

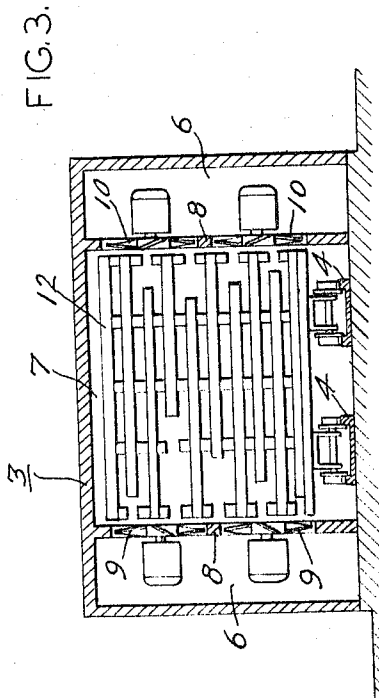
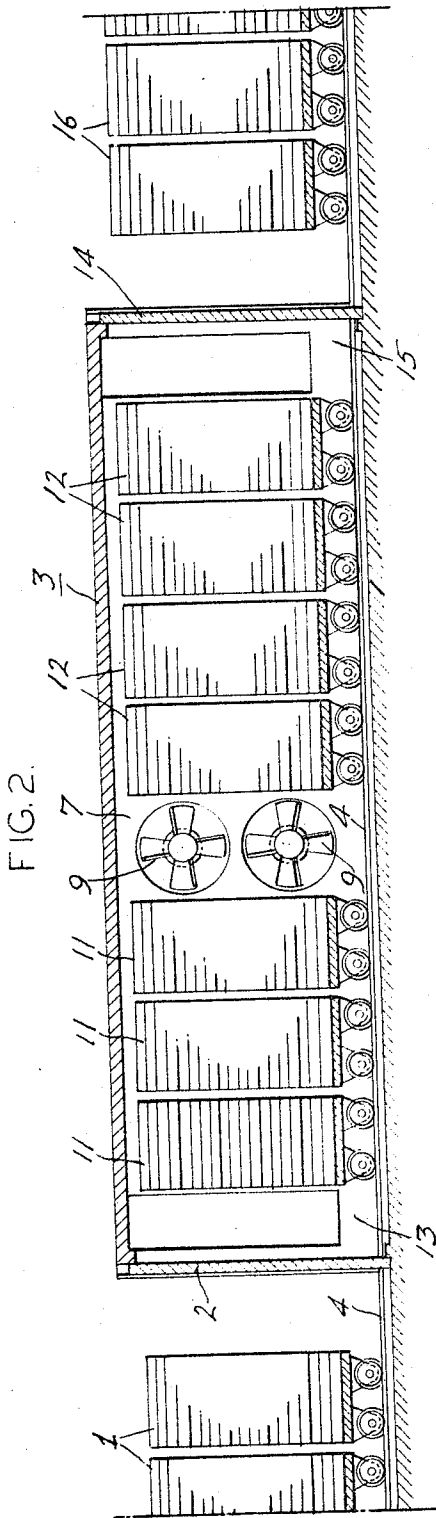
May 27, 1969

