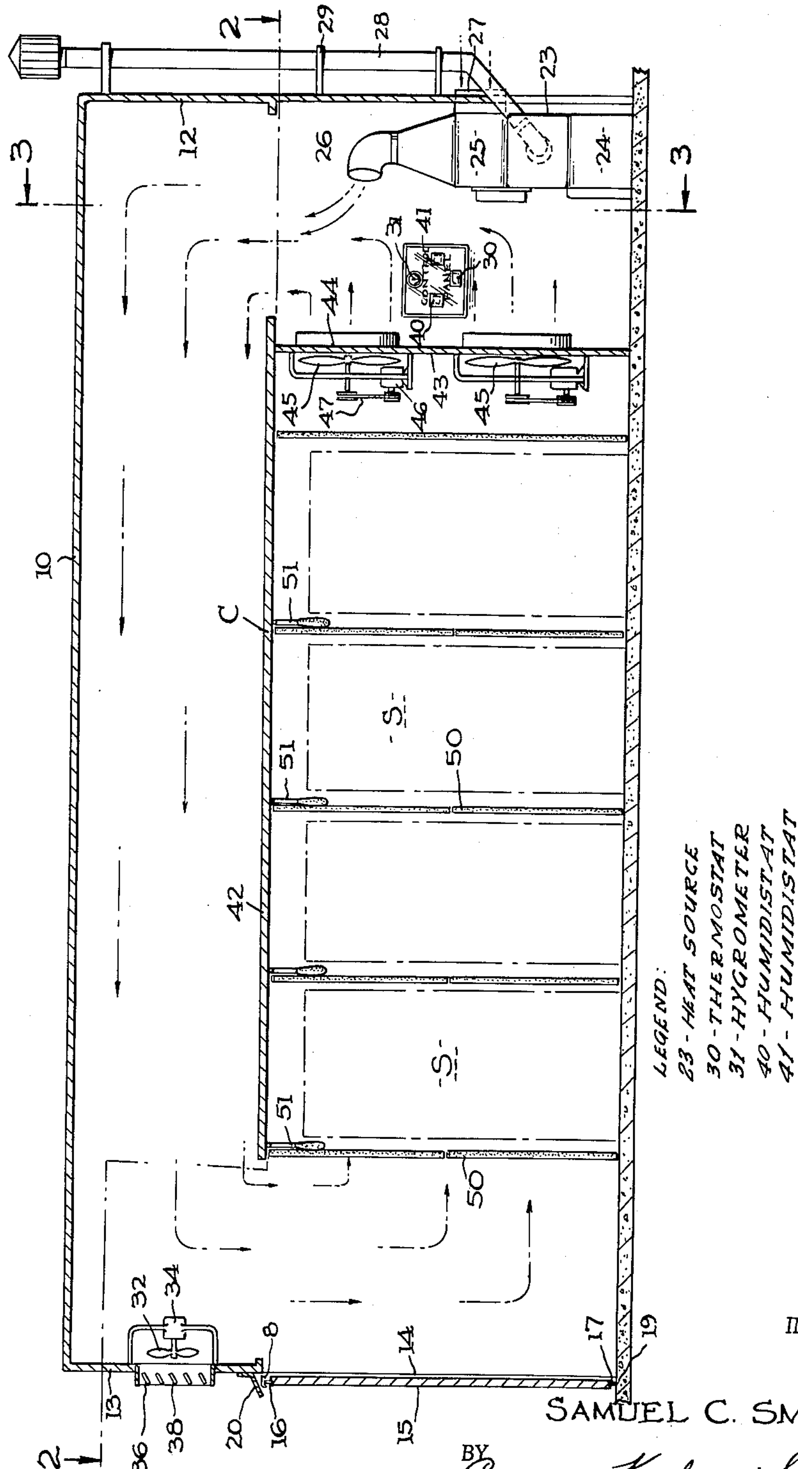

FIG. 1.

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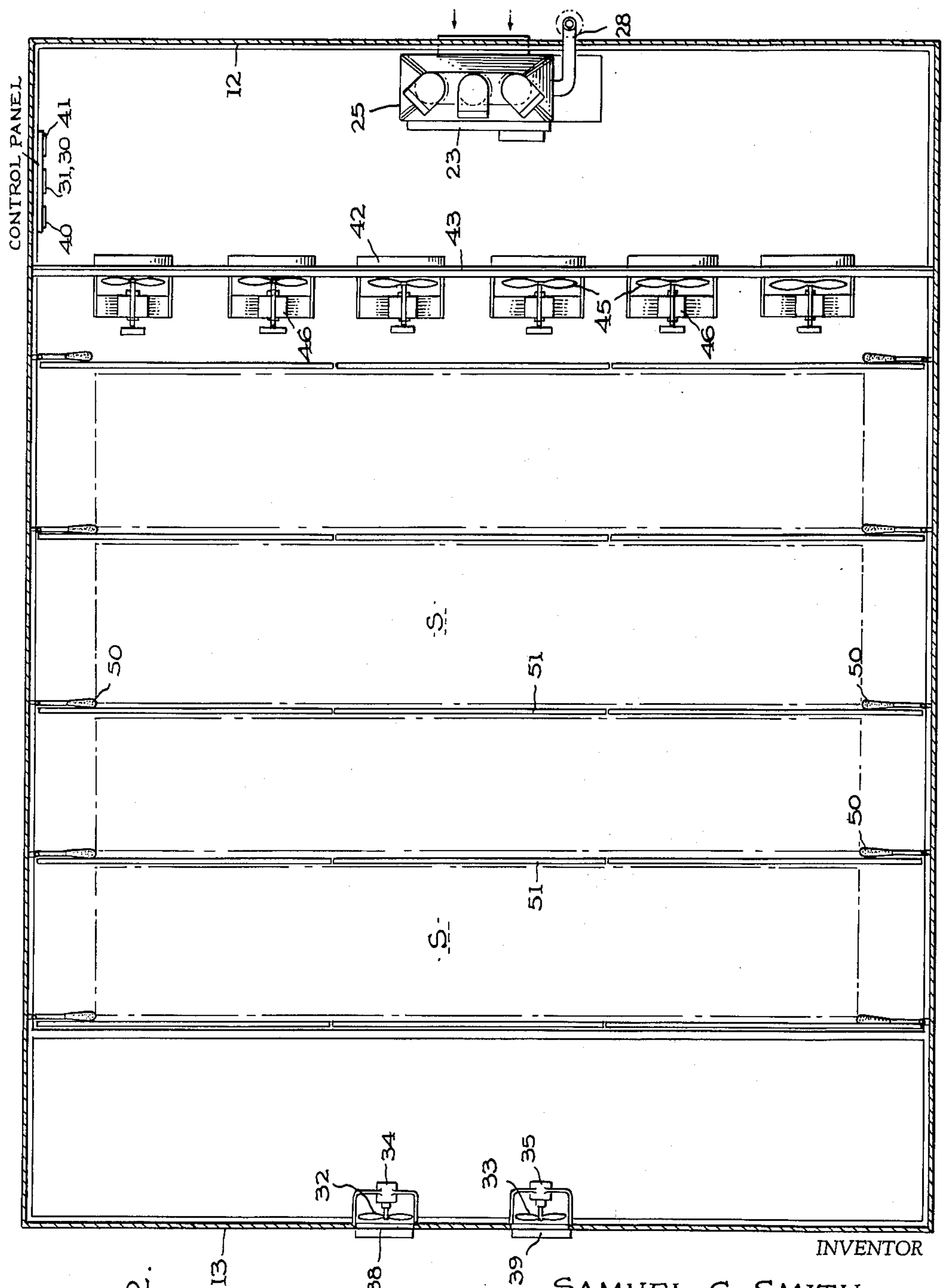

FIG. 2.

