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ACCELERATED AIR-DRYING OF SPRUCE AND BALSAM FIR LUMBER

by
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ABSTRACT

Because of the growing demand for dry softwood lumber, and the importance of speed in the drying process, the Ottawa Laboratory conducted a pilot study of forced air-drying.

Separate piles of 1- and 2-inch lumber were dried by directing the air flow from multiblade fans, 4 feet in diameter, through the lumber pile. The airflow had an average terminal velocity of 450 fpm as it left the pile. Two humidistats switched the fans off when the air humidity exceeded 90 percent or was less than 35 percent.

The results of this work indicate that drying 1- and 2-inch spruce-balsam lumber with forced air-circulation is feasible. Because of the reduction in shipping weight, the delivered cost of forced-air-dried lumber is less than the delivered cost of green lumber. The required drying time for forced air-drying is considerably less (41 and 22 percent for 1- and 2-inch lumber respectively) than for conventional air-drying, although it costs more than conventional air-drying.

EXTRAIT

Le bois tendre et sec étant employé de plus en plus à
l'heure actuelle, il importe de réduire autant que possible le
temps nécessaire au séchage du bois. Les chercheurs du labo-
ratoire d'Ottawa ont donc entrepris une étude sur le séchage
à air propulsé.

Des ventilateurs, d'un diamètre de 4 pieds et à plusieurs
pales, propulsent à travers les piles séparées de bois de
sciage (celui-ci épais d'un ou 2 pouces) un courant d'air à une
vitesse qui, en sortant de la pile, mesure en moyenne 450 pieds
à la minute. Soigneusement réglés, les ventilateurs cessent de
fonctionner quand l'humidité de l'air dépasse 90 p. 100 ou de-
vient moindre que 35 p. 100.

Il est démontré que pour le bois de sciage d'Épinette et de
Sapin baumier, épais d'un ou deux pouces, le séchage à air pro-
pulsé est faisable. Bien que le coût soit plus élevé que celui
du séchage ordinaire, le temps requis est sensiblement réduit
(de 41 et 22 p. 100 pour le bois épais d'un pouce et de 2 pouces
respectivement); en outre, le bois étant devenu plus léger, on
économise sur le transport.

Frontispiece (a). Piling of experimental material.
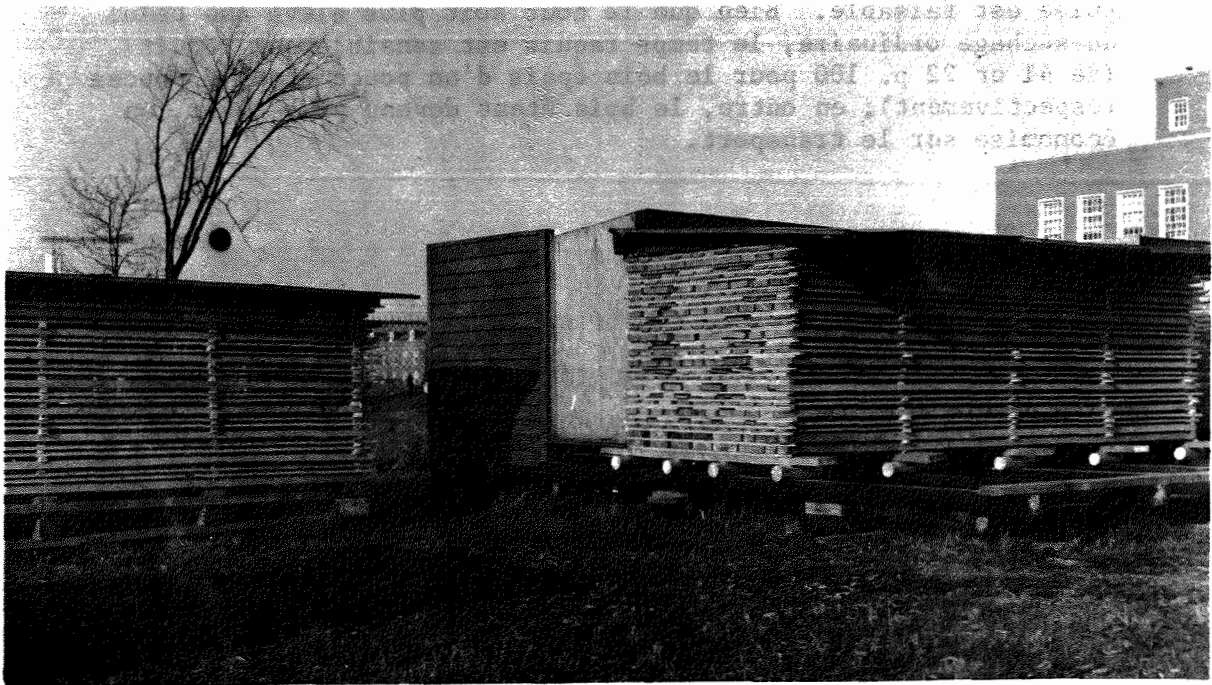
Frontispiece (b). Forced-air-drying unit in operation.