L. MALMQUIST
APPARATUS FOR THE CIRCULATION OF A GASEOUS MEDIUM THROUGH
A DRYING CHANNEL

3,445,939

Filed Aug. 30, 1967

Sheet 2 of 3



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FIG. 4

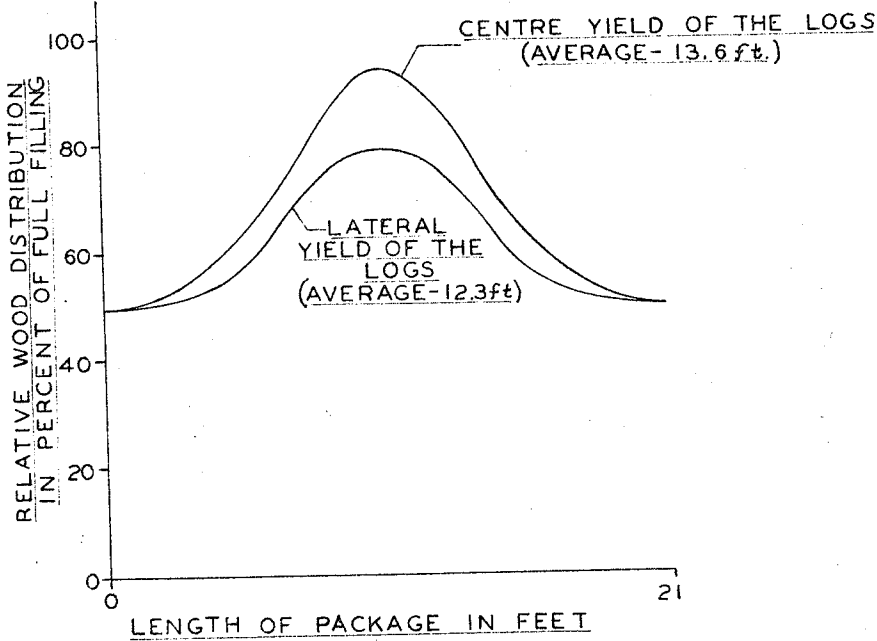
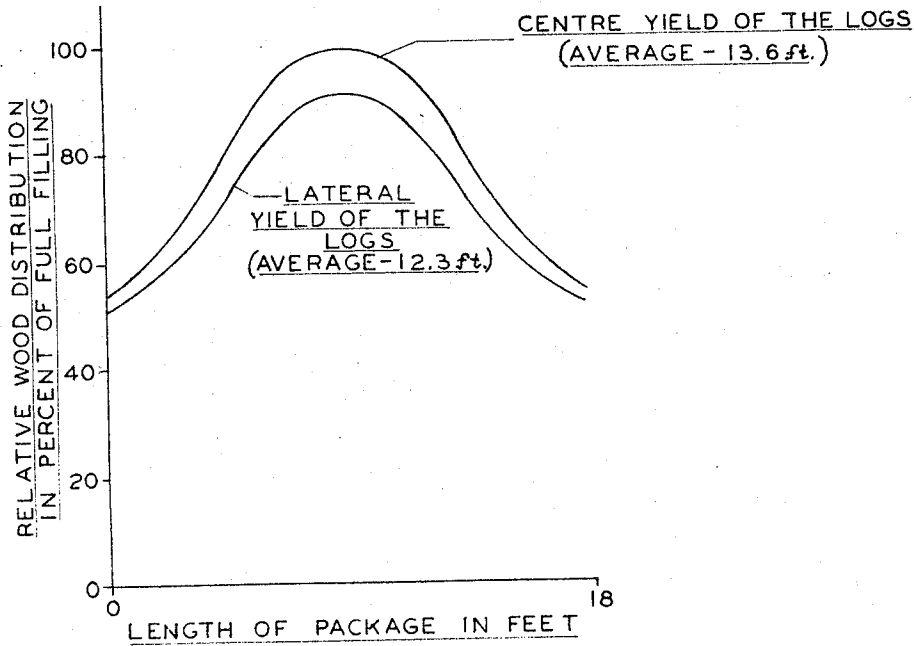


FIG. 5

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APPARATUS FOR THE CIRCULATION OF A GASEOUS MEDIUM THROUGH A DRYING CHANNEL

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 12,169/66

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U.S. Cl. 34—223

3 Claims 10

ABSTRACT OF THE DISCLOSURE

A dryer for lumber of varying lengths stacked in packages for conveyance through the dryer in a direction perpendicular to the length of the pieces of lumber. Drying medium is introduced into the dryer at an intermediate point along the length of travel of the material by axial fans having their axes perpendicular to the longitudinal vertical center plane of the drying channel. The drying medium is recirculated heated air, and the condition of the medium is controlled by heat exchangers in the return passages, fresh air inlets at one end and moist-air outlet at the other end, all controlled by sensors in the respective return channels.

