# SOME EXPERIMENTS WITH HIGH TEMPERATURE DRYING (1)

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Drying lumber at temperatures above the boiling point of water is not a new process. In 1867 a patent was granted in the United States for "Apparatus for Drying and Seasoning Lumber by Superheated Steam." Tiemann (2) in "The Kiln Drying of Lumber" published in 1917 described the experimental work he carried on with his associates on the drying of lumber by superheated steam. In 1918 Tiemann was granted a patent for his superheated steam kiln. It is reported that in the same year several of these kilns were in operation on the west coast. However, very little has been heard of these kilns since that time.

Drying wood at temperatures above 212° F. was revived in Germany during World War II, and German investigators were instrumental in creating interest in this form of kiln-drying in Europe, the United States and Canada.

There are two processes of high temperature drying. The first developed by Tiemann and other experimenters, uses superheated steam; i.e., steam above the boiling point of water. In this system the steam occupies the kiln to the complete exclusion of air. The steam can give up its superheat without condensing and thus act as a drying agent. Since there is no air present, relative humidity relationships are not applicable and temperature is the only control possible. Superheated steam, like air, requires circulation to carry its heat to the lumber.

A mixture of air and steam is used in the other process. This process was developed by German technologists and is the one being used by the Ottawa and Vancouver Laboratories. It resembles the conventional type of drying in that both wet and dry bulbs are used for control and different degrees of saturation are possible.

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(1) A contribution from the Vancouver Laboratory, Forest Products Laboratories of Canada, a Division of the Forestry Branch, Department of Northern Affairs and National Resources.

(2) Tiemann, H. D., "The Kiln Drying of Lumber." J.A. Lippincott Co., 1917.

In 1952, a small pilot kiln was loaned to the Ottawa Laboratory of the Forest Products Laboratories of Canada by a German manufacturer and preliminary investigations were started on Eastern species. Two runs each were also made on Douglas fir, western hemlock and western red cedar. This kiln was of a semi-commercial type, all metal construction, holding 500 ft. b.m. of lumber, electrically heated, with a steam line for humidification. There was a thermostat to control temperature but no means of controlling humidity, although the rate at which the humidity fell could be controlled, to a certain extent, by the intake and outlet dampers.

Ladell (3) reports that in general the quality of the dried lumber was very good. The extremely rapid drying, however, caused severe casehardening. Very little checking--either end or surface--resulted, and the knots remained firm; although some splitting of tight knots was observed in hemlock and Douglas-fir. Twisting, bowing, cupping and crook were negligible. The material milled satisfactorily, and there was slight discoloration. A charge of white pine was dried, and there was no trace of chemical brown stain, possibly because of the relatively short period during which the lumber was under conditions of high temperature and relative humidity.

Variation in moisture content, both in individual boards and throughout the charges, was considerable, but conditioning treatments carried out on subsequent charges materially reduced this variation. Some of the data obtained are listed in Table 1.

After the results had been thoroughly analyzed, it was apparent that this kiln was not satisfactory for experimental work and that certain important factors could not be evaluated until new equipment became available. A new kiln

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(3) Ladell, J. L., Mimeo. O-170, High Temperature Kiln-drying of Canadian Woods. Dept. of Northern Affairs and National Resources, Forestry Branch, Forest Products Laboratories Division, Ottawa.

Table 1.--Drying tests - Western species.