ACCELERATED AIR-DRYING OF
SPRUCE AND BALSAM FIR LUMBER

by

M.Y. Cech and D.R. Huffman[1]

INTRODUCTION

Because of the growing demand for softwood lumber dried down to
19 percent moisture content (M.C.), and to the progressive reduction in
the market for lumber which has not been dried to this level, the drying
phase of the lumber manufacturing process is currently the focus of con-
siderable attention and research. During the drying process in stickered
lumber piles, the amount of moisture moving to the lumber surfaces is often
greater than the amount which can be absorbed or removed by the normal flow
of air. Prevailing winds generally have a low moisture absorption capacity
owing to their low temperature (compared to that used in kilns) and to their
low velocity through the pile. Wind velocity is often reduced to a negli-
gible level because of overcrowded lumber yards. Natural wind is therefore
of limited value because it cannot be ordered when needed nor can it be
shifted to the direction and speed most desirable for efficient drying.

To provide a sufficient inventory to fill the normal, fluctuating
demand for dry lumber, a company relying on conventional air-drying would
require a very large lumber inventory at various stages in the drying pro-
cess. This would require a large amount of tied up capital and high carry-
ing charges. A far better solution is to develop a method of drying lumber
quickly and cheaply, with reduced degrade, so that a rapid, profitable
turnover of a small inventory is possible. With this objective in mind,
forced air-drying experiments were conducted at the Ottawa laboratory using
lumber donated by the Maritime Lumber Bureau. Additional studies are under-
way in New Brunswick.

MATERIAL AND METHODS

In August 1967, the laboratory received green 1- and 2-inch
eastern spruce and balsam fir lumber, 16 feet long, consisting of equal
amounts of "construction" and "standard" grades. Each species (two) and

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[1]Department of Forestry and Rural Development of Canada, Forest Products
Laboratory, Ottawa.

each thickness (two) was divided into two equal groups. The first group
consisted of two piles designated for forced air-drying in the units illus-
trated in the frontispiece. The fan units were parallel to, and 4 feet
away from, the lumber piles. This distance was used because it provided
more uniform airspeed distribution throughout the pile (with respect to
length and height) than at any other position. The first pile comprised
mixed 1-inch spruce and balsam fir, and the second pile mixed 2-inch mat-
erial.

The second group consisted of two matched control piles which
were stacked to one side of the fan unit where they were subjected simply
to normal outdoor-drying conditions. In all cases the lumber was stacked
in layers separated by 13/16-inch sticks to form piles 6 feet wide and 7
feet high. Sample boards were built into the piles in the usual way for
determining the progress of drying. A plywood roof was erected over each
pile to protect it from rain and sun.

Each fan unit consisted of two multiblade fans, 4 feet in diameter,
mounted at 8-foot centers on a wooden platform 16-1/2 by 6 feet. These
fans were driven by a 10 hp motor through three V-belts at 265 rpm. The
airspeed tests indicated that the air current produced by the fans had a
terminal velocity of 450 fpm as it left the pile. Electric power consump-
tion was kept to a minimum by installing two humidistats to stop the fans
when the humidity was too high or too low. The low level was set at about
35 to 40 percent, to avoid checking. A watt-hour meter and a timer were
installed to measure the total power consumed during the drying test.

Sample boards were removed daily from all piles for weighing to
determine the rate of drying; and periodically every board in each pile
was weighed and examined by a grader. Warp measurements were made using a
dial gauge mounted on a specially constructed table. No data were collected
on surface and end checking because this type of degrade was practically
nonexistent. The study started in mid-August and continued until the end of
October.

RESULTS AND DISCUSSION

Drying Rates

Figures 1 to 4 illustrate, graphically, the average drying rates
in the forced-air and control piles (based on all boards used in this study).
Balsam fir dried faster than spruce. In the case of 1-inch material dried
with forced air, the M.C. loss per hour of drying was 22 percent higher
than in spruce. In 2-inch material the M.C. loss was 16 percent higher. In
the control piles the M.C. loss per hour was 16 and 17 percent higher for
1- and 2-inch balsam fir respectively.