The present invention relates to an apparatus for the circulation of a gaseous medium through a drying channel substantially intended for a substantially continuous feeding therethrough of wood which with its longitudinal direction perpendicular to the channel is stacked in batches on conveying means feeding the wood batches by steps in the longitudinal direction of the channel, and wherein the channel by an intermediate space is divided in its longitudinal direction into two sections in which the drying medium in one section flows in counter-current to the feed direction of the wood and in the other section in the feed direction of the wood.

Wood to be dried usually is piled batchwise to packages, with intermediate ribs (crossers) disposed perpendicular to the longitudinal direction of the wood for rendering the drying medium possible to circulate about the wood when the drying medium is blown against a wood package perpendicularly to the longitudinal direction of the wood. As the wood pieces are not all of the same length but have a certain spread with respect to their length, the wood quantity per unit of volume varies within a package in the longitudinal direction of the wood and, as a rule, in such a manner, that the compactness of the wood is greatest in the centre of the package and smallest at its two ends. The latter also applies to such cases when the wood is piled in piling machines and the wood pieces thereby are automatically drawn level to the package ends, so that every second wood piece is drawn level at one end of the package and every second wood piece at the opposite end. Thus, a wood package to be dried comprises a correspondingly greater amount of water in its centre than at its ends.

When a wood package is blown at perpendicularly to the longitudinal direction of the wood with a drying medium, for example air with a constant speed and constant humidity, disregarding the difference in flow resistance as it is caused by the difference in wood compactness, the air subsequent to its passage through the package will be saturated with water vapour more in the centre of the package than at its ends. When several wood packages are passed through subsequently in series by the same air, the difference in humidity will increase successively for every package passed through. This inconvenience which manifests itself in a successively delayed

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drying in the centre of the wood package in relation to its end, is particularly accentuated in drying channels arranged for longitudinal circulation of the air, with the wood packages being advanced transverse to the flow direction of the air, because the air then passes through a greater number of wood packages in series.

In order to counteract said inconvenience, the initial flow conditions upon the entrance of the drying air into the first package must be arranged such, that a greater air quantity is blown through the drying channel in its centre than farther out to its side walls, in order thereby to effect the greater evaporation required in the centre of the channel so that a uniform drying of the wood in its longitudinal direction is obtained.

The solution of the problem offered by the invention is characterized in that in the longitudinal side walls of the channel, symmetrically with respect to the central longitudinal vertical plane of the channel, axial fans are mounted with their shafts substantially perpendicularly to said plane and adapted to blow the drying medium into the channel in the intermediate space between said two sections. By such an arrangement the impulse flow produced by the axial fans will be concentrated to the centre of the channel and, owing to the symmetry, be deflected at a right angle in the longitudinal direction of the drying channel, thereby bringing about the desired effect. Furthermore, by the symmetric counterflow, the air rotation produced by the fans will bring about a resultant equal to zero, and the rotation energy partially will be transformed into static pressure against the centre of the channel, whereby the desired effect is increased additionally as well as the tendency of an oblique initial flow direction, as it would occur in the case of asymmetry, is eliminated and the otherwise useless rotation energy partially is utilized.

The function of the apparatus further is dealt with in connection with the description of the figures whereof

FIG. 1 shows a longitudinal section seen from above of a drying channel in which the invention is applied,

FIGS. 2 and 3 are longitudinal and transverse sectional views of the drying channel, taken on the lines 2—2 and 3—3 respectively of FIG. 1, and

FIGS. 4 and 5 are plots showing the distribution of wood in average packages of 18 and 21 ft. lengths respectively in Swedish saw mills.