| Run no. | Species | Thickness | Average drying temp.* | Air-vent settings |  | Average moisture content |  | Warming up period |  | Drying time |  | Cooling period |  | Conditioning period |  | Total time |  | Average drying rate ** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  | Intake | Exhaust | Initial | Final |  |  |  |  |  |  |  |  |  |  |  |
|  |  | in. | °F. |  |  | MC-% | MC-% | hrs. | min. | hrs. | min. | hrs. | min. | hrs. | min. | hrs. | min. | % MC/hr. |
| 1 | Western hemlock | 1 | 237 | 1/3 open | wide open | 75.2 | 5.2 | 2 | 29 | 25 | 26 | 4 | 10 | 0 | 44 | 32 | 49 | 2.8 |
| 2 | " | 2 | 237 | " | " | 56.4 | 7.0 | 3 | 01 | 45 | 59 | 5 | 09 | 1 | 00 | 55 | 09 | 1.1 |
| 3 | Douglas fir | 1 | 235 | " | " | 47.3 | 8.2 | 4 | 03 | 17 | 31 | 5 | 56 | 0 | 40 | 28 | 10 | 2.2 |
| 4 | " | 2 | 237 | " | " | 41.2 | 7.2 | 2 | 40 | 34 | 55 | 5 | 53 | 1 | 01 | 44 | 29 | 1.0 |
| 5 | Western red cedar | 1 | 234 | " | " | 45.4 | 6.6 | 1 | 44 | 24 | 11 | 6 | 05 | 0 | 45 | 32 | 45 | 1.6 |
| 6 | " " | 2 | 235 | " | " | 36.1 | 12.5 | 2 | 38 | 28 | 32 | 5 | 50 | - | nil | 37 | 00 | 0.8 |

*Drying temperatures were maintained at approximately 230° F. for most of run, and were increased to approximately 250° F. when charge was below the fiber saturation point.

**During drying period only.

embodying many improvements, including reversible circulation, was designed and built at the Ottawa Laboratory, Forest Products Laboratories of Canada. Recent tests in this new kiln have shown that variations in moisture content can be largely eliminated by using a sufficiently high circulation rate (500 ft./min.) and reversing the circulation at regular intervals.

In view of the large number of species and sizes that need to be tested in Canada, it was decided to design and construct an additional small high temperature unit at the Vancouver Laboratory.

This paper provides a brief description of the latter kiln, the method of operation, and some of the findings that have been observed to date.

## Description of Equipment at Vancouver Laboratory

Restrictions of space at the Laboratory limited the size of the unit so that, compared with a commercial installation, it is relatively small; holding approximately 100 ft. b.m. of 1" lumber. However, for experimental work this is somewhat of an advantage, since matched charges can be dried under different schedules simply by cutting long boards into lengths suitable for the kiln.

The chamber is constructed of sheet aluminum and insulated with glass wool. The joints of the inner walls are welded so that no moisture can escape into the insulation. Drains are provided in the floor to carry away condensed moisture. Circulation is provided by two aluminum 18" propeller type fans above a false ceiling. The speed of these fans can be varied to give air velocities through the load of between 400 and 1100 feet per minute. One fan revolves clockwise and the other counter-clockwise, so as to eliminate spiralling circulation, and thus provide a uniform flow of air across the kiln. Automatic air outlets and inlets are provided. Heating is by electrical coils automatically controlled by the recording instrument, although provision is made to heat the installation by steam coils if necessary. Humidity during the run is provided by an immersion heater. During the warming up period, however, live steam from a boiler is used for this purpose.

The recorder controller instrument has a range of 80° F. to 300° F. There are wet and dry bulbs on the incoming air side which record and control. A third bulb on the outgoing air side records only and may be used as a wet or dry bulb.

Doors and dampers have silicone rubber gaskets to make them vapour-proof. Silicone rubber has been found to retain its resiliency at high temperatures and so far has remained soft and pliable. The kiln has been in use for 8 months.

Recently, a platform scale was installed. This scale weighs the whole load in the kiln so that the rate of drying and the moisture content can be determined at any stage of the drying period. This gives better control of the final moisture content, since it is not possible to use test boards with high temperature drying as with conventional drying.

## Procedure

Lumber is piled in the kiln in the usual manner and the weight recorded. Moisture content determinations are made by cutting sections from a selected number of boards. The oven-dry weight of the load is therefore determined, and the weight at 8 percent is calculated. When the load reaches this predetermined weight, the heat is turned off.

Warming up is accomplished by injecting live steam into the kiln. This was found to be the best and quickest method of heating the lumber thoroughly. When the temperature reaches 212° , the controller is set to the temperature required, and the run is on its way. The live steam is then turned off. The moisture evaporated from the lumber with the addition of vapour from a small immersion heater keeps the wet bulb at the required setting.