Forced air-drying is compared with conventional air-seasoning in
Table 1. It is interesting to note that the 1-inch green forced-air material
reached an average M.C. of 19 percent approximately 10 to 11 days sooner than
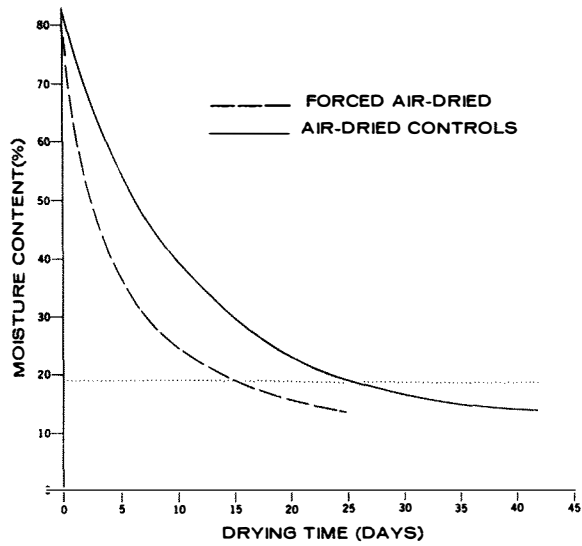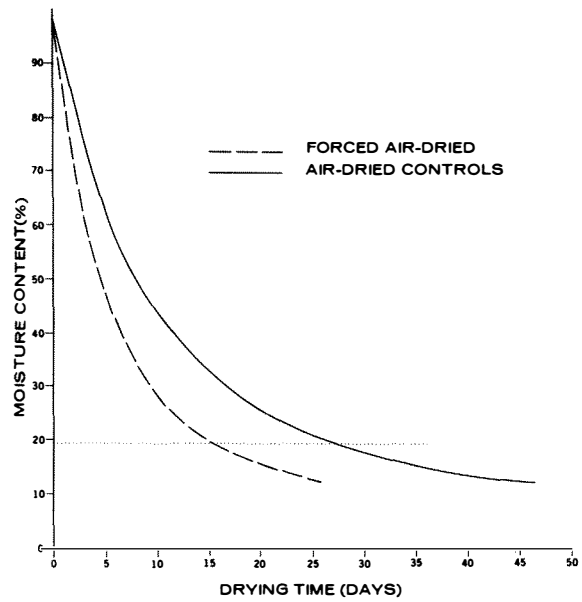
Figure 1. Drying rate for 1-inch spruce.

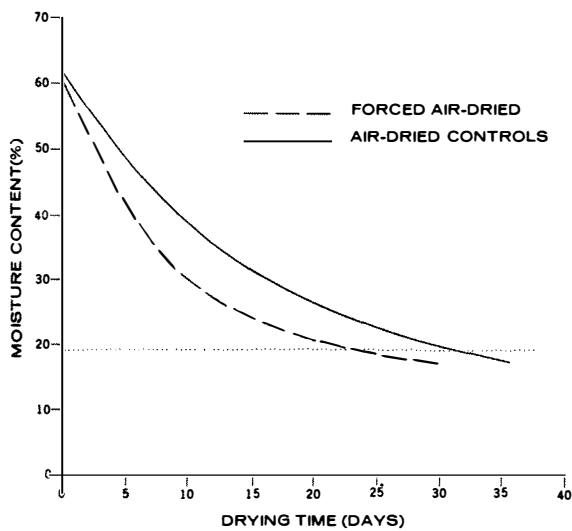Figure 2. Drying rate for 1-inch balsam fir.
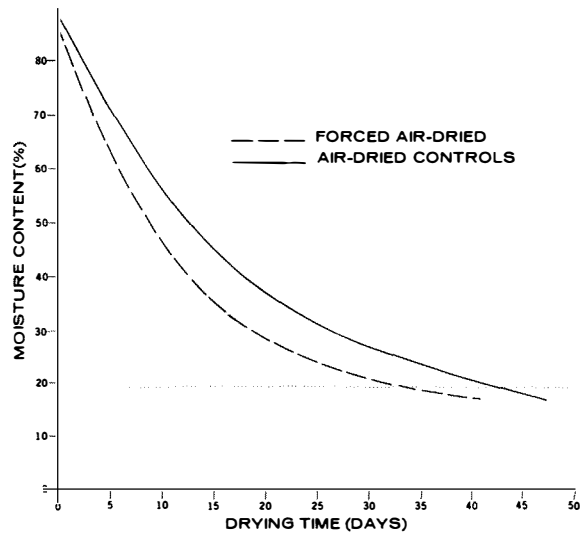

Figure 3. Drying rate for 2-inch spruce.

Figure 4. Drying rate for 2-inch balsam fir.