From the dryer according to FIG. 1 one completely dried wood package at a time is taken out through the discharge end while at the same time all the other packages in the dryer are advanced by one step and a new package is inserted at the receiving end.

In FIG. 1 a number of wood batches 1—also called wood packages—wait outside of the receiving door 2 of a wood dryer 3. The wood is piled on cars which can travel on rails 4 through the dryer 3. The dryer 3 comprises a central drying channel for wood and drying air return passages 5, 6 placed on the side. The drying channel is divided into a first and a second section which are separated by an intermediate space 7. In the side walls 8 of the channel, directly in front of the intermediate space 7, axial fans 9, 10 are arranged in pairs in full symmetry with respect to the central longitudinal vertical plane of the channel. In the first section of the channel three wood packages 11, and in the second channel section four packages 12 are located. Between the packages 11 in the first section of the channel and the receiving door 2, a free space 13 is provided, and between the packages 12 in the second channel section and the discharge door 14 of the dryer 3 a free space 15 is provided. Outside of the discharge door 14 some completely dried wood packages 16 are located.

In the return passages 5 and 6 hot water heat exchanger 17 and 18 respectively are provided for heating the dry-

ing air. In the return lines 19, common to a pair of heat exchangers, motor valves 20 are mounted. The left-hand return air passages 5 are provided with inlets 21 for dry ventilation air, and the right-hand passages 6 comprise corresponding outlets 22 for moist ventilation air. Each of said outlets 22 is provided with an exhaust fan 23 and a motor-operated damper 24. The motor valves 20 and dampers 24 are actuated by controls 25 which receive their impulses from measuring means 26 and 27 for dry and wet bulb temperature respectively, which means are located in the return air passages 6.

In operation the circulation fans 9 and 10 press drying air into the intermediate space 7 and further in two directions through the wood packages 11 and 12. In the spaces 13 and 15 between the packages and the doors, the air is deflected in order to return to the circulation fans 9 and 10 through the return air passages 5 and 6. Hereby the air is heated at its passage through the heat exchangers 17 and 18. The air returning through the left-hand return air passages 5 is mixed with dry ventilation air, and from that part which returns through the right-hand passages 6 a corresponding amount of moist ventilation air is sucked out by the exhaust fans 23. During its flow through the return air passages 6 the air passes around the measuring means 26 and 27 where the dry and wet bulb temperature of the drying medium is measured. The measuring values from the means 26 and 27 are forwarded to controls 25 which via the valves 20 and dampers 24 influence the heating of the drying air and the flow of ventilation air, so that at the points 26 and 27 a certain condition of the drying air is obtained.

As is explicitly motivated above and in the following, it is highly desirable that the wood package is passed through about its central line by more air than along its edges. This is achieved in that the dryer 3 is constructed entirely symmetrically with respect to a central longitudinal vertical plane through the drying channel and in that the circulation fans 9, 10 are placed in the side walls 8 of the channel directly in front of the intermediate space 7 and arranged in pairs accurately in front of each other. The air flow when it is being delivered from an axial fan always has an axial speed profile which is very non-uniform, and thereby the flow has an axial kinetic energy exceeding that which corresponds to the mean speed required for its transport. Part of the axial kinetic energy, therefore, can be transformed into a static pressure increase by slowing up the flow. For obtaining the pressure increase right in the middle of the channel—where no walls or guide bars can be inserted, because they would obstruct the feed of the wood package—according to the invention fans are placed in every side wall, in pairs and directly in front of each other. Hereby the air is slowed in the middle of the channel without any wall having to be mounted for impeding the flow. Furthermore, in the air flow after an axial fan wheel there always is a rotation component, i.e. a tangential speed component which does not contribute to the transport of the air, but which can produce asymmetry—even when the flow channel walls are symmetric with respect to a plane through the fan shaft. Due to the fact that each of the opposite fans is given its rotating direction in relation to a coordinate system stationary in the room, the impulse moments from the two fans entirely neutralize each other, and the air flows are given a more uniform distribution in the two directions opposite to and in the motion direction respectively of the wood. Also a certain transforming of the rotation energy into static pressure is effected.