When the moisture content of the load, determined by the weight, reaches 8 percent, the heat is turned off and the dry bulb allowed to drop to the wet bulb setting. This is equivalent to conditioning, and it has been found that casehardening is almost eliminated by this procedure.

When the wet and dry bulb temperature are at the same reading, the immersion heater is turned off and the whole charge allowed to cool to 100° F. It was found that if the charge was removed at elevated temperatures, severe end and surface checking occurred.

## Results and Discussion

The results of two series of kiln runs, one western hemlock and one Douglas fir, are shown in Tables 2 and 3. Due to mechanical difficulties, it was not possible to vary the circulation rate except in the last two runs of hemlock so that most of the data on hemlock are based on a circulation of 420 feet per minute through the load. The circulation for the fir runs was 800 feet per minute. Kiln checks were assessed as slight, medium and severe. Slight checks ranged from almost invisible hair checks to visible checks which would completely surface out on machining. Medium checks consisted of those appearing as fine checks after dressing which might degrade the piece. Through checks and splits were classified as severe checks. Considering the harsh conditions in the kiln, the degrade was not considered severe.

Figures 1, 2 and 3 show the drying rates of 1-inch hemlock under varying conditions of temperature, steam saturation and air speed. These drying rates were recorded only for the last few runs when it was possible to weigh the whole kiln charge at regular intervals.

## General Observations

The data discussed in this paper are of a preliminary nature only, and much more work is required before definite and final recommendations can be made. Past research in respect to high temperature drying using superheated steam disclosed that the construction materials in conventional kilns did not stand up to heat and resultant corrosion. That still holds true today. High temperature kilns must be made of materials that do not deteriorate through the action of heat and superheated vapour. Aluminum seems to stand up satisfactorily and is one of the cheapest materials for this purpose.

Table 2.--Schedules, times, moisture content and degrade of eight charges of 1" Western hemlock

| Circ. F.P.M. | D.B. °F. | W.B. °F. | R.H. % | Wet steam sat. | Time in hours | | | | Moisture content - % | | Degrade - percent | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Warm | Dry | Cool | Total | Initial | Final | None | Slight | Med. | Severe |
| 420 | 220 | 200 | 67 | 80 | 1 | 39½ | 5 | 45½ | 65 | 9 | 92 | 5 | 3 | - |
| 420 | 220 | 180 | 42 | 50 | 3/4 | 28 | 5 | 33-3/4 | 63 | 8 | 90 | 10 | - | - |
| 420 | 240 | 200 | 47 | 80 | 1 | 18 | 5 | 24 | 58 | 9 | 78 | 8 | 7 | 7 |
| 420 | 240 | 180 | 30 | 50 | 3/4 | 14½ | 5 | 20¼ | 58 | 9 | 73 | 17 | 8 | 2 |
| 420 | 265 | 200 | 30 | 80 | 1 | 13 | 5 | 19 | 63 | 11 | 95 | - | - | 5 |
| 420 | 265 | 180 | 19 | 50 | 1-3/4 | 12 | 5 | 18¼ | 61 | 11 | 85 | 5 | 8 | 2 |
| 600 | 220 | 200 | 67 | 80 | 1 | 30½ | 5 | 36½ | 60 | 10 | 88 | 7 | 3 | 2 |
| 600 | 220 | 180 | 42 | 50 | 3/4 | 19-3/4 | 5 | 25½ | 57 | 10 | 96 | 4 | - | - |

Table 3.--Schedules, times, moisture content and degrade of six charges of 1" Douglas fir