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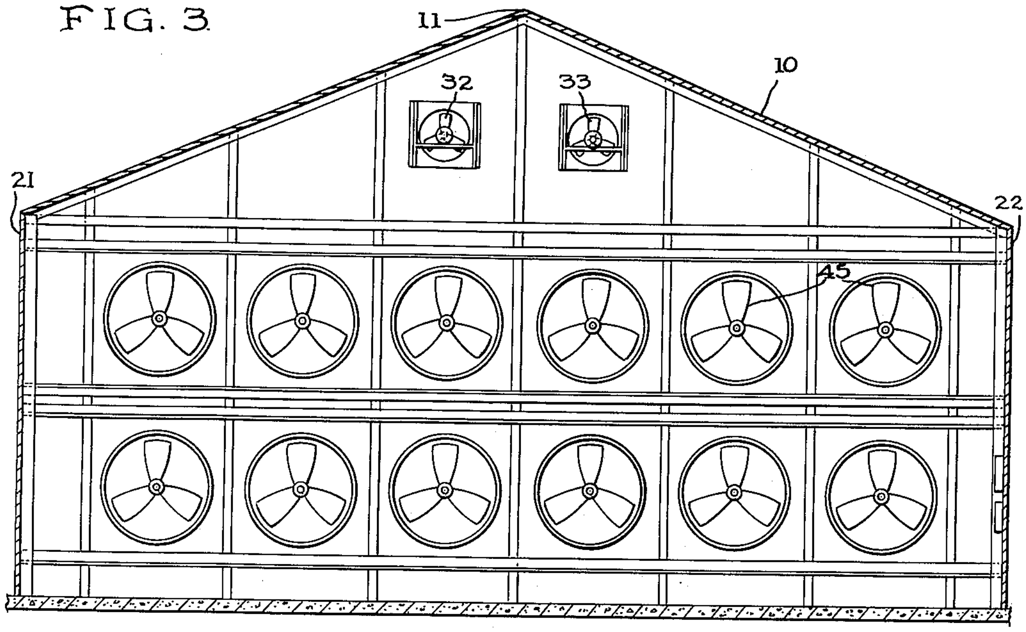
FIG. 3



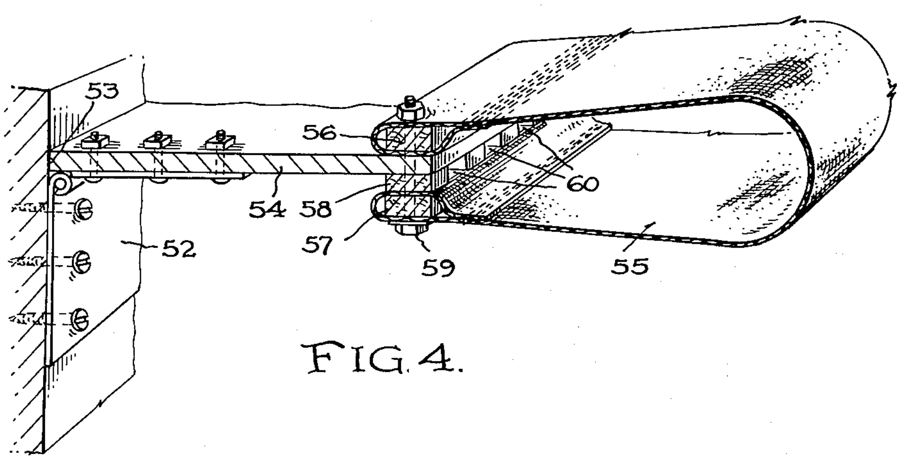


FIG. 4.

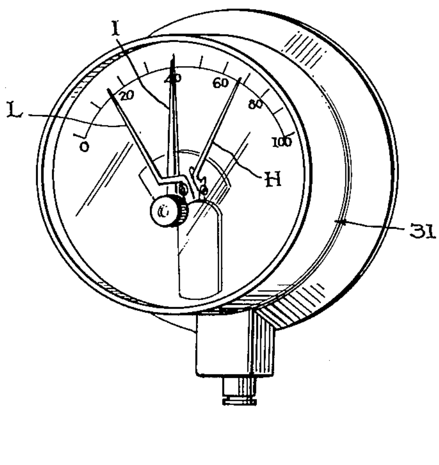


FIG. 5.

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Feb. 15, 1966 S. C. SMITH 3,234,659

LOW TEMPERATURE, HIGH HUMIDITY METHOD OF LUMBER DRYING IN A KILN

Filed May 8, 1961 5 Sheets-Sheet 4

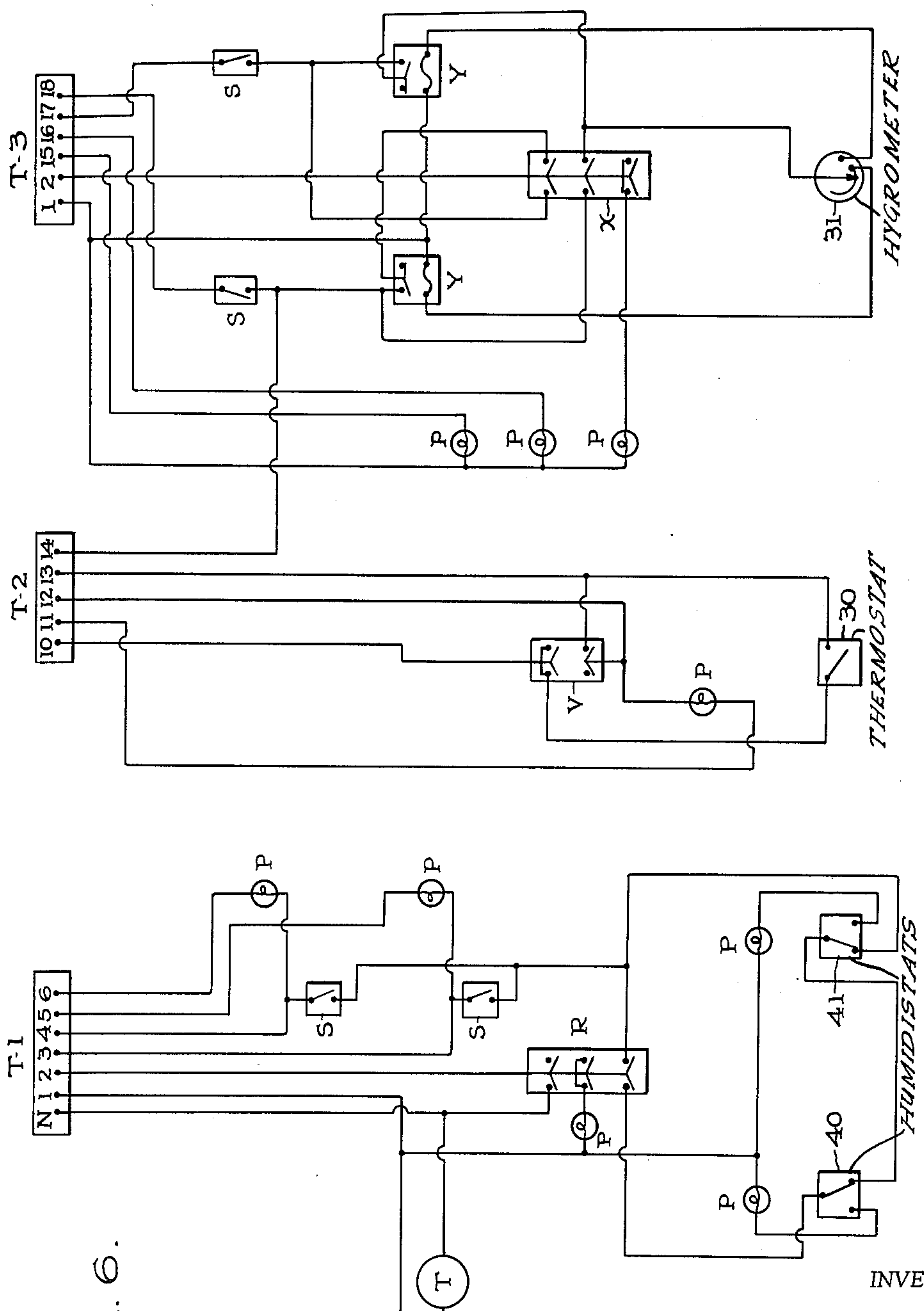

FIG. 6.