The higher static pressure created in the intermediate space 7 along the central line of the drying channels presses in more drying air along the central line of the wood packages 11 and 12 than along the sides thereof.

In FIGS. 4 and 5 the relative wood distribution obtained by piling wood in a package where the wood is drawn level to both ends of the package is drawn as

a function of a longitudinal coordinate which is equal to zero at one end of the package and equal to 18 feet (FIG. 4) and 21 feet (FIG. 5) at the other end. The figures are based on statistics from 58 Swedish sawmills, which shows the distribution of the wood length both for the centre yield and the lateral yield of the logs. The wood distribution is indicated in percent of full filling of the package, i.e. the case in which all wood had the same length equal to the length of the package. The normal package length which is equal to the maximum length of the wood, amounts at present for Swedish sawmills to 21 feet, but a change to 18 feet maximum length is taken into consideration. In both cases the wood quantity is substantially greater in the centre of the package than at its ends and, thereby, the quantity of water to be removed by drying is substantially greater in the package centre than at the ends thereof.

In a drying channel in which the wood packages are advanced in the longitudinal direction of the wood extending at right angle to its feed direction through the channel, and the drying air flows through the wood packages in the longitudinal direction of the channel in a counter-flow to the wood, as is the case in conventional longitudinal circulation dryers for wood, the dry temperature of the drying air ϑ_t will fall more in the centre of the package than at its ends, owing to the greater wood quantity and, consequently, greater evaporation in the package center, provided that the same air quantity per m.² of front area of the package, circulates about the wood in the entire package, while its wet bulb temperature ϑ_v remains constant. If it is assumed that the air flow through the channel has stream-line shape without transverse mixing of air in the longitudinal direction of the wood packages, it is possible from the wood distribution according to FIGS. 4 and 5 to calculate the difference in the temperature drop of the drying air through the dryer at the centre of the package and at its ends. If it is assumed, for example, that the side yield is dried in a 21 feet package with a wet bulb temperature $\vartheta_v=32^\circ$ C. and a dry temperature in the discharge end of the dryer of $\vartheta=50^\circ$ C., the drying air according to a Mollier diagram for moist air has a water content $x_0=0.0230$ kg./kg. If the drying air flow in relation to the wood flow is chosen such, that the drying air is saturated with water vapour in the centre of the package at its outflow out of the wood in the receiving end of the dryer, its water content there is $x_1=0.0308$ kg./kg. and the water amount taken up by the air through the evaporation is 0.038–0.0078 kg./kg. According to FIGS. 4 and 5 the relative wood quantity in the package centre is 70% and at the package ends 50%. When drying from the same starting moisture ratio to the same final moisture ratio, the evaporation at the package ends is only

$$\frac{50}{79} \cdot 0.0078 = 0.0049 \text{ kg./kg.}$$

and the water content of the drying air subsequent to the passage in the dryer is

$$0.0230 + 0.0049 = 0.0049 \text{ kg./kg.}$$

which according to the Mollier diagram corresponds to a temperature $\vartheta_t=38.7^\circ$ C. The psychrometer difference $\vartheta_t - \vartheta_v$, thus, would be in the centre of the package 0° C. and at the ends of the package $38.7 - 32.0 = 6.7^\circ$ C.