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TABLE 1. DRYING TIME (DAYS) *(From Green to 19% M.C.)*

	Spruce		Fir	
	1-inch	2-inch	1-inch	2-inch
Air-dried controls	24.8	31.3	26.9	43.4
Forced air-dried	14.9	24.2	15.4	33.8
Percent decrease in drying time	39.9	22.7	42.8	22.1

the controls. In 2-inch material the decrease in drying time was somewhat less; both spruce and balsam fir attaining 19 percent M.C. earlier than the controls - in 7 and $9\frac{1}{2}$ days respectively. The greater saving in drying time, in the case of thinner stock, occurs because of the shorter distance the moisture must travel from the core to the board surface. Consequently, the interior moisture can be moved to the surface faster than the fan system can supply a sufficient volume of air to remove all of the surface moisture. In 2-inch stock, the rate at which moisture reaches the surfaces from the core is much less than the available airflow can absorb and remove it.

Figure 5 shows the daily drying conditions and the resulting average equilibrium moisture content (EMC) during the test period. Although the drying conditions can be described as average for that time of the year, the fans operated only 490 out of 960 hours (Figure 6). Power consumption ranged from 0.25 to 1.60 kw per hour of fan operation. This was apparently influenced by wind velocity and direction. The average power consumption was 0.96 kw per hour.

Degrade

As stated previously, surface and end checking were practically nonexistent in both the forced-air material and controls. Warp measurements were made on all boards and the average values are given in Table 2. Most forced-air boards developed less twist, crook, and bow than did the controls; however, the 2-inch spruce and balsam fir lumber developed slightly greater twist during forced air-drying. The amount of warp developed in both control and forced-air material was substantially below the limits allowed in construction grade by the spruce grading rules.

Cost Considerations

In order to make a comparison of forced and conventional air-drying costs, it is necessary to consider a commercial-size drying unit. From the results obtained in current laboratory forced-air studies using larger piles, it is apparent that such a unit could handle up to 7M fbm of 1-inch or 10M fbm of 2-inch lumber without affecting the drying time or
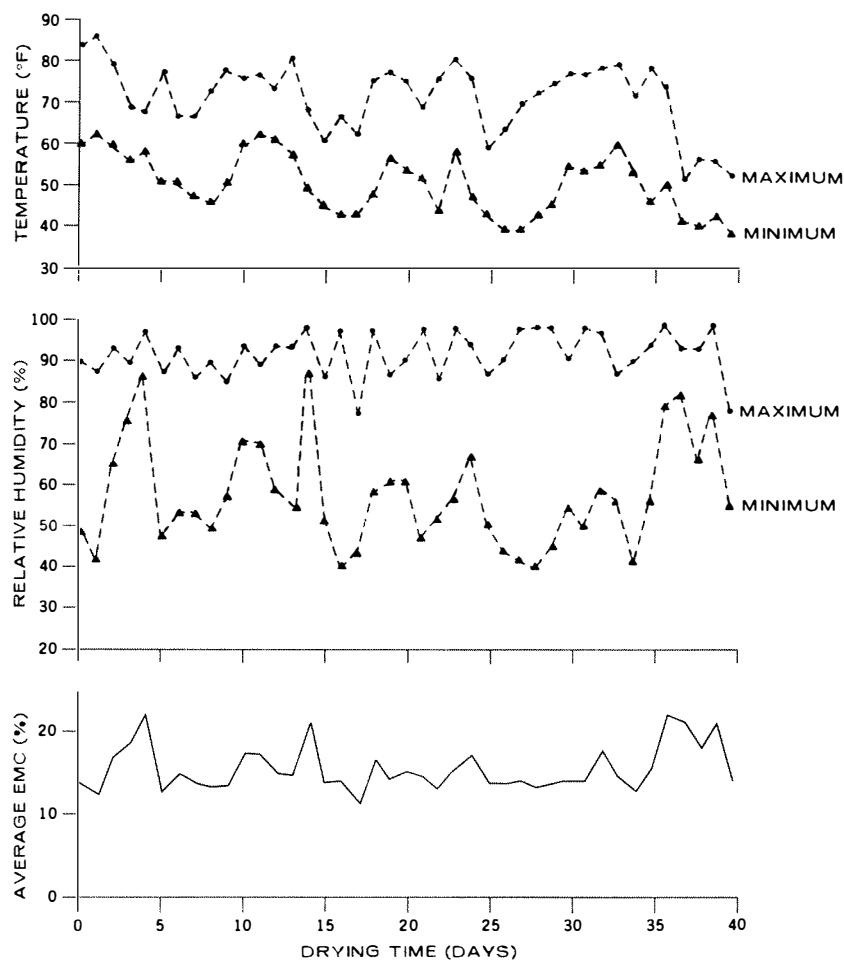
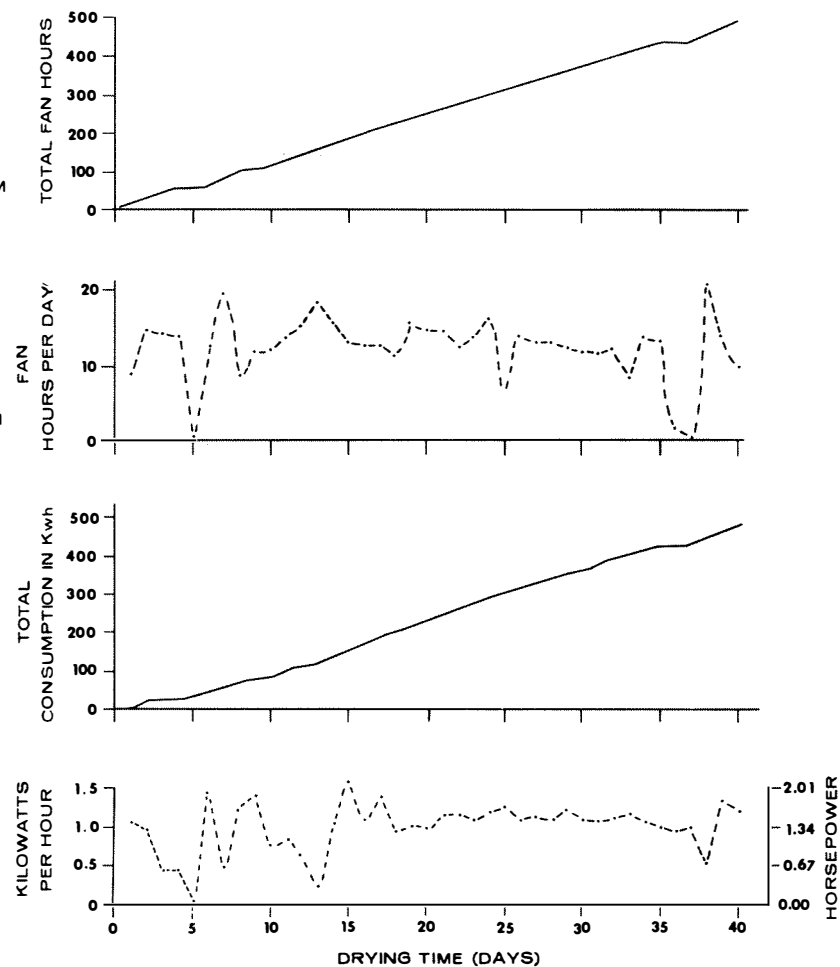Figure 5. *Daily drying conditions commencing August 16, 1967.*