| Circ. F.P.M. | D.B. °F. | W.B. °F. | R.H. % | Wet steam sat. | Time in hours | | | | Moisture content - % | | Degrade - percent | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Warm | Dry | Cool | Total | Initial | Final | None | Slight | Med. | Severe |
| 800 | 220 | 200 | 67 | 80 | 1 | 28 | 4 | 33 | 34 | 7 | 93 | 5 | - | 2 |
| 800 | 220 | 180 | 42 | 50 | 1 | 26 | $4\frac{1}{2}$ | $31\frac{1}{2}$ | 33 | 8 | 93 | - | 7 | - |
| 800 | 240 | 200 | 47 | 80 | 1-3/4 | 18 | $4\frac{1}{2}$ | $24\frac{1}{4}$ | 33 | 5 | 93 | 5 | 2 | - |
| 800 | 240 | 180 | 29 | 50 | 2 | 14 | $5\frac{1}{4}$ | $21\frac{1}{4}$ | 32 | 5 | 92 | 7 | 1 | - |
| 800 | 265 | 200 | 31 | 80 | 4 | 10 | 5 | 19 | 32 | 5 | 74 | 7 | 11 | 8 |
| 800 | 265 | 180 | 18 | 50 | 3 | 8 | $4\frac{1}{4}$ | $15\frac{1}{4}$ | 34 | 7 | 78 | 7 | 7 | 8 |

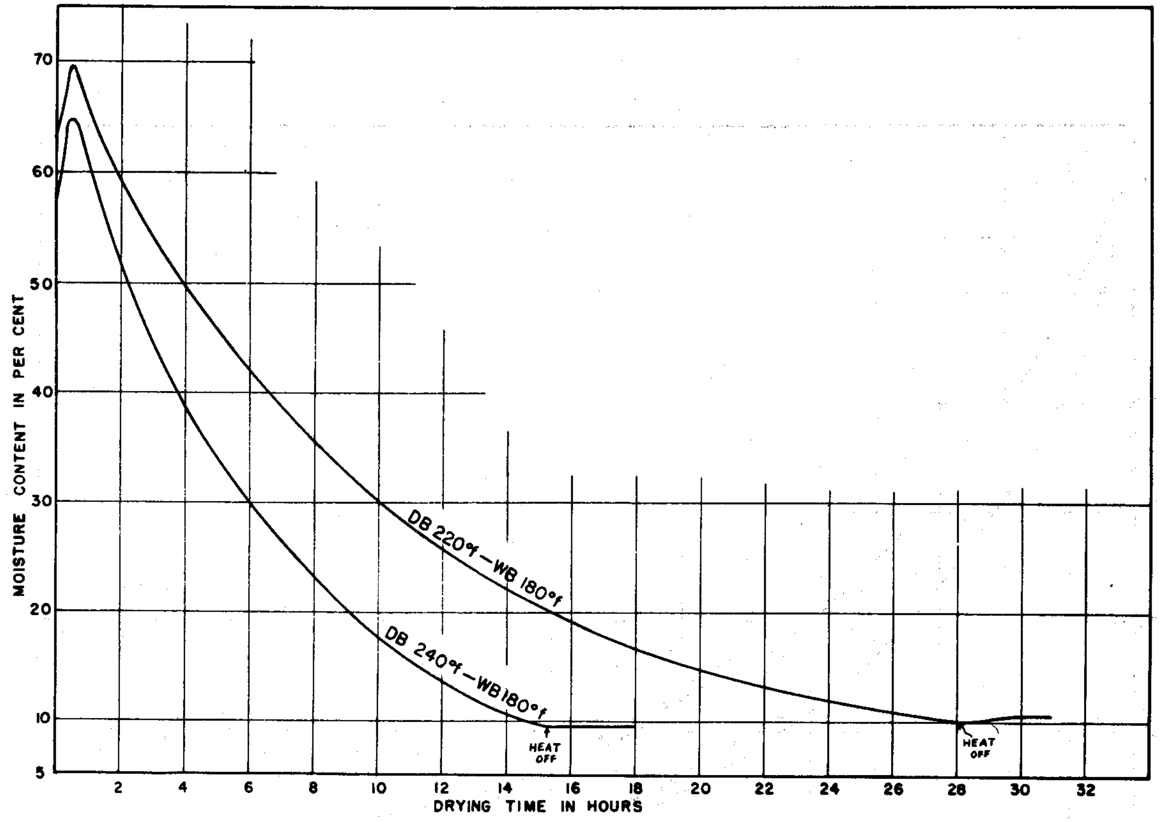


Figure 1.--The effect of temperature in kiln drying of 1" western hemlock at air speed of 420 feet per minute across the charge.

