increased during the drying process. In those patents, one of several control devices was shown as arranged to accomplish these results. In my present process, however, I have found that no special provision need be made to effect the lowering of average relative humidity and the raising of average dry-bulb temperature as the drying process progresses.

Thus, the wood as first placed in the kiln is relatively cool and absorbs a relatively large amount of heat during the humidifying period. In order to raise the dry-bulb temperature within the kiln to the point where the steam-spray is shut off, therefore, more steam and hence more moisture must be introduced into the kiln than at later stages in the drying process when the lumber is relatively warm. As a result, the relative humidity at the end of a steaming period near the beginning of the drying process is somewhat higher than it is at the end of a steaming period later on in the drying process. In the specific example of controlling temperatures set forth above as suitable for the drying of two-inch maple lumber, the relative humidity near the end of a steaming period early in the drying process may reach or exceed 90%; whereas, at the end of a steaming period near the end of the drying process, it will be approximately 75%.

Further, early in the drying process, when the lumber is relatively wet and cold, it will absorb a larger amount of heat than it would if warmer and drier; and as a result of this, the heating period is terminated during these early stages by the operation of the time-controlled switch 66 before the maximum dry-bulb temperature provided by the thermostatic switch is reached. Later in the drying process such maximum temperature will usually be reached and the supply of heating steam cut off by the action of the temperature-controlled switch 50 before the heating period is terminated by the time-controlled switch 51.

During the earlier stages of the process, when the wood is relatively cool and wet, the cooling cycle is much shorter than it is at later stages when the wood has become relatively dry and warm. This fact aids materially in the satisfactory conditioning of the lumber; for as the drying process proceeds the need for efficient transference of moisture from the interior of the wood to

the surface becomes greater, and the longer cooling period from the higher temperature is more effective in producing this moisture transference.

In order to make clear the changes in dry-bulb temperatures and in relative humidities during the drying process, I have shown in Fig. 12, merely by way of example, a chart in which dry-bulb temperature and relative humidity curves are plotted against time. The vertical lines on this chart are spaced at four-hour intervals, and correspond to the closing of the time-controlled switch **66**. Dry-bulb temperatures are indicated by the upper full-line curve, and relative humidities by the lower full-line curve. The controlling temperatures are those mentioned above; namely, 135°, 154°, and 170° F. These curves, which are somewhat idealized, show the increase in both temperature and relative humidity during the spraying period, the decrease in relative humidity and the continued increase of temperature during the heating period, and the decrease in temperature during the cooling period.

Superposed on the temperature and relative humidity curves, I have shown dotted-line curves which represent respectively mean dry-bulb temperature and mean relative humidity. From these dotted line curves, it will be apparent that the mean temperature rises and the mean relative humidity falls as the drying process continues. The areas between the full-line curve representing changes in relative humidity and the dotted-line curve representing mean relative humidity have been shaded to show that the total of the time-humidity areas below the mean-humidity line is much larger than the total of the corresponding areas above the line. This indicates the effectiveness of my new process in removing moisture from the wood.

The fact that the time-humidity areas below the mean humidity line are in the aggregate much larger than the time-humidity areas above such line is due to the drop in relative humidity during the second period of each cycle and to the practically unchanging humidity during the cooling period. The drop in relative humidity during the heating period is caused by the continued rise in kiln temperature which follows the termination of the humidifying period.

It will be noted that during the early cycles the heating period is terminated at four-hour intervals by the action of the time-controlled switch **66**. As drying continues, however, the temperature reached at the end of each heating period becomes higher; and eventually, here shown as in the ninth cycle, the kiln temperature has reached such a point that the heating period is terminated by the action of the thermostatic switch **65** instead of by the action of the time-controlled switch **66**.

The time-controlled switch **66**, however, continues to close periodically; so that rather infrequently there may occur a cycle such as is indicated at A, in which the time-controlled switch **66** closes during the spraying period. When this occurs, the supply of heating steam to the kiln is shut off, but the steam-spray continues until the kiln has reached the temperature at which the spraying period terminates. Thereupon, the kiln and its contents cool until the minimum temperature is reached, and a new cycle is then instituted. Such an abnormal cycle, which as stated occurs infrequently, has no harmful effect; as it results merely in the addition of a slightly greater quantity of moisture.

It is also possible that after several cycles during which the heating periods have been terminated by the thermostatic switch there may occur a cycle, such as B, in which the time-controlled switch closes early in the heating period. Such an event likewise has no harmful effect, as that particular cycle is merely shortened; and following it, normal cycles again occur.

The temperatures set forth above as examples—namely 135° F., 154° F., and 170° F.—as marking termination of the various steps of the cycles in the drying process are suitable for the kind of lumber under consideration—that is, two-inch maple lumber. As in my prior patents, the low relative humidity value attained during each cycle is below that which would be safe for the lumber if continued. The controlling temperatures, as will be readily understood by those skilled in the art, should vary with the character and size of the lumber being dried. In general, it may be noted that higher temperatures and lower relative humidities will be used in drying thin, soft woods, and vice versa. The relative humidity is determined chiefly by the temperature at which the spraying period terminates—that is, by the location of the intermediate-temperature contact **76** of the switch **65**. If higher relative humidities are desired this intermediate-temperature contact is moved to the right to raise the temperature at which it is engaged by the contact arm **70** and thereby to lengthen the spraying period. If lower relative humidities are desired the intermediate-temperature contact is moved to the left in order that it will be engaged by the contact arm **70** at a lower temperature.