Figure 6. *Fan operating time and power consumption.*

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TABLE 2. MEASUREMENTS OF WARP AT 19% M.C.

	Warp		
	Twist in./in./ft.	Crook in./ft.	Bow in./ft.
	$(x\ 10^{-3})$	$(x\ 10^{-3})$	$(x\ 10^{-3})$
1-inch			
Spruce			
Forced-air	0.33	9.38	2.04
Air-dried controls	0.73	11.06	2.02
Fir			
Forced-air	0.42	8.97	2.06
Air-dried controls	0.60	10.10	2.26
2-inch			
Spruce			
Forced-air	1.31	7.39	1.88
Air-dried controls	0.57	8.10	2.32
Fir			
Forced-air	1.90	9.40	2.26
Air-dried controls	1.22	11.00	2.91
Allowable in construction grade according to spruce grading rules	10.4	63.0	104.0

power consumption to any significant degree. The cost calculations in this report are based on a unit with this drying capacity.

The cost of shipping dry lumber is compared with the cost of shipping green lumber and the resultant savings per thousand board feet are shown in Table 3. The cost of fans, motor, mounts, humidistats, and wooden

TABLE 3. EFFECT OF FORCED AIR-DRYING ON DELIVERED COST OF SPRUCE AND BALSAM FIR LUMBER (_per M fbm_)

Lumber thick-ness (in.)	Unseasoned weight of mixed charge (lb.)	Shipping weight-seasoned (lb.)	Shipping cost		Cost of drying		Net saving ($)
			Green ($)	Forced air-dried ($)	Electri-city ($)	Equipment ($)	
1	3310	2390	23.17	16.73	0.25	2.13	4.06
2	3141	2390	21.99	16.73	0.41	3.27	1.58

housing (including erection) was about $960. Straight-line depreciation of this cost on the basis of five 200-day years is about $0.96 a day. Cost of electricity consumed was estimated at one cent per kwh. Other costs, such as interest and insurance on inventory; cost of labor for stickering; operating lift trucks; moving roof, etc., are not included. Obviously, the interest and insurance charges would be considerably lower for forced air-drying, whereas the lumber handling costs would be about equal. Shipping weights for both green and seasoned lumber were calculated using data from this study, i.e., 100 and 85 percent M.C. in 1- and 2-inch lumber respectively. The freight rate was estimated to be $0.70 a hundred pounds (Fredericton to Toronto).

It is important to realize that these data are based on a relatively small study conducted in one location. The various factors which determine the final cost of drying, such as electric power and freight rates; the weight and moisture content of green lumber; and the ambient drying conditions will all vary considerably according to the location of the sawmill. However, it is felt that the limited cost information presented in this report will allow a sawmill manager to make a preliminary assessment for his particular operation.

For each thousand board feet of 1-inch lumber, forced air-drying reduced the weight of green lumber by 920 lb.; and for 2-inch lumber, by 751 lb. The shipping costs, influenced by this reduction in weight, were therefore reduced by $6.44 and $5.26 per M fbm respectively. The net savings after deducting the costs of drying were $4.06 and $1.58 respectively per M fbm (Table 3).

Comparison with Conventional Air-drying

Tables 1 and 3 indicate that the drying times and costs for conventional air-dried 1-inch spruce are 24.8 days plus handling costs, whereas forced-air material requires 14.9 days and costs $2.38 per M fbm plus handling costs. The obvious question arises: is the saving of 9.9 days worth the additional cost of $2.38 when the combined interest and insurance charges are much less than $2.38 and the air-drying degrade is within acceptable limits?

The main considerations are the effect of the drying method on the total lumber volume that can be dried per year and especially on the volume that can be dried per month during the peak-demand season. This study was conducted in mid-August during optimum air-drying conditions. However, if we consider the ambient air-drying capacity in early spring or late fall, the situation is much different. One-inch lumber piled for air-drying in late March will not reach 19 percent M.C. until late June; but if it is forced air-dried it will reach 19 percent by mid-May, i.e., the saving in drying time would be about 2 to 3 times the 40 percent saving achieved in August. The results of previous unpublished studies indicate that lumber piled for conventional air-drying later than mid-September will not reach 19 percent M.C. until the end of next May, or about 240 days. On the other hand, forced air-dried lumber would be ready by late October.

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It is obvious that a comparison between conventional air-drying and forced air-drying should be based on an 8-month drying season rather than on the short July-August period when most areas enjoy optimum air-drying conditions.

Forced air-drying will permit a much higher annual production of lumber at 19 percent M.C., with a much smaller inventory and, most important, it will produce a considerable volume of dry lumber in May and June when conventionally air-dried lumber is just not ready.

Moisture Content Uniformity

Moisture content distribution before and after drying is shown in Figures 7 to 10. The M.C. distribution in the green material was probably somewhat wider than normal owing to partial air-drying of the exposed board surfaces during shipping from New Brunswick.

The data for 1-inch lumber (Figures 7 and 8) show that material dried with forced air-circulation had a less uniform M.C. distribution than the controls. For instance, in spruce, a maximum variation of ±6 percent M.C. from the average (i.e., an M.C. range from 13 to 25 percent) included 93 percent of the control boards and only 73 percent of the boards that were forced air-dried.

In 2-inch lumber, however, the forced-air-dried material had a more uniform moisture content distribution (Figures 9 and 10). In spruce a range of ±6 percent in M.C. (from the average) included 95 percent of the forced-air material and 91 percent of the air-dried controls. In balsam fir, the conventionally air-dried controls had substantially greater variation in final moisture content, but this wide variation was also present in the green material.

This study indicates that forced air-drying does not increase the final M.C. variation in 2-inch material in comparison to conventional air-drying. Forced air-drying did increase the moisture content variation in 1-inch lumber, but it would not be considered significant in commercial practice.