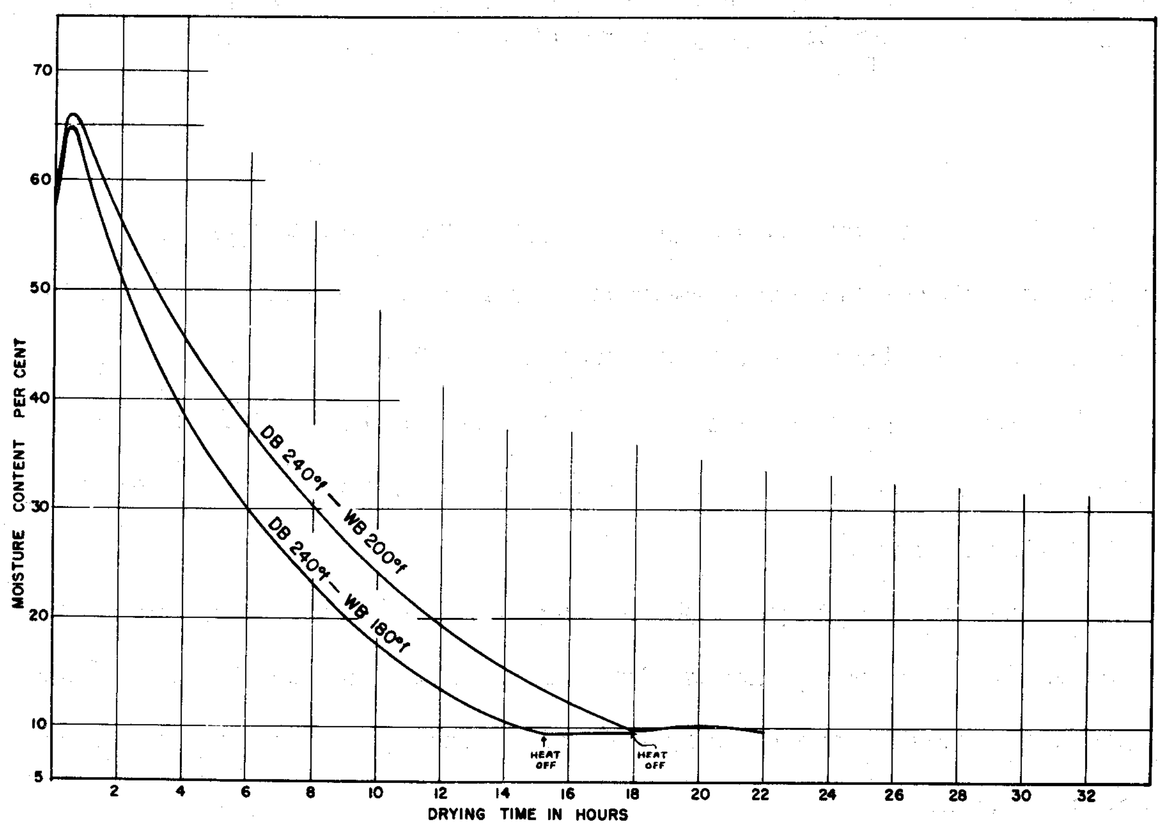


Figure 2.--The effect of wet bulb depression in kiln drying of 1" western hemlock at air speed of 420 feet per minute.