In reality, the difference in the psychrometer difference is not so great, which partly is due to the fact that a certain transverse mixing of air occurs in the intermediate space between the wood packages, i.e. the air flow is not streamlineshaped, and partly due to the fact that because of the variation in the psychrometer difference the wood will dry to a lower moisture ratio at the package ends and, consequently, the total evaporation there will be somewhat greater than assumed in the calculation. At measurements of the dry and wet bulb temperatures of the drying air close to the receiving end of

a dryer, when ¾" side boards are being dried, the psychrometer difference 0° C. and 3.7° C. respectively were obtained at the same psychrometer difference in the discharge end as it was assumed in the calculation, i.e. 50-32=18° C. The transverse yield, thus, is not sufficient for compensating for more than about half of the non-uniformity, due to the wood distribution in the packages, of the drying conditions in the centre and at the ends of the package.

As the moisture absorption in the air all the time is equal to the evaporation from the wood, and a change in the moisture content of the air is almost proportional to a change in its temperature, the psychrometer difference varies through a longitudinal circulation dryer very close to linear with the wood moisture ratio. In view of the psychrometer differences 0° C. and 3.7° C. at the receiving end and 18° C. at the discharge end of the dryer, therefore, the mean psychrometer difference at drying in the package centre and at the package ends in reality is

$$\frac{18+0}{2}=9.0 \text{ and } \frac{18+3.7}{2}=10.85^{\circ}\text{C}$$

respectively, and, thus,

$$\frac{10.85-9.0}{9.0} \cdot 100 = 20.5\%$$

greater at the package ends during the drying. This constitutes a considerable systematic non-uniformity in the drying conditions, which gives rise to an over-drying of the package ends. This over-drying causes both a non-uniform moisture ratio in the dried wood and a non-uniform shrinkage during the drying in the longitudinal direction of the wood, thereby giving rise to additional stresses in the wood which may result in cracks and deformations of the wood. If the wood is to be dried only to a moisture ratio such as to prevent storing damages caused by mould development, due to the over-drying the outgoing mean moisture ratio must be lower than it had to be at uniform drying, because the wettest portions at the centre of the package must be dried to the moisture ratio limit providing safety against mould development.

It, therefore, is understood that the apparatus which according to the invention increases the circulation air quantity in the centre of the channel and decreases it to the side walls of the channel, offers a considerable gain with respect to the uniformity of the drying. By dividing the drying channel into two sections, the number of wood packages passed through by the drying air in series, counted from the package initially passed through, is reduced and, thereby, the desired effect is increased.

What is claimed is:

1. In apparatus for drying material in packages having a greater distribution of material at their longitudinal center than at their ends; said apparatus comprising opposed side walls defining therebetween an elongated drying channel, means to advance said packages stepwise along said channel with the longitudinal direction of the packages disposed perpendicularly to the longitudinal direction of the channel, said advancing means operating to leave a space intermediate the ends of said channel dividing it longitudinally into two sections, and means to supply drying medium to said space to cause flow of drying medium counter-current to the direction of advance in one section and concurrent to the direction of advance in the other section,

the improvement wherein said supply means includes axial fans mounted in said opposed side walls confronting each other with their shafts substantially perpendicular to the central longitudinal vertical plane of the channel and adapted to blow drying medium into said space in flows which merge in said central plane and increase static pressure to provide more drying medium along said plane.

2. Apparatus according to claim 1 wherein the directions of rotation of said confronting axial fans are such that the merging flows are rotating counterdirectionally to thereby neutralize the rotary motion of each other.

3. Apparatus according to claim 1 or 2 wherein said packages are of substantially uniform length, and said material comprises wood pieces of varying lengths, stacked in said packages, said varying lengths being no greater than the length of said packages and averaging greater than one half the length of said packages, said supply means including a return channel for drying medium paralleling said drying channel and means in said return channel to control the condition of the drying medium to effect sufficient drying of the package centers to prevent the formation of mould.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,445,939 Dated May 27, 1969

Inventor(s) Lars Malmquist

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, line 7, "dmaper" should be --damper--. Column 4, line 41, "s" should be -- s. --; line 59, "0.0049 kg./kg." should be --0.0279 kg./kg.--.

SIGNED AND
SEALED

MAR 3 - 1970

(SEAL)

Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents