# KILN DRYING PARTIALLY AIR-DRIED LUMBER

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With the increasing costs of energy and the interruption of supply of natural gas for lumber drying, there is considerable interest in reducing reliance on fossil-fuel energy sources and, in particular, in reducing energy costs. Several suggestions have been made in the literature toward these objectives.

Probably the most significant advances toward reducing dependence on fossil fuels have been in improvements in waste-wood burners for heat recovery and, in particular, for the direct-fired drying of lumber. At this stage, commercially available burners of this type are expensive units, with elaborate fuel-preparation systems, and are designed for the range of about 8-to-64-million BTU per hour. In the near future, we can expect to see the development of smaller units requiring less fuel preparation, so that they will be available at considerably less cost. These should be economically attractive to smaller kiln-drying operations.

Another method of reducing costs that has been suggested in the literature is to partially air-dry the lumber prior to kiln drying. When we consider that a charge of 100 Mfbm will lose 40 to 50 tons of water over a period of two days, and that each pound of water requires about 2000 BTU (including losses) to evaporate, it appears that substantial savings can be made if the heat requirement can be reduced. The idea becomes particularly attractive when we remember that a considerable amount of the moisture is removed fairly rapidly under mild drying conditions.

If we are to pursue this idea logically, we should be able to answer three questions:

(1) What period of air drying is economically sound?
(2) How does one measure the lumber moisture content after air drying?
(3) With what kind of a schedule, and for what duration, should one dry partially air-seasoned wood?

## Economics

Although our cost analysis will not be exact, we will get a good idea of the relative costs of several components of air drying and kiln drying, so that we can estimate when it is feasible to air dry.

First, let us look at the cost of operating a kiln. We choose a 100 Mfbm unit presently costing about $200,000. We assume a 15-year life and bank interest rates of 10 percent (high by U.S. standards, low by Canadian).

Cost of Kiln Drying

Capital Cost

| | |
|---|---|
| Amortization \$200,000/15 yr. | \$13,333 per yr. |
| Average annual interest \$200,000 x 0.10 x 1/2 | 10,000 |
| Maintenance costs, assume 3% | 8,000 |
| | \$31,333 per yr. |

At 350 days per yr. operation:

$$\text{Daily cost} = \frac{31,333}{350} \simeq \$90 \text{ or } 0.90 \text{ per M day}$$

Labor and operating costs

Labor: 1 person @ \$20,000 per yr.
= \$80 per day
= \$160 per 2-day charge

Fuel: 1 Mfbm contains 83 cu. ft.
At 25 pcf dry weight, 40% mc removed (55% to 15% average mc) = 830 lb. water per M fbm
At 2000 BTU per lb. and 9¢ per therm =

| | |
|---|---|
| | \$1.50 /M |
| Electricity (estimate) | .30 |
| | \$1.80 for 40% mc |
| | 0.45 for 10% mc |

Other costs

Degrade - variable

Cost of Air Seasoning

(1) Transportation - variable, depending on yard lay-out
Assume 5 minutes (1/12 hr.) to pick up and transport load and return
Labor = \$10/hr.
Forklift = \$10/hr. (assumed)
Forklift load = 1.5 Mfbm

$$\text{Cost} = \frac{\$10 + \$10}{12} \times \frac{1}{1.5} = \$1.11 \text{ per M trip}$$

(2) Land rent - variable

(3) Land preparation and maintenance - variable

(4) Bank interest on lumber @ \$150/M, 10% interest =

$$150 \times 0.10 \times \frac{1}{52} = \$.30 \text{ per M week}$$

Is air drying an economical operation?

Case I: The mill has adequate kiln capacity. Lumber is air dried to reduce fuel costs only. Assume 1 week air drying reduces mc from 50% to 40%. Then the cost of air drying comprises:

| | |
|---|---|
| Transportation | \$1.11 per M |
| Bank interest | .30 per M |
| Total | \$1.41 per M |

Gain by air drying
(fuel savings) .45 per M for 10% reduction

Net loss 0.96 per M

Not economically sound. The handling costs and interest on lumber value more than balance any savings in reduced fuel consumption.