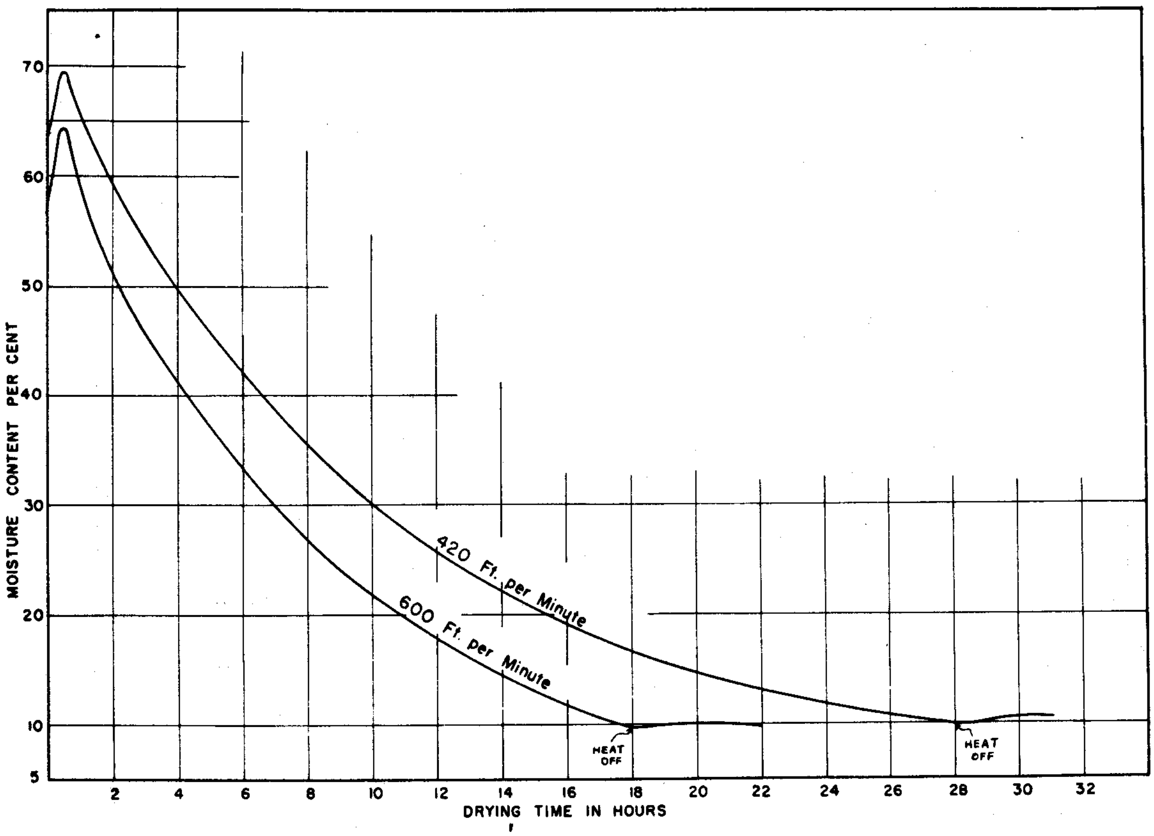


Figure 3.--Effect of air speed in kiln drying of 1" western hemlock at a constant temperature of 220° F. dry bulb and 180° F. wet bulb.

There are many advantages in high temperature drying. Speed of drying is probably the most important, as far as a sawmill operator is concerned. On the other hand, since time in the kiln may be critical, the operator must be prepared any time of the day or night to discharge a unit and charge it immediately. If this is not done, much of the advantage of fast drying is lost.

Another advantage is the saving of space which may be important to mills or woodworking plants with limited plant accommodation. These units will probably occupy only a third of the space required for a conventional kiln.

As yet very little is known on the effect of high temperature on the wood, itself. It has a tendency to darken the wood slightly, especially the light species such as western hemlock and spruce. The few tests on strength values which have been made at the Vancouver laboratory have not been conclusive.

Some of the lumber was run through a moulding machine at a commercial woodworking plant. The machining qualities appeared to be excellent. Test piles of air-dried, conventionally kiln-dried and high temperature dried lumber, erected outside show some indications that absorption of moisture is retarded in the high temperature material.

Studies on high temperature drying are being continued at the Ottawa and Vancouver Laboratories. Studies at the Ottawa Laboratory have shown that for eastern white spruce final moisture content uniformity can be brought within acceptable limits by using a high circulation rate and periodic reversal of air flow. At the present time studies are being made on yellow birch (an eastern hardwood) to determine the effect of temperatures, humidity and air flow on the drying of this species.

At the Vancouver Laboratory work is being continued on the effect of temperature, humidity and circulation on the drying of western Canadian species. Up to the present tests have been made on 1" material. It is hoped shortly to commence studies on 2" western hemlock and Douglas fir. These thicknesses are more difficult to dry without degrade and some modifications of procedure may be necessary.