SUMMARY AND CONCLUSIONS

(1)   The results of this work indicate that drying 1- and 2-inch spruce and balsam lumber with forced air-circulation is feasible. Due to the reduction in shipping weight, the delivered cost of forced-air-dried lumber is less than the delivered cost of green lumber. The required drying time for forced air-drying is considerably less (41 and 22 percent for 1- and 2-inch lumber respectively) than for conventional air-drying, although it costs more than conventional air-drying.
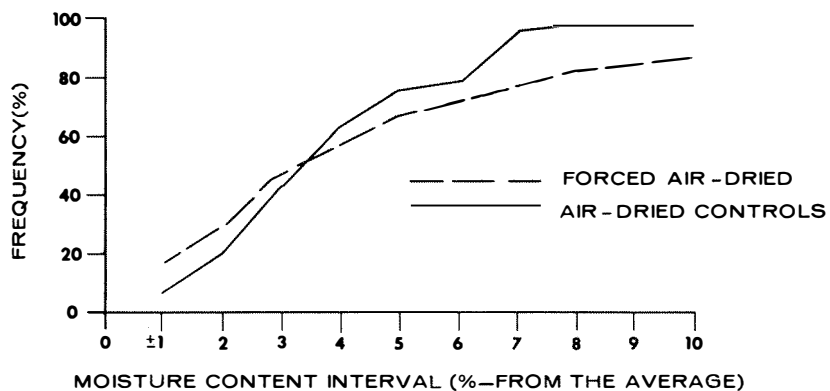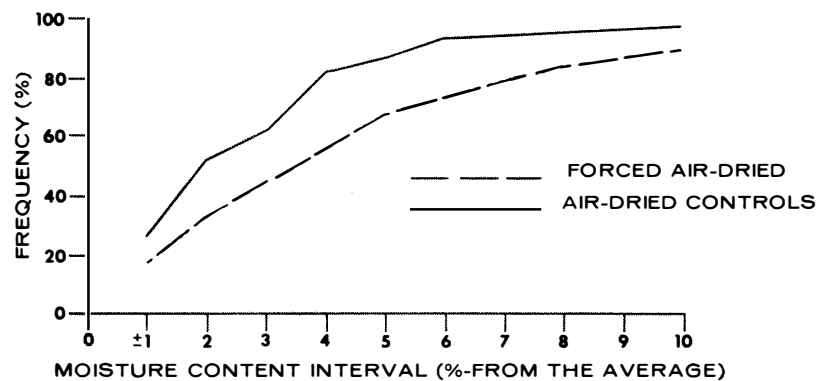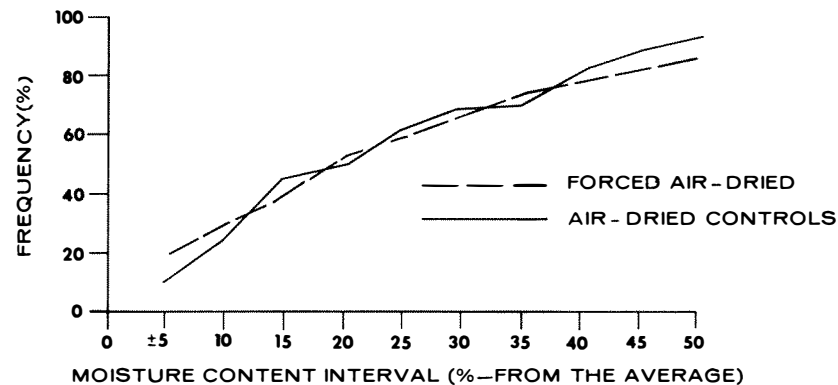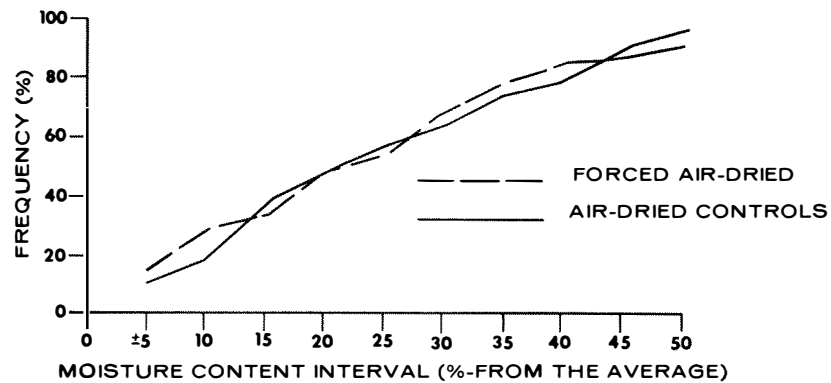
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Figure 7. *Moisture content distribution in 1-inch spruce.*
Top: Green (82.5% average M.C.)
Bottom: Air-dried (19% average M.C.)

Figure 8. *Moisture content distribution in 1-inch balsam fir.*
Top: Green (99.6% average M.C.)
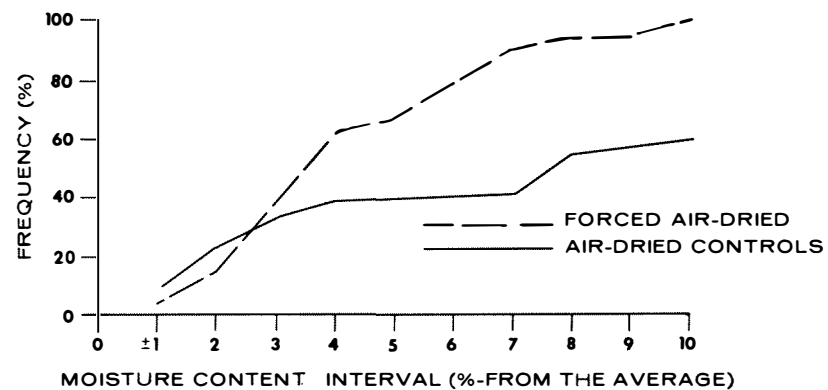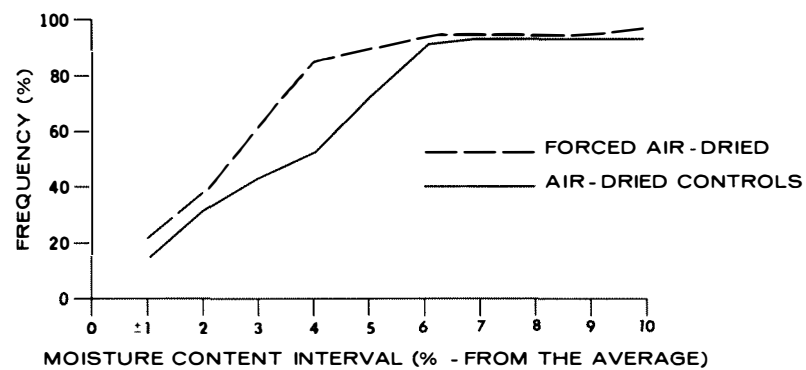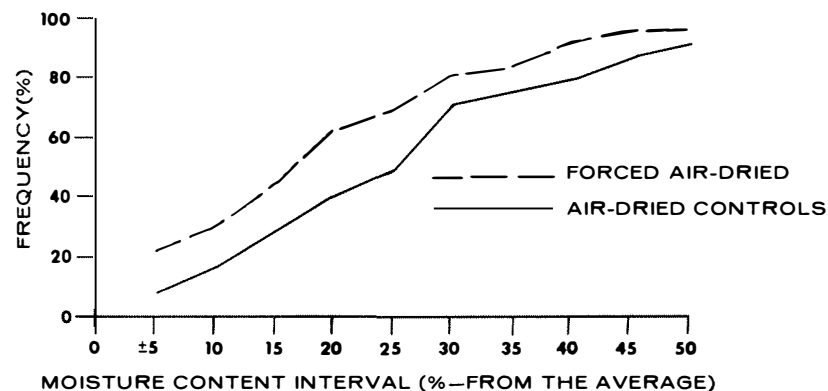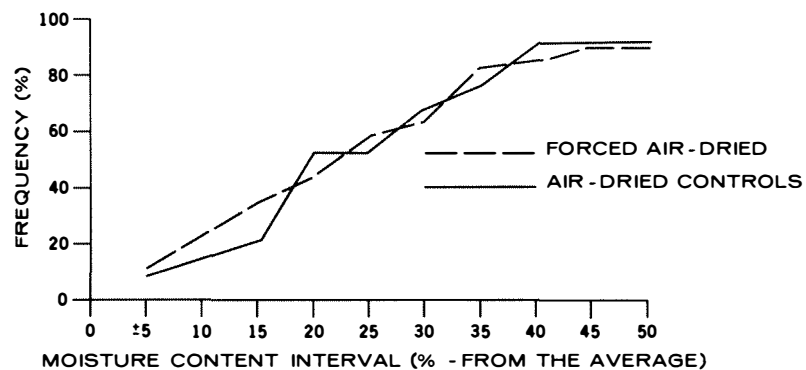*Bottom: Air-dried (19% average M.C.)*

Figure 9. *Moisture content distribution in 2-inch spruce.*
Top: Green (62% average M.C.)
Bottom: Air-dried (19% average M.C.)

Figure 10. *Moisture content distribution in 2-inch balsam fir.*
Top: Green (88.8% average M.C.)
Bottom: Air-dried (19% average M.C.)

(2)   Required investment for a forced-air-drying unit is small enough
to make this drying process feasible in many sawmills presently without
dry-kilns.

(3)   Although balsam fir usually has a higher initial moisture content
than spruce, it was found that fir dried slightly faster, resulting in a
similar total drying time. Therefore segregation of these two species is
not required (unless fir "sinker stock" is involved).

(4)   The 1-inch forced-air material had a wider variation in final
moisture content distribution than 2-inch lumber, due to the substantially
faster drying rate of the 1-inch lumber.

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