Case II: The mill has insufficient kiln capacity. Lumber is air dried to reduce fuel costs and save capital costs. Assume 1 week air drying reduces kiln residence 1/2 day. Then the cost of air drying comprises:

| | |
|---|---|
| Transportation | $1.11 per M |
| Bank interest | .30 per M |
| Total | $1.41 per M |

| | |
|---|---|
| Gain by air drying | |
| Capital costs = 0.90/2 | 0.45 per M |
| Fuel savings | 0.45 per M |
| | 0.90 per M |
| Net loss | 0.51 per M |

The cost of transportation alone exceeds the potential savings. It is still not economically sound.

Case III: The mill has adequate kiln capacity, but has an interrupted fuel supply which usually occurs in cold weather. Air seasoning not a solution. Find an alternate fuel.

Case IV: The mill is drying temperature-sensitive or collapse-prone lumber. Should air drying be considered?

Drying temperature-sensitive or collapse-prone lumber usually requires weeks of drying time. If this is attempted in a kiln, kiln amortization alone would cost $6.30 per week. If the kiln operator is not gainfully employed elsewhere, there is an additional $4.00 per M week in labor costs. And, in addition, there is the cost of fuel, which will exceed $1.80 per M for a slow schedule. Faster schedules will result in considerable degrade. For example, if we assume 10% loss due to degrade of lumber at $150 per M, the degrade cost is $15 per M. Under these circumstances, air drying looks very attractive. At $1.11 for transportation and $0.30 per week interest costs, it is economical to air dry 17 weeks in order to reduce kiln-drying time by 1 week. It is economical to air dry almost a year to reduce degrade losses by 10%.

How to determine the moisture content of partially air-dried lumber

The measurement of mc in partially air-dried lumber cannot be done easily with any degree of reliability. In the past, we have recommended forklift weighing. The method consists of putting a calibrated pressure gauge in the hydraulic system of a lift. The pressure on the gauge should be proportional to the load being lifted. Unfortunately, there is enough friction in the hoist cylinder to make readings inconsistent and unreliable. The best method is to install electronic scales in either the loading area or in the kiln. The advantages will become more obvious with increasing emphasis on drying time and lumber quality.

Another possibility is to use a resistance moisture meter. Readings are reasonably reliable only to about 25 percent mc or with less accuracy to 35 percent. Where there are wet spots in the core of the lumber, the method is quite unreliable. However, it should be expected that, where wet spots exist, the potential for collapse or degrade of temperature-sensitive species is still present and the lumber should not be kiln dried. Consequently, resistance moisture meters provide a good practical method of estimating initial mc.

What kind of schedule should be used for partially air-dried lumber?

In a "normal" drying schedule, conditions are made relatively mild at the beginning of a schedule and they are increased in severity as drying slows down. The result is that the drying rate follows a curve something like that depicted in Figure 1, although other curves have been found by other operators. When the curve of Figure 1 is plotted on linear-logarithmic paper, it appears as Figure 2. Note that the X-axis (time) is not in hours, but is elastic and may be expanded or contracted to meet the duration of given schedules, provided that it is done uniformly. Twenty-four laboratory schedules for 5 different species were plotted on this curve and, with one exception, all gave an excellent fit. Because these schedules were from different initial mcs, they ranged from 46 to 154 hours drying time. The fit of various species and schedules is shown in Figures 3 to 7. (Data from Salamon et al. 1971, 1972, 1975.)

The schedule that does not provide a good fit to these graphs is for alpine fir dried by a low-high schedule (Figure 7). In this schedule, the lumber, which is collapse-prone, is dried slowly to about 25 percent mc average. The temperature is then increased dramatically and the circulating-air velocity increased 2 to 3 fold. As a result, the drying rate in the second part of the schedule is increased substantially over what it would have been if initial conditions had been modified "normally." This is reflected in the hump of the data points. In the first phase, drying is retarded so that the mc change is very slow; in the second phase, drying is accelerated so that mc change is fast.

Since the graph describes the relative amount of time required to pass through any part of the mc range, if partially air-dried lumber is being dried on a schedule used for green material, the graph indicates how much of the schedule can be discarded - that is, it tells where the

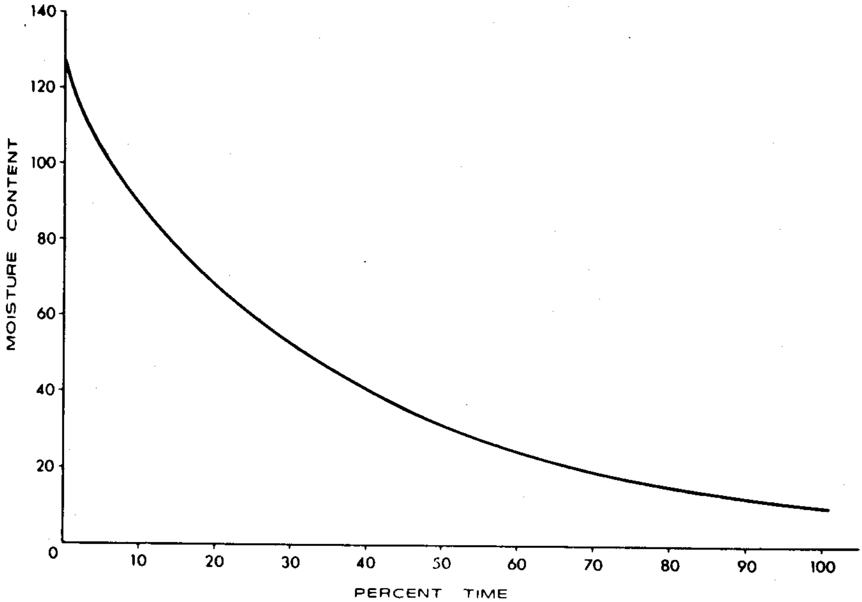

Figure 1. Typical drying curve (linear plot).

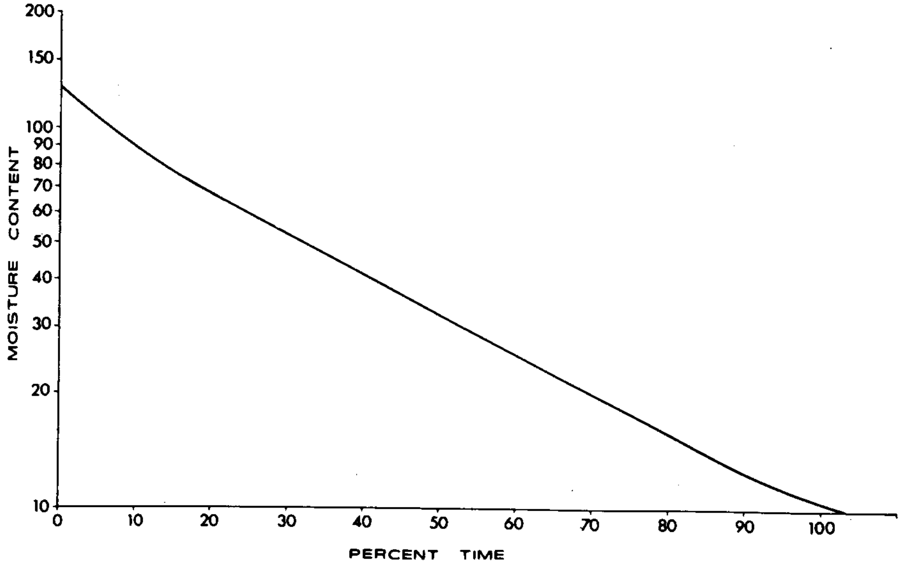

Figure 2. Typical drying curve (semi-logarithmic plot).