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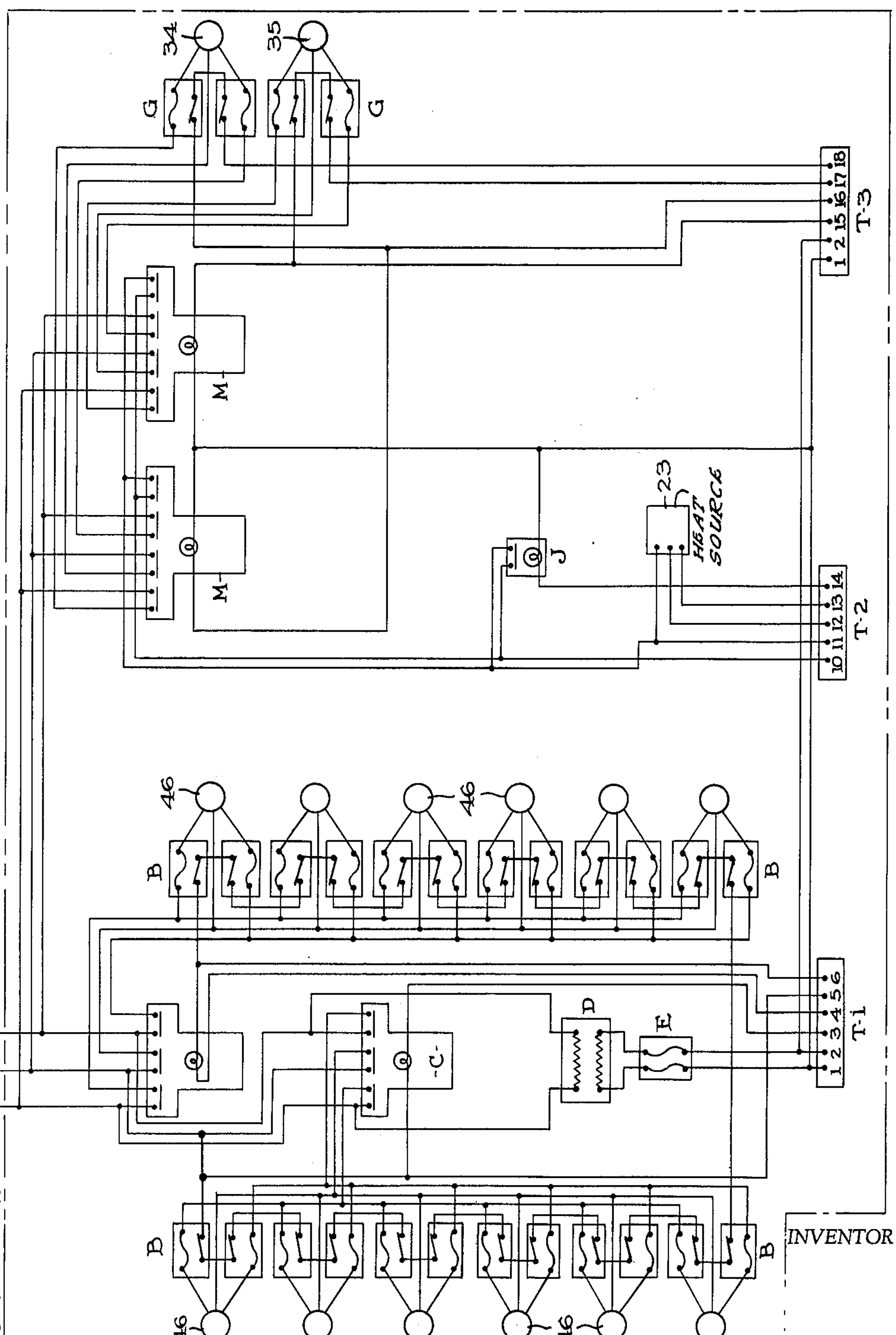

FIG. 7.

SERVICE ENTRANCE CONDUCTORS

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United States Patent Office 3,234,659
Patented Feb. 15, 1966

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3,234,659

LOW TEMPERATURE, HIGH HUMIDITY METHOD OF LUMBER DRYING IN A KILN

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Filed May 8, 1961, Ser. No. 108,488
4 Claims. (Cl. 34—26)

This invention relates to a method for drying green lumber of all types from its original high moisture content down through the preliminarily dried moisture content of approximately 20% to the ultimate final moisture content of approximately 7%, required by the industry, at which percentage the lumber is in "completely dried" condition and ready for use by the industry.

The invention contemplates the provision of a special building, which is as nearly air-tight as possible, provided with an interior compartment designed to contain the stacked green lumber, a bank of circulating fans, a forced air heater for the system, exhaust fans and controls therefor. The building is so designed that a continuous circulation of low temperature, humid air is maintained at all times through the building and lumber compartment, the circulation being a forced air fan circulation in which the air is pulled through the lumber stacks at a uniform rate of speed by the bank of twelve circulating air fans. After passage through the lumber stacks the circulating air may be conditioned by heated air from the forced air heater. It is then circulated forwardly through the upper portion of the building, over the lumber compartment, past the exhaust fans and is then recirculated through the stacked lumber which is positioned in the lumber compartment in the lower portion of the building.

Doors are provided at the forward end of the building for loading and unloading lumber and are preferably as nearly air tight as they can be made. Further, the building is completely insulated over its interior with 2" fiberglass insulation provided with an aluminum foil facing which serves as a vapor barrier. The overall dimensions of the building are preferably 80 feet in length, by 40 feet in width, by 25 feet in height and the lumber stacking and drying compartment thereof is 40 feet in width, 50 feet in depth and 15 feet in height, as will be discussed in detail further on in this specification.

The bank of twelve air circulating fans is preferably provided in a partition running laterally the width of the building at the rear end of the lumber compartment, positioned forwardly of the forced air heater. Thus, humid air pulled through the lumber stack compartment by the air circulating fans may be subjected to heated air blown into the air stream from the forced air heater, when conditions so require. The exhaust fans for the system are preferably positioned in the upper section of the forward wall of the building, above the doors thereof and are called into operation to exhaust humid air from the system when the humidity of the circulated air therein rises above a prescribed optimum relative humidity. The exhaust fans are positioned behind louvered vents which are normally closed and which open when the exhaust fans are called into action by their control humidistat when the relative humidity of the circulated air within the enclosure rises above the optimum level.

The invention contemplated the drying of green lumber by air of high humidity and comparatively low temperature, which is an entirely new concept in the field of lumber drying. This type of drying has numerous advantages over conventional methods, takes a comparatively short time and positively prevents excessive surface drying of the wood which in the past resulted in splitting, checking and other damage to the wood and actually slowed the drying operation.

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Under conventional methods of lumber drying, the lumber is first stacked in a yard, where it is subjected to the excessive heat of the sun, the excessive moisture of rain, fog and dampness in the air and wide temperature variations which results in a high percentage of spoilage, due to checking, splitting, rot and other weather damage. After a period of some 5 or 6 months in the yard, where spoilage frequently reaches 20%, the lumber has dried unevenly to approximately 20% moisture content and is then ready for the dry kilns. It will be understood that this yard-dried lumber is not of a uniform moisture content when it is placed in the dry kilns.

The conventional dry kiln is usually a building or other enclosed space in which air is forced over steam coils or direct fired heaters (oil or gas) and circulated through lumber being dried.

The extremely high temperatures employed and scheduled by the authorities such as Forest Products Laboratories, requires the use of live steam to raise the relative humidity to prevent "case hardening," "surface checking," and/or other conditions which either slow down the drying process or actually damage the lumber. The introduction of live steam usually results in a further rise in temperature or total heat of air being circulated. Excess moisture when required to be removed is usually exhausted through gravity type vents either manually or automatically controlled.

The cost of operation of the conventional dry kiln is high due to the fact that all the standby losses, such as conduction losses through walls, floor, and roof, are proportional to the temperature differences employed in the two systems.

The soaking process with high temperature high humidity air represents in addition to the cost of the fuel required to provide steam for the humidity sprays continued fuel consumption to eventually drive off all moisture including the moisture removed from the lumber before the final moisture content of 6% to 7% in the lumber itself can be achieved.

This invention is designed to eliminate both the wasteful and time-consuming preliminary yard-drying of the lumber and the excessive terminal hot air drying in the conventional dry kiln, with its attendant spoilage and high percentage of waste.

In a previous application, Serial No. 823,892, I have set forth a method and installations for the preliminary drying of green lumber down to approximately 20%, which is referred to as "fan air drying." In that method, the green lumber is stacked within an enclosure wherein it is protected from atmospheric deviations in heat and humidity and from the ravages of the elements and is subjected to a steady and uniform circulation of atmospheric air of selected humidity, which is pulled through the lumber enclosure, from its open, forward extremity by a bank of fans at the rear extremity of the enclosure and is then exhausted to the atmosphere. This method for the preliminary drying of green lumber down to approximately 20% moisture content results in uniformly dried, well preserved, preliminarily dried lumber and has practically eliminated spoilage in the lumber and reduced preliminary drying of the lumber from approximately 6 months, required for yard-drying, down to from 7 to 10 days, depending upon the type of wood being dried and its "green" moisture content. As aforesaid, with this "fan air" preliminary drying, drying time is drastically reduced, a high quality, uniformly preliminarily dried product results and spoilage is reduced to an absolute minimum.

The present invention carries the concept of "fan air drying" considerably further and makes available a method in which both the preliminary drying of the green lumber, down to approximately 20% moisture content, and the final "kiln" drying, down to approximately 7% moisture content, may be accomplished rapidly and efficiently with practically no spoilage and in a remarkably short time.

This new method, which is the subject of the present application, contemplates certain important additions to and improvements in the "fan air" system, primarily in the building or enclosure housing the unit whereby an air channel or passage is provided through the upper or roof portion of the building for recirculation of the humid drying air through the upper portion of the building and back through the stacked lumber. It further contemplates the provision of a forced air heater positioned at the rear extremity of the building, adjacent to and rearwardly of the bank of air circulating fans whereby heat may be added to the circulating air, when required, either to reduce its humidity or to accomplish the final, "kiln drying" stage of the drying operation. In addition, a pair of exhaust fans and appropriate louvers and controls therefore are provided in the upper, forward wall of the building, at the forward end of the recirculating air passage, which may be called into play to exhaust excessively humid air from the system to maintain a constant desired humidity in the circulating air of the system.

A lumber compartment is provided within the building which is rectangular in shape, approximately 40 feet wide by 50 feet deep and 15 feet in height, which is open at its forward extremity adjacent the doors of the building and is provided with a rear wall in which are uniformly mounted in two rows a bank of twelve air circulating fans which serve to pull the circulating air through the open, forward end of the enclosure, through the stacked lumber and then force it rearwardly and upwardly to the recirculating air duct under the roof of the building for recirculation back through the open end of the enclosure and through the lumber stack. The side walls of the building comprise the side walls of the lumber compartment in the installation and are preferably provided at intervals with vertically disposed swinging air foil baffle members which are hinged to the walls and swing inwardly against the sides of the lumber stacks to prevent escape of circulating air thereabout. Similar downwardly swinging, hinged air foil baffles are provided, laterally disposed beneath the ceiling of the lumber enclosure, in alignment with the side wall baffles to prevent escape of circulating air over the upper surfaces of the lumber stacks and to insure complete and uniform circulation of the processing air through the lumber stacks.

This invention contemplates the drying of the green lumber by air of relatively high humidity, i.e., up to 82% to 90% R.H., and of comparatively low temperature, i.e., from 50–120° F. By drying the green lumber with air of high humidity and low temperature the lumber remains soft at all times, there is never excessive surface drying and thus interior moisture is readily removed and an even "flow" of moisture from the lumber is maintaned. For example, in one experimental operation, with a temperature of 70° F. and a 90% relative humidity of the air, the drying rate was very rapid and soft green maple was dried down to 25% moisture content with an 83° dry bulb, and 80° wet bulb without stain in 8 days.

This theory of drying of green lumber with air of high humidity and low temperature is revolutionary and the primary reason for its efficacy is the fact that with circulating air of high humidity the lumber is maintained soft and its interior moisture is thus readily extracted, even into high humidity circulating air.

Further on in this specification test charts appear illustrating the efficiency of this high humidity air drying method.

It is therefore a primary object of this invention to evolve a method for the drying of green lumber, both soft and hard woods, from their original, green, moisture content of approximately 100%, down to a "preliminarily dried" moisture content of approximately 20% and then to complete the drying operation down to the final moisture content of approximately 7% in a short period of time.

It is another object of this invention to evolve improved controls for this high humidity drying of lumber.

It is a further object of this invention to evolve such a method in which the temperature of the circulated air is maintained in a comparatively low range, i.e., between 40° and 120° F.

It is another object of this invention to evolve such a drying method in which the green lumber, fresh from the saw, may be completely dried down to final moisture content of approximately 7% in a small fraction of the time previously required for this drying operation and in which spoilage of lumber during the drying operation is reduced to an absolute minimum.

A further object of this invention is to evolve an improved control system which will maintain a substantially constant humidity in the circulated air and which will require the minimum of heating of the processing air.

Other and further objects of this invention will become apparent as this specification proceeds.

Referring to the drawings:

FIG. 1 is a cross-sectional side view of the installation, taken on its longitudinal axis, showing the complete installation with the lumber stacks in position within the lumber compartment and with the drying process underway;

FIG. 2 is a top plan view of the drying unit, taken on line **2—2** of FIG. 1, showing the relative positions of the lumber compartment, the bank of air circulating fans in its rear wall, the forced air heater adjacent the rear wall of the building and the evacuating fans positioned in the forward wall of the building;

FIG. 3 is an end view of the building taken from its rear extremity, on line **3—3** of FIG. 1, showing the air circulating fans positioned in the rear wall of the lumber drying compartment, the air circulating space beneath the roof and the exhaust fans located in the upper extremity of the forward wall of the building;

FIG. 4 is a fragmentary perspective view of one of the air foil baffle members for the lumber compartment;

FIG. 5 is a plan view of the electric contact hygrometer which controls the exhaust fans;

FIG. 6 is a schematic showing of the control panel circuits for the system; and

FIG. 7 is a schematic showing of the control circuits for the circulating fans, the forced air heater and the exhaust fans.

In the drawings, like numerals designating like parts throughout, **10** indicates the outer building or housing for the installation which is preferably rectangularly shaped at its lower extremities and is brought to a peak **11** at its upper extremity to provide an air circulating duct beneath the roof portion of the building, above the ceiling of the lumber compartment. Building **10** is preferably formed of sheet metal or analogous material and is fully insulated over its interior with 2" fiberglass insulation, faced with metal foil to provide a vapor barrier over the insulation. It is provided at its rear extremity with a rear wall **12** and at its forward extremity with a depending forward wall **13**. Forward wall **13** is preferably provided at its lower extremity with a door space **14** which extends the full width of building **10** and may be opened or closed by means of laterally sliding doors **15** provided at their upper and lower extremities with appropriate rollers **16** and **17** running in track housings **18** and **19** provided along the upper and lower edges of door space **14**. Doors **15** are also insulated over their interior surfaces with 2" fiberglass, faced with metal foil. An angular baffle strip **20** is provided along the upper edge of door space 14, extending outwardly over the upper edges of doors 15 to prevent ingress of rain or other precipitation. Doors 15 are preferably four in number and are overlapped to make a completely air tight closure with each other and with side walls 21 and 22 of the building, when they are in closed position. Door space 14 preferably extends the full width of the building, at its forward extremity, thus allowing free access to the interior of the building when doors 15 are in completely open position.

The overall dimensions of the building are preferably 80 feet in depth, 40 feet in width and 25 feet in height, from the ground to rooftree 11. These dimensions may be varied within a wide range, depending upon the nature of the installation desired.

Positioned adjacent rear wall 12 of building 10 is a forced air heating unit 23, which is preferably of a standard make, provided at its lower extremity with pressure blowers and motor 24, a burner and combustion chamber 25 and exhaust vent 26. Inlet duct 27 is provided through rear wall 12 of the building and an appropriate exhaust stack 28 for smoke and combustion products is provided through rear wall 12 of the building and affixed thereto by appropriate brackets 29. This heater is preferably gas fired and is equipped with a thermostat 30 which cannot exercise any control until the hygrometer 31, controlling the exhaust fans, is brought into play, as will hereinafter be discussed at length.

Positioned in forward wall 13 of the building, above doors 15, are exhaust fans 32 and 33 driven by motors 34 and 35, which are appropriately mounted in brackets behind vents 36 and 37 let through wall 13. Louvers 38 and 39 are provided outwardly of vents 36 and 37 in wall 13 and are so designed as to remain in closed condition until fans 32 and 33 are called into operation by the hygrometer 31. Exhaust fans 32 and 33 are preferably of standard make and are humidistatically controlled by hygrometer 31 which closes the circuits to the fan motors 34 and 35, respectively, when the relative humidity of the circulated air exceeds certain values, for example 20% R.H. and 82% R.H., respectively, and which, conversely, breaks the circuits to one of the fan motors when the relative humidity of the circulated air falls below 82% and to the other when it falls below 20% R.H.

Hygrometer 31 is preferably of the electric contact type, well known in the art, and is provided with two control hands, H and L, H to be set at the "high" humidity limit, for example 82%, and the other L set on the "low" humidity limit of, say 20%. Main indicating hand I of hygrometer 31 indicates the relative humidity within the building and when the indicating hand I moves in a clockwise direction past the first, or "low" control hand L it closes the circuit to the motor of one of the exhaust fans 32 and when it passes the other or "high" control hand H it closes the circuit to the motor of the second of the exhaust fans 33. Conversely, as the humidity of the circulating air falls below 82% and as the indicating hand I moves in a counterclockwise direction past control hand H the circuit to exhaust fan 33 is broken and when the R.H. falls below 20% the circuit to exhaust fan 32 is broken.

Exhaust fans 32 and 33 serve a dual purpose in the installation. Due to their control by hygrometer 31 they both exhaust excessively humid air when the R.H. in the system rises above the optimum high level of approximately 82% and, conversely, when the humidity falls below 82% the hygrometer control cuts off one or both of them, as required. They also serve to create a reduced pressure within the building which permits a free movement of water vapor from the lumber into the circulated air. Each exhaust fan preferably is capable of exhausting 3,000 c.f.m., whereby, depending upon whether or not one fan is cut out, up to 6,000 c.f.m. may be evacuated from the building, as required.

A further enlargement on the function of exhaust fans 32 and 33 will be presented later in this specification.

Referring now to the lumber stacking compartment per se, this compartment is defined by a ceiling section 42, preferably of insulated metal, which extends laterally the entire width of the building beneath the roof thereof and spaced below the roof, from side wall 21 to side wall 22 thereof and is affixed thereto at its lateral edges. Ceiling 42 is preferably insulated by 2" fiberglass and foil on both surfaces and is supported at its rear extremity by a vertical rear wall 43, also extending the complete width of the building between side walls 21 and 22. Rear wall 43 is also preferably formed of insulated steel. As shown in FIG. 1, ceiling 42 is disposed some 10' beneath the rooftree 11 of the building, leaving a free air space between it and the roof portion of the building. The forward extremity of the lumber stack compartment is open to permit free circulation of the processing air therethrough.

As shown, rear wall 43 of the lumber compartment is preferably provided with a parallel series of upper and lower circular orifices 44, preferably twelve in number, in which are appropriately mounted twelve air circulating fans 45 which are driven from motors 46 by means of V-drive belts 47. Circulating fans 45 are preferably 48 inches in diameter and are preferably each capable of circulating approximately 20,000 cubic feet of air per minute. Thus, the lumber stacks are subjected to an air circulation of some 240,000 cubic feet of air per minute.

Air circulating fans 45 are designed to run continuously, maintaining a continuous and uniform circulation of air through the lumber stacks at all times, both day and night, and may be stopped when the relative humidity of the circulated air rises above or falls below the optimum levels, i.e., below 20% R.H. or above 82% R.H. They may be provided with appropriate high and low level humidistat controls 40 and 41, the control range being between approximately 20% R.H. and 82% R.H. Normally, these humidistats 40 and 41 are cut out and in usual operation fans 45 run continuously throughout the entire drying cycle.

As shown in FIGS. 1 and 3, preferably four lumber chambers are defined within the lumber stack compartment within the building, the lumber compartment being formed by ceiling 42 and rear wall 43 thereof and the lumber chambers being defined therewithin by a series of vertical baffles 50 and a series of aligned depending ceiling baffles 51. As the dimensions of the lumber stack compartment are preferably 40' x 50' x 15', these baffles are preferably spaced some 10 feet apart down the length of the lumber stack compartment and preferably stacks 48" in depth and 16' in width are formed therewithin prior to the commencement of the drying process.

Each lumber stack is on the order of 4' in depth, 16' in width and 14' in height. Stacks are placed end to end. Each layer of lumber in each stack is preferably separated by appropriate spacers to provide easy access of the circulating air to all portions of each stack and all surfaces of each layer of lumber.

Referring specifically to the baffle members per se, it will be seen that vertical baffles 50 are preferably hingedly mounted in parallel vertical position at approximately 10 foot intervals against side walls 21 and 22 of the main building structure in such fashion that they may be swung forwardly toward the forward end of the building and door space 14 to an angle of some 90° to lie flush against said walls during the loading and unloading of the lumber compartment. Vertical baffles 50 preferably extend from the floor of the building vertically to a point just beneath ceiling 42 of the lumber stack compartment and, as shown, are preferably four in number and aligned with each other in their hinged mounting on walls 21 and 22. Baffles 50 are on the order of 2' in width so as to impinge against the lumber stacks at their inner, air foil extremities.

Depending downwardly from ceiling **42** and hingedly attached thereto are ceiling baffles **51**, of the same overall configuration and dimensions as vertical baffles **50**, aligned with vertical baffles **50** and spaced apart a distance of some 10 feet. Depending baffles **51** are preferably hingedly attached to the undersurface of ceiling **42** and extend laterally the entire width of the building.

A detail of one of baffles **50** and **51** is shown in FIG. 4 of the drawings. It will be seen that baffles **50** and **51** are comprised of a hinge member **52**, affixed either to the side walls of the building or to the undersurface of the ceiling **42** of the lumber stack compartment in such fashion that baffles **50** and **51** may be swung forwardly through an angle of 90° to flush position towards the entrance door **14** of the building but will be limited in their rearward movement to a rectangular position with respect either to side walls **20** and **21** or ceiling **42** of the lumber compartment by the rectilinear butt end **53** of baffle panel **54**.

The inner, air foil extremity of each baffle comprises a canvas or Pliofilm envelope **55** which is appropriately affixed at the extrimity of baffle panel **54** by means of outer blocks **56** and **57** and inner blocks **58**, maintained in place by bolts **59**. Inner blocks **58** are provided down their entire length with a series of air vents or orifices **60**, providing access to the interior of air foil envelopes **55** for the processing air pulled through the lumber stack compartment by the circulating fans **45**. In each instance these air inlet orifices **60** are disposed on the forward side of baffles **50** and **51** whereby circulating air pulled through the lumber enclosure by fans **45** will inflate envelopes **55** to maintain them firmly against the top and lateral extremities of the lumber stacks, yet will maintain envelopes **55** in such flexible condition as to conform to any irregularities in the lateral or upper surfaces of the lumber stacks to prevent escape of circulating air therearound.

Thus, when it is desired to "open" the lumber stack compartment within the building to emplace or remove stacks of lumber therefrom, vertical baffles **50** are swung rectangularly forwardly with respect to side walls **21** and **22** and depending baffles **51** are swung upwardly with respect to ceiling **42** of the lumber stack compartment to allow removal or emplacement of lumber therewithin. As aforesaid, by virtue of the flexible and inflatable nature of these air foil envelopes provided at the inner extremities of vertical baffles **50** and depending baffles **51** all irregularities in the lumber stacks are compensated for and a complete air seal is attained both at the lateral extremities of each stack and over the upper surfaces thereof.

An installation is provided in accordance with this invention in which some 240,000 cubic feet of air per minute are continuously circulated through the lumber stack compartment in a constant flow over all surfaces of the stacked lumber at a speed of 350–500 f.p.m. The optimum humidity of the circulated air and the temperature thereof are carefully controlled at all times to provide optimum and uniform moisture removal from each piece of lumber in each of the lumber stacks within the lumber stack compartment. When it is desired to lower the humidity of the circulating air the setting of hygrometer **31** may be lowered, as desired, toward or below the lower limit of 20% R.H.

During the preliminary drying stage of the process, it is normally unnecessary to bring the air heating unit **23** into operation, as the relatively humid circulating air, of up to 82% R.H. performs this initial drying rapidly, down to 20% moisture content of the stacked lumber, without the necessity of adding heat to the circulating air. However, when a moisture content of approximately 20% has been attained in the lumber and it is thus "preliminarily dried" the further drying of the lumber down to the final 7% moisture content becomes more difficult and it then becomes necessary to progressively reduce the humidity of the circulating air and to progressively raise its temperature, as moisture removal becomes more difficult.

As an example of the performance of the unit on various types of green lumber fresh from the saws the following test chart is included showing experimental processing at Memphis of various types of soft woods from July 28 through August 3, 1960, showing the progressive loss in weight, or moisture content, for each wood during this seven day period. No heat was added to the circulating air during this drying operation.

	Oven Test, Percent Moisture	Weight Bone Dry	1 p.m. 7–28	10 a.m. 7–29	10 a.m. 7–30	10 a.m. 7–31	10 a.m. 8–1	10 a.m. 8–2	10 a.m. 8–3
Black Gum	99.6	35.45	70–12	62–3	56–7	51–11	49–13	47–15	46–7 31.0%
Cotton Wood	138.4	20.24	48–4	42–2	36–5	31–15	29–4	26–13	25–4 24.8%
Hack Berry	74.8	26.57	46–7	42–5	40–0	38–9	37–4	35–8	34–1 28.2%
Sap Gum	116.4	29.14	63–1	54–12	46–6	42–6	40–8	38–8	36–15 26.8%
Elm	110.6	25.28	53–4	47–6	42–12	38–2	36–0	33–15	32–12 29.5%

The above test chart shows the progressive weight loss, i.e. moisture removal, in pounds and ounces, day by day, from July 28, 1960 to August 3, 1960, of five different woods dried in the subject low temperature kiln without the addition of heat to the circulating air.

The control circuits for the installation are schematically shown in FIGS. 6 and 7 of the drawings and will now be described.

FIG. 6 discloses a schematic wiring diagram for the control cabinet for the installation and FIG. 7 discloses a similar schematic wiring diagram for the circulating fan motors, the heating unit and the exhaust fan motors. These circuits are substantially conventional and the units thereof are well known in the art. Other analogous circuits may be utilized within the spirit of this invention, the present circuit, however, being preferred.

A brief discussion and enlargement on these circuits will now be given.

Referring to FIG. 6, terminal strips **T1**, **T2** and **T3** are shown for the control cabinet, corresponding to terminal strips **T1**, **T2** and **T3** of the master circuits for the installation control, respectively of the circulating fan motors, the heating unit and the exhaust fan motors. Thus, referring to the first circuit, based on terminal strip **T–1** of FIG. 6, it will be seen that terminal strip T–1 includes contacts N and **1** through **6**. Humidistats **40** and **41** of the three wire, snap acting type are shown as basic controls for the air circulating fan motors **46** of circuit **T1** of FIG. 6. One of these humidistats is set to break the circuit on "high," 82% R.H., and the other on "low," 20% R.H. It will be noted that switch R in **T1** circuit is a three way switch "on," "off," "automatic." With this switch on "automatic," high and low humidistats **40** and **41** control the air circulating fan motors **46** and thus cut them out on low relative humidity of 20% and high relative humidity of 82%, the low and high settings of said humidistats, respectively. However, with switch R set on "manual" humidistats **40** and **41** are cut out of the circuit and fan motors **46** will run continuously, regardless of the moisture content of the circulating air. Normally, this is the setting used in the system whereby the air circulating fans **45** operate throughout the entire preliminary and final drying cycles.

Also included in this circuit is a double pole, double throw switch R "on," "off" and "automatic." Center position is "off." "S" indicates an SPST switch and "T" designates a fan motor for an aspirating air supply fan for humidistats **40** and **41**. Pilot lights P are also included indicating operating conditions. As aforesaid, terminal strip circuit T–1 is the control cabinet circuit for the circulating fan motors **46** of FIG. 7 and may be under the control of "high" and "low" humidistats **40** and **41**.

Referring to terminal strip T2 of FIG. 6 and its circuit it will be seen that terminal strip T2 includes contacts **10–14**, corresponding to contacts **10–14** of terminal strip T2 of FIG. 7, for the control of the forced air heater **23** of the installation. This circuit includes thermostat **30** which is designed to close the circuit on "low," and a double pole, double throw switch V with two settings, i.e. "manual" and "automatic." An indicating pilot light is also included.

Referring to terminal strip T–3 of FIG. 6, it will be seen that it includes contacts **1**, **2** and **15** to **18** and covers the corresponding control circuit based on terminal strip T–3 of FIG. 6. This circuit controls the motors **34** and **35** of exhaust fans **32** and **33**, shown in FIG. 7. It includes "high" and "low" single pole switches S, electric contact hygrometer **31**, provided with "high" and "low" adjustable control hands H and L, thermal gas relays Y, one of which makes on "high" and the other on "low" and a three pole, double throw switch, "manual" and "automatic" designated as "X." Pilot lights P are also included.

As aforesaid, the function of control group No. 1 is to operate the motors of the circulating air fans **45** within preset conditions of "high humidity" and "low humidity," if desired. With selective switch R in the "automatic" position the control is through humidistats **40** and **41**, one of which is set to break the circuit on a predetermined "low" relative humidity of, say 20%, and the other to break the circuit to the fan motors on a predetermined "high" relative humidity of, say 82%.

The selective switches S control the operation of one half of the fan motors in each bank of air circulating fans for 50% reduced air circulation. With switch R in manual position, fan motors **46** run continuously. With switch R in "automatic" position fan motors **46** run under the control of "high" and "low" humidistats **40** and **41**.

Referring to control group No. 2, based on terminal strips T–2, the thermostat **30** closes the circuit on "low" and acts as the high limit (120° F.) for the forced air heater **23** of FIG. 7 to maintain a preset temperature through thermal gas relays Y. The heat source **23** may be a gas or oil fired heater, steam or hot water or oil control valve or electric heating coils. Selector switch V in "manual" position calls for continuous operation of the heat supply. In "automatic" position, the "low" contact of hygrometer **31** controls the heat source and thermostat **30** is the high limit control for the heat source. As will be seen, control group **2** and control group **3** are interlocked by line **14** so that the heat source **23** is controlled through the thermal gas relays Y.

Control group **3** operates through electric contact hygometer **31** to control motors **34** and **35** of exhaust fans **32** and **33**. Hygrometer **31** is provided with adjustable control hands H and L set at "high" and "low" relative humidity, respectively, whereby the R.H. of the circulating air will control the operaton of exhaust fans **32** and **33** which are called into operation to discharge air from within the building through the automatic gravity type discharge shutters.

The low temperature kiln motor control cabinet wiring diagram comprises starters, relays and contactors of all circulatng fan motors and exhaust fan motors. The automatic operation of circulating fan motors and exhaust fan motors as required by the various controls and the instrument control cabinet terminal strips T1, T2 and T3 are wired to the various motors controls, as indicated.

Referring to FIG. 7, the motor control circuits are shown, based on terminal strips T–1, T–2 and T–3, corresponding to the terminal strips of the motor control cabinet shown in FIG. 6. It will be seen that the air circulating fans **45** are arranged in two banks and may be under the control of high and low level humidistats **40** and **41** and that the components of this circuit include thermal overload relays B for each circulating fan motor **46**. Three pole magnetic contacts C for each bank of fans are included and a transformer D converting line voltage to secondary control voltage of 110 volts. A fuse block E is included in the control circuit.

Referring to terminal strips T–2 and T–3 of FIG. 6 and their circuits, "G" indicates thermal overload relays, one for each of the exhaust fans **32** and **33**. Four pole magnetic contractors indicated at "M" are also included, one for the motor of exhaust fan **32** and the other for the motor of exhaust fan **33**. A magnetic relay J of the single pole type energizes the holding coils in magnetic contractors M. Heat source **23**, which may be a gas fired heater or any analogous type of heater, is shown.

It will be appreciated that terminal strips T–1, T–2 and T–3 of the control cabinet are wired directly to terminal strips T–1, T–2 and T–3, respectively, of the motor control circuits.

It will thus be seen that the air circulating fan motors **46** may be under the direct control of the control humidistats **40** and **41**, one for high level humidity control and the other for low level humidity control. It will further be seen, by reference to FIG. 7, that the operation of the heater **23** and the exhaust fan motors **34** and **35** are in interlocked control to the hygrometer **31** whereby both heat put into the system by heater **23** and humid air exhausted therefrom by the exhaust fans is directly controlled through the setting of the control hands H and L of hygrometer **31**. It is thus possible through the instrument control cabinet for the operation to follow a schedule from the loading of the green lumber into the kiln until the final ultimate moisture content of approximately 7% is reached. These schedules will vary with different species of wood and will be controlled by the thickness thereof, hardness, initial moisture content and certain other variables. The operating schedules are quite flexible and require only the adjustment of the two hygrometer control hands H and L. Normally, heater **23** is not called into action to put heat into the circulating air during the "preliminary drying" of the lumber down to say, 20% M.C., the drying down to this point being done by the circulating air alone. When a 20% M.C. is reached the heater **23** is then set in operation to heat the circulating air to complete the final drying of the lumber down to approximately 7% M.C.

Referring back to the overall building structure **10**, it is preferably completely fabricated of sheet steel, insulated throughout on its interior walls with 2″ fiberglass covered with an aluminum foil vapor barrier. Doors **15** are also provided with fiberglass insulation covered with foil over their interior surfaces to provide complete insulation at the forward extremity of the building. Further, ceiling **42** and rear wall **43** of the lumber compartment are also formed of sheet steel, appropriately insulated. Industrial steel structures of this type are manufactured by several nationally known manufacturers and are available in a number of widths, lengths and heights, as desired.

The manner of operating the drier is as follows:

If the lumber processing compartment contains stacks of dried lumber on which the treating cycle has been completed, doors **15** are first opened, opening the lower, forward extremity of the building **10**. The forwardmost of vertical baffles **50** and horizontal baffles **51** are then swung flush outwardly to walls **21** and **22**, and ceiling **42**, respectively. The first stack of lumber is then removed from the forwardmost compartment. With this stack removed, the second set of baffles **50** and **51** are swung flush against the walls and ceiling and the second stack of lumber is removed. This process is repeated for the next two stacks until the inner compartment is emptied. With the inner lumber compartment completely emptied of the dried lumber, and with the baffles flush against the walls and ceiling of the compartment, green lumber is then stacked in the rearmost of the lumber compartments until this compartment is filled from wall to wall of the building to a height of some 14 feet. With the rearmost compartment thus filled, side wall baffle **50** and ceiling baffle **51** are then swung inwardly at right angles to the walls and ceiling, respectively, sealing the edges and top of this rearmost stack. This loading process is repeated through the next three compartments of the inner chamber until all four compartments contain complete lumber stacks and all baffles **50** and **51** are in registering position with respect to the stacks, as shown in FIG. 1 of the drawings. With the entire lumber compartment thus filled and with the baffles turned inwardly in sealing position doors **15** are then closed to near air tight position and the motors **46** of air circulating fans **45** are energized, starting the circulating fans **45**. This initiates a flow of air into the open forward extremity of the lumber stack compartment, through the lumber stacks, through circulating fans **45**, through the air return duct D under the roof of the building and back through the lumber stacks, in continuous cycle. When the relative humidity of the circulated air rises above 82%, high level exhaust fan **33** is called into operation by hygrometer **31** to exhaust excessively humid air from the building until the moisture content of the circulated air is reduced to 82%.

During the preliminary stage of the drying of the green lumber, hygrometer **31**, set preferably at a "high" of 82% R.H. and a low of 20% R.H., controls the operation of low level exhaust fan **32** and high level exhaust fan **33** and does not call fan **33** into action until the circulated air exceeds 82% R.H. When the relative humidity of the circulated air exceeds 82% hygrometer **31** closes the circuit to the motor of exhaust fan **33** and fan **33** begins exhausting humid air from the interior of the building, louvers **39** being forced to open position by the forced draft from fan **33**. When the relative humidity of the circulating air is lowered below 82% hygrometer **31** breaks the circuit to the motor fan **33**. As aforesaid, low level fan **32** is called into action by hygrometer **31** as soon as the drying cycle starts and continues to run until the relative humidity of the circulated air falls below 20%.

When the moisture content of the lumber has been reduced to about 20% the humidity of the circulated air is also reduced until at 20% R.H. the low level control hand L of hygrometer **31** is passed by the indicating hand I thereof and the circuits to the low level exhaust fan **32** and the air heater are broken. This shutting off of exhaust fan **32** and the air heater enables the relative humidity of the circulated air gradually to rise again to 20%, at which point hygrometer **31** again calls exhaust fan **32** and the air heater into action.

It is the practice to permit the air circulating fans **45** to continue operating for several hours after the heater and exhaust fan **32** have stopped operating, these extra hours of air circulation equalizing the moisture content of the lumber between core and shell and producing a fine quality of lumber in optimum condition.

Louvers **38** and **39** of exhaust fans **32** and **33** serve a two-fold purpose. When exhaust fans **32** and **33** are not operating the pressure from the outside atmosphere maintains louvers **38** and **39** in closed condition until such time as pressure builds up within the building, due to rise in temperature or pressure, whereupon louvers **38** and **39** open partially and permit the escape of excess moist air or other vapors. This results in a rapid rate of drying even when exhaust fans **32** and **33** are not operating.

As aforesaid, the force feed heater is equipped with a modulating thermostat **30**, set at a high limit of 120° F. Thus when the temperature within the building reaches 120° F. the heater is cut off.

As humidity is the primary factor in this drying system, heat may only be added to the air within the building so long as it will not disturb the balance of moisture in the air. However, the air temperature may be gradually raised, while maintaining the proper relative humidity, this extra heat causing the lumber to give up a little extra moisture and at the same time maintaining a relative humidity and temperature in proper balance.

As an example, with the humidity control set at approximately 82%, the temperature can range from 55° F. to 120° F. with an increased difference of only 3° between wet and dry bulb reading at any time. At 82% R.H. and 55° F. the dry and wet bulb reading will be 55° D.B. and 52° W.B. At a temperature of 75° F. and 82% R.H. the dry and wet bulbs would read 75° D.B. and 71° W.B. At 115° F. and 82% R.H. dry and wet bulb readings would be 115° D.B. and 109° W.B., a range in spread of 3° W.B. to a maximum of 6° W.B.

In the final stages of the drying operation, from 20% moisture content of the lumber down to the final 7% moisture content the humidity of the circulated air progressively falls down to below 20% at which point low level exhaust fan **32** and the air heater are cut out by hygrometer **31**.

Thus it will be seen that during the preliminary drying stage of the operation in which the green lumber is dried down to approximately 20% moisture content, the relative humidity of the circulating air is maintained at high level, i.e., up to 82% R.H. thus maintaining the lumber soft and the surface moist, whereby the lumber readily gives up its moisture to the circulating air. The relative humidity of the circulating air is not reduced below this point until the later stages of the drying operation when the moisture content of the lumber is drastically reduced.

As aforesaid, hygrometer **31** is provided with two control hands, L and H, control hand L being set at the low limit relative humidity, about 20% R.H. and control hand H being set at the high limit relative humidity, normally 82%. Hygrometer **31** is also provided with a sweep indicating hand I which indicates the relative humidity of the air within the building. When the humidity is above 20% indicating hand I makes contact with the low limit control and the circuit is closed to low limit exhaust fan **32** and also to the forced air heater **23**, both of which then start operating with exhaust fan **32** exhausting circulating air and the air heater initiating heating of the circulating air. As the relative humidity of the circulating air increases and rises up to 82%, the top humidity limit, the indicating hand I of hygrometer **31** contacts the high level control hand H of the hygrometer, set at 82% R.H., and the circuit to the motor of exhaust fan **33** is closed and exhaust fan **33** goes into operation to exhaust excessively humid air from the building until the relative humidity thereof drops below 82%, at which point the indicating hand I breaks the circuit with the high level control hand H and the circuit to exhaust fan **33** is broken. Normally, when green lumber is being processed, the high level control hand H is set at 82% R.H. on the dial of hygrometer **31** and the low level control hand L is set at 20% R.H. thereon. As aforesaid, the high level control hand is set at 82% on the hygrometer dial and the circuit to high level exhaust fan **33** will be closed and broken when ever required to maintain a balanced high level relative humidity to 82% within the building.

When the lumber being dried has dried sufficiently to eliminate a relative humidity as high as 82% in the system, high level exhaust fan **33** will cease to operate, but the air heater and low level fan **32** will continue to operate until the lumber is dried down to the point where a 20% relative humidity can no longer be maintained. At this stage the heater **23** and the low level exhaust fan **32** are cut off by hygrometer **31** until the circulating air cools to such a point that there is a slight increase in relative humidity up to 20% at which time the circuit is again closed by the indicating and low level control hands I and L of hygrometer **31** whereby the heater and low level exhaust fan **32** again start to operate. This terminal end of the cycle is continued until the lumber is thoroughly dried down to approximately 7% M.C.

In drying 4/4 soft maple, sap gum, tupelo gum, elm, and hackberry, it has been found that from 5 to 10 days are required to dry the heaviest boards down to 20% M.C. When the process is initiated with green lumber of the above species and is carried through on an uninterrupted cycle, 12 days is the longest average time required to complete the drying cycle from over 100% M.C. down to the final completely dried moisture content of 7%. In the operation of these drying cycles temperatures in the building may range from 50° F. to 120° F., with a relative humidity range of from 85% down to 18%.

In starting with cold, air-dried lumber, of M.C. from 20% to 30%, the drying time down to approximately 7% has averaged approximately 7 days, room temperature never exceeding 120° F., the top limit of the thermostat control for the forced air heater.

As aforesaid, the thermostat control for the forced air heater is set for a high temperature limit of 120° F. whereby maximum temperature in the system never exceeds this temperature. Normally the processing temperature ranges from room temperature in the building, say approximately 54° F., to a top limit of 120° F. The average drying cycle period for green lumber from over 100% M.C. down to 7% M.C. has been approximately 12 days.

The following chart shows an actual test run at Memphis, Tennessee, on 235 board feet of end-coated green maple lumber between the dates of February 9, 1961, and February 21, 1961.

The test was conducted as follows: At 4 p.m. the charge of green maple lumber, 235 board feet, weighing exactly 1,000 pounds, was placed on a platform scale inside the drying compartment. Part of this lumber was frozen and, as aforesaid, oven tests had previously established moisture contents in the various lumber lots of from 28.4% to 89.8%.

At 5:00 p.m., February 9, the doors of the building were closed and the circulating fans were turned on, initiating air circulation within the dryer.

A check at 8:30 p.m., February 9, showed a temperature increase within the dryer to 47° F., dry bulb, and 46° F., wet bulb. This one degree depression indicated an extremely high humidity within the drying compartment. Despite this high humidity and the comparatively low temperature within the compartment, on the following morning the 1,000 pound sample weighed only 994 pounds, a loss of 6 pounds of moisture, indicating that drying had already begun. At that time relative humidity within the compartment was 94%.

Reference to the chart will show that sample A–1 of the green maple was loaded at a moisture content of 86.9%; sample A–2 at a moisture content of 89.8%; sample B–1 at a moisture content of 60.6%; sample B–2 at a moisture content of 41.7% and sample C–1 at a moisture content of 28.4%. The original total weight of these five samples was 1,000 pounds, at the time of loading, on February 9, 1961.

Ten and a half days later, the moisture content of sample A–1 was 6.6%; A–2 was 7.0%; B–1 was 6.9%; B–2 was 6.7% and sample C–1 was 6.0%. In this period the weight of the 235 board feet of maple lumber had been reduced to 764 pounds, a moisture loss of 236 pounds, and the entire sample stack of lumber was in finally dried condition and ready for manufacturing.

It will be noted from the test chart that temperature within the dryer was maintained at a low level during the first two days of the test and was then gradually increased up to a maximum of 120° F., which temperature was maintained through the last five days of the operation. Wet bulb temperature within the drying compartment rather closely followed this dry bulb temperature during the first six days but well off sharply during the last four and a half days.

Maple run in new kiln 2–9–61—2–21–61

Date	Time	Sample A–1	Sample A–2	Sample B–1	Sample B–	Sample C–1	235′ Weight on scale	Inside Board Temp.		Dry Bulb	Wet Bulb	Dep.	RH
								In Kiln	Out Kiln	Inside Kiln		Inside Kiln	
2–9	4. p.m.	86.9%	89.8%	60.6%	41.7%	28.4%	1,000			43	40	3	77
2–10	8 a.m.						994	51	35	52	51	1	94
2–11	8 a.m.						951	92	39	93	89	4	85
2–13	8 a.m.	54.1	61.2	44.7	33.1	22.5	905	96	58	97	93	4	86
2–14	8 a.m.						878	100	48	102	94	8	74
2–15	8 a.m.	29.4	38.4				854	101	57	104	92	12	63
2–16	8 a.m.						830		56	115	99	16	56
2–17	8 a.m.		17.4	17.6	14.9		806		61	120	97	23	43
2–18	8 a.m.						791		59	120	91	29	33
2–19	8 a.m.			11.0	9.6		778		33	120	82	38	19
2–20	8 a.m.	7.6	10.5	8.5		6.6	769		40	120	80	40	17
2–21	8 a.m.	6.6	7.0	6.9	6.7	6.0	764		46	120	80	40	17

Oven tests were made of five samples of this green maple lumber before being placed in the drying compartment. These tests indicated that the moisture content of the various lots of green maple ranged from 28.4% to 89.8%. Holes were drilled in several sample boards and thermometers placed inside. Sample boards outside of the dryer were also equipped with thermometers for comparison purposes.

During the first night the outside temperature fell from 37° to 24° F. but the temperature inside the dryer rose to 52° F., without the addition of any heat whatsoever to the circulated air within the dryer.

With respect to relative humidity inside the drying compartment it will be noted that it reached a peak of 94% on the second day of the test and then progressively dropped down to a final low level of 17% on the last two days of the test during the final drying stage.

As aforesaid, when this stack of lumber was removed from the drying compartment, it was ready for manufacturing, at an average moisture content of 6.7%. It will be noted further that samples A–1 and A–2 were loaded at moisture contents of 86.9% and 89.8%, respectively, and were removed 10½ days later at respective moisture contents of 6.6% and 7.0%.

For different species of woods different instrument settings are required. For all species of soft southern hardwoods, the following schedule is normally adhered to.

For green or partially dried lumber

(1) Start 12 circulating fans and operate for 12 to 24 hours without heat or exhaust.

(2) Set hygrometer high limit H at 82% R.H. and low limit L at 18 to 22% R.H. as required.

(a) Release of moisture from lumber raises R.H. to 82% to 90%. At 82% R.H. or over, high limit hygrometer contact H causes exhaust fan **33** to operate continuously, throwing away excess moisture.

(b) R.H. being in excess of low limit setting energizes thermal gas relay to heat source supervised by high limit thermostat set at 120° F., and to exhaust fan **32**.

(c) As the lumber dries, the R.H. is lowered, and controls function to maintain the balanced atmosphere at optimum drying conditions. For example, usually the balance will occur at some point between 80° F. and 104° F. depending upon rate of release of moisture from lumber and temperature difference with outside. The reason for reaching equilibrium is that the loss due to latent heat of evaporation and heat input are balanced. This will continue for approximately 12 to 24 hours depending on heat loss to outside, after which a lower R.H. will be reached and another point of balance at a higher temperature will be obtained, still below the high limit setting of 120° F.

In the final drying stage to reach the desired 6% to 7% E.M.C. the temperature will gradually climb to the maximum of 120° F. and the R.H. will uniformly go lower, until the R.H. reaches the low limit setting of 20% at which time the circuit to the heat source and exhaust fan **32** are interrupted through the gas relay causing intermittent operation of heat source and exhaust fan **32**, maintaining the preset 20% R.H. low limit setting. This final period of intermittent operation of heat source and exhaust fan tends to equalize the moisture content of the lumber between core and shell, finally achieving a difference of ±1% M.C. between core and shell, which is greatly superior to conditions obtained in conventional dry kilns.

For more difficult to dry hardwoods, optimum results can be obtained by raising both high limit and low limit settings of the hygrometer, thus maintaining a higher R.H. in the circulating air throughout the entire drying cycle.

For air drying only, to approximately 20% M.C., when heat is not available or desired, the same instrument settings are used as are used with heat. Temperature and relative humidity will reach a balance to produce satisfactory air drying.

This low temperature kiln air dries lumber very efficiently without added heat. The removal of moisture from the lumber provides a substantial temperature increase within the system without the necessity of adding heat by way of the air heater until the terminal stage of the drying has been reached, i.e., approximately 20% M.C.

Further, the reduced pressure created by the circulating fans and the exhaust fans results in rapid air drying with the use of added heat until the end of the drying cycle, i.e., from approximately 20% M.C. to 7% M.C., is reached.

The invention is susceptible of numerous modifications without departing from the spirit thereof. Throughout,

equivalents may be substituted for all elements of the installation within the spirit of the invention. The installation and method disclosed herein are by way of illustration, only. Attention is directed to the appended claims for a limitation of the scope of the invention.

What is claimed is:

1. A method of drying green lumber comprising stacking the lumber within an enclosure, sealing the enclosure, pulling through the lumber stack a constant, high speed circulation of humid air up to about 80% relative humidity and of low temperature for a sufficient period of time to reduce its moisture content to 20% and subsequently drying the lumber down to 7% moisture content by progressively increasing the temperature to a maximum of about 120° F. and lowering the humidity of the circulated air to a minimum of about 20%.

2. A method of drying green, sawed lumber of high moisture content comprising stacking it in a sealed compartment, rapidly pulling and circulating air of high humidity up to about 82% and low temperature between 40 and 120° F. through said stacks at a constant rate of flow until the moisture content of said lumber is reduced to about 20% and then progressively reducing the humidity to a maximum of about 20% and increasing the temperature of said circulating air to a maximum of about 120° F. and continuing its circulation through said stacks until the moisture content of the lumber is reduced to 7%.

3. A method of drying lumber from its initial, green moisture content down to a final moisture content of 7% which comprises stacking the green lumber within a sealed enclosure, subjecting it to a constant speed low temperature air circulation throughout the drying cycle while maintaining the relative humidity of the circulating air of about 82% during the preliminary stages of drying and then above 20% R.H. at the later stages thereof and raising the air temperature to a maximum of 120° F. throughout the remaining drying time.

4. A method of drying green lumber comprising stacking the lumber in a series of sealed stacks within an enclosure, sealing the enclosure, pulling a draft of humid air of about 80% R.H. and a temperature of between 40 and 120° F. and maintaining said air at constant and high velocity circulation through said stacks for a sufficient period of time to reduce the moisture content of the lumber down to about 20% R.H. and subsequently progressively increasing the temperature of the circulated air to a maximum of about 120° F. and lowering the humidity of the circulated air to a minimum of about 20% until the lumber is dried down to a final moisture content of about 7%.

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