The improved process disclosed in this application has several advantages over the simple process set forth in my prior patents. In the first place, lumber can be dried with a saving of from **15** to **25** percent in drying time, even over the shortened drying time the simple process of my said prior patent provided, and in some instances the saving is even greater. In the second place, my improved process effects a marked decrease in the amount of steam used for humidifying. In some instances this decrease amounts to over 60 percent. This appears to be due to the fact that the cooling period which has been introduced in each cycle by my present invention has the effect of transfusing moisture from the interior of the lumber towards the surface, and the lumber thereby becomes less absorbent during the spraying cycle which follows.

My present process can be carried out by simple temperature-responsive mechanism responsive to dry-bulb temperatures within the kiln, and no wet-bulb control with its complications need be used. Further, by my present process I am enabled, without providing any special apparatus therefor, to obtain lower average relative humidities and higher average dry-bulb temperatures as the drying process proceeds.

It may be of advantage in certain circumstances to control the drying cycle in accordance with the temperature existing in the interior of the lumber being dried rather than in accordance with the temperature of the air in the kiln. This may readily be done by mounting the fluid pressure motor member **73** within a sample piece of lumber of the same kind and size as the lumber being dried, as shown in Fig. 13. This method of control will necessitate a re-setting of the contacts **75**, **76**, and **77** of the thermostatic switch **65**, since the range of temperature variation within the lumber will be smaller than that of the

air in the kiln. It has an advantage, however, in that one setting of the contacts 75, 76, and 77 may serve in controlling the drying of a wide variety of sizes and kinds of lumber.

If the drying process is controlled in accordance with temperatures in the interior of a sample board, such sample board should be located in the kiln at a point where conditions of air-circulation and air temperature approximate the average for the kiln.

I believe that this arrangement for controlling the thermostatic switch is broadly new whether applied to the process of this application or to other drying processes.

I claim as my invention:

1. The method of drying wood, which consists in exposing it to air, and subjecting such air to variations of temperature and relative humidity in repetitions of a cycle including a period in which temperature and relative humidity are raised, a second period in which temperature is further raised and relative humidity lowered, and a third period in which temperature is decreased.

2. The method of drying wood, which consists in exposing it to air in a kiln, repeatedly alternately raising and lowering the temperature of such air, and terminating each temperature-raising upon the first-occurring of two events, one of which is the attaining of a predetermined temperature and the other of which is the expiration of a predetermined time, the termination of each temperature-raising by the occurrence of a predetermined temperature being independent of time, and the termination of each temperature-raising after the expiration of a predetermined time being independent of temperature.

3. The method of drying wood, which consists in exposing it to air and subjecting such air to variations of temperature and relative humidity in repetitions of a cycle including the following steps; first, a period in which the temperature and relative humidity are increased, such period being terminated independently of humidity conditions when a predetermined dry-bulb temperature is reached; second, a period in which the temperature is further raised and relative humidity decreased; and third, a period in which dry-bulb temperature is decreased until a second predetermined dry-bulb temperature is reached.

4. The method of drying wood set forth in claim 3 with the addition of terminating the second step of each cycle near the end of the drying process when a predetermined dry-bulb temperature exists in the kiln.

5. The method of drying wood, which consists in exposing it to air in a kiln, repeatedly alternately raising and lowering temperature and relative humidity within the kiln by varying the supply of heat and moisture to the kiln, and controlling the supply of heat and moisture to the kiln during at least a portion of the drying process solely in accordance with dry-bulb temperature therein.

6. The method of dry-kiln operation, which consists in exposing to air in the kiln the material to be dried, and subjecting it to variations of temperature and relative humidity in repetitions of a cycle including a period in which temperature and relative humidity are raised, a second period in which temperature is further raised and relative humidity lowered, and a third period in which temperature is decreased.

7. The method of dry-kiln operation, which consists in exposing to air in the kiln the material to be dried, and subjecting such air to variations of temperature and relative humidity in repetitions of a cycle including the following steps; first, a period in which the temperature and relative humidity are increased until a predetermined dry-bulb temperature is reached; second, a period in which the temperature is further raised and relative humidity decreased; and third, a period in which dry-bulb temperature is decreased until a second predetermined dry-bulb temperature is reached.

8. The method of dry-kiln operation set forth in claim 7 with the addition of terminating the second step of each cycle near the end of the drying process when a predetermined dry-bulb temperature exists in the kiln.

9. The method of dry-kiln operation which consists in exposing to air in the kiln the material to be dried, cyclically raising and lowering the temperature and relative humidity of such air by varying the supply of heat and moisture to the kiln, and controlling the supply of heat and moisture to the kiln at least during some cycles solely in accordance with the dry-bulb temperature therein.

10. The method of dry-kiln operation which consists in exposing to air in the kiln the material to be dried, repeatedly alternately raising and lowering the temperature of such air, and terminating each temperature-raising upon the first-occurring of two events, one of which is the attaining of a predetermined temperature and the other of which is the expiration of a predetermined time, the termination of each temperature-raising by the occurrence of a predetermined temperature being independent of time, and the termination of each temperature-raising after the expiration of a predetermined time being independent of temperature.

11. The method of drying lumber, which consists in exposing it to air in a kiln and, during at least a large part of the drying process, controlling the supply of heat and moisture to the kiln solely in accordance with dry-bulb temperature.

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