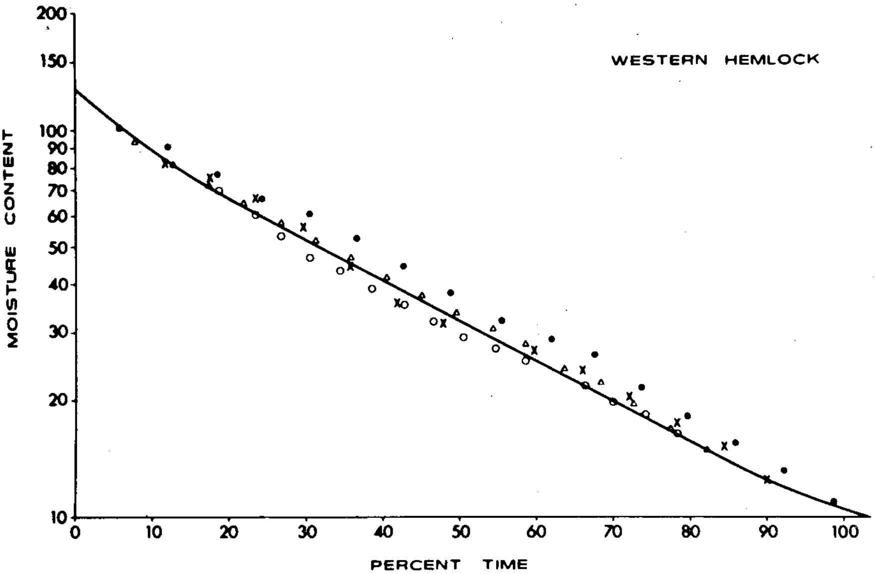


Figure 3. Relative drying rate for western red cedar, five runs from 110 to 154 hours.

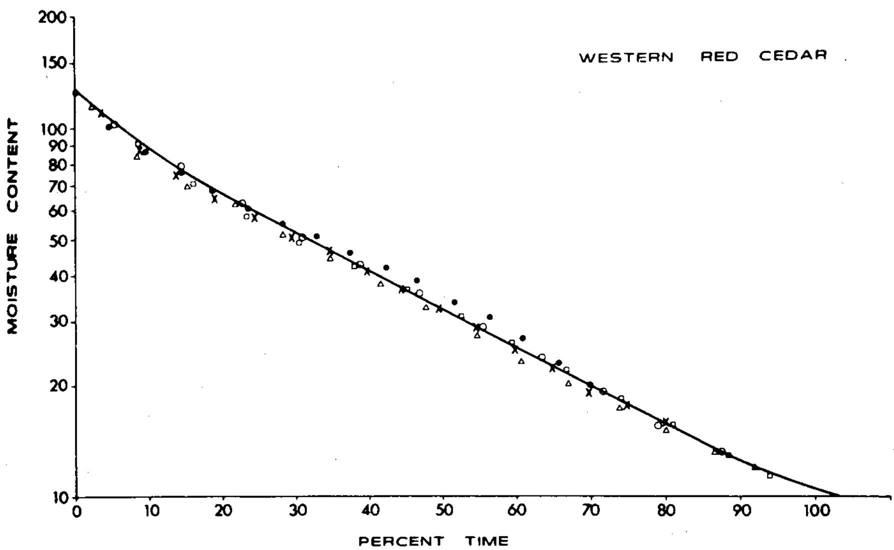


Figure 4. Relative drying rate for western hemlock, four runs from 84 to 144 hours (low-high schedule).

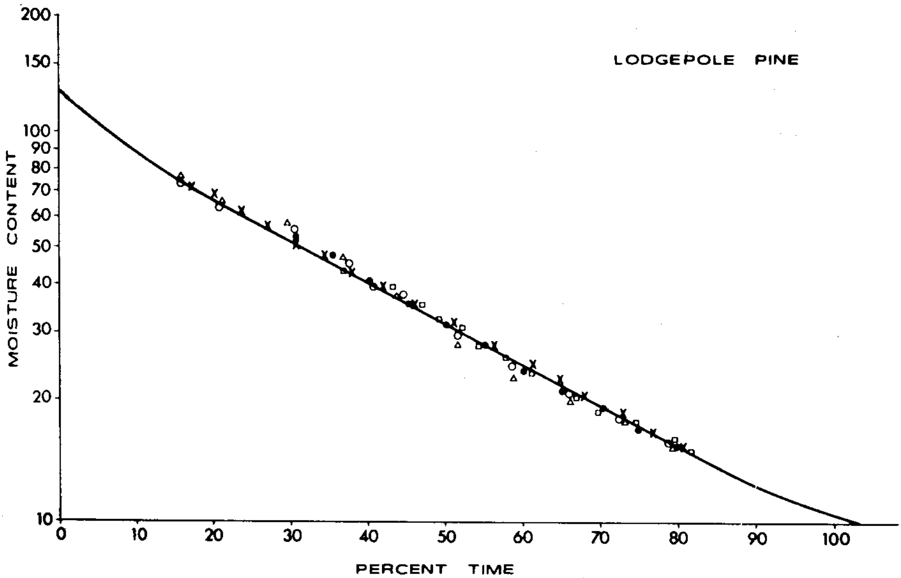


Figure 5. Relative drying rate for lodgepole pine, five runs from 82 to 111 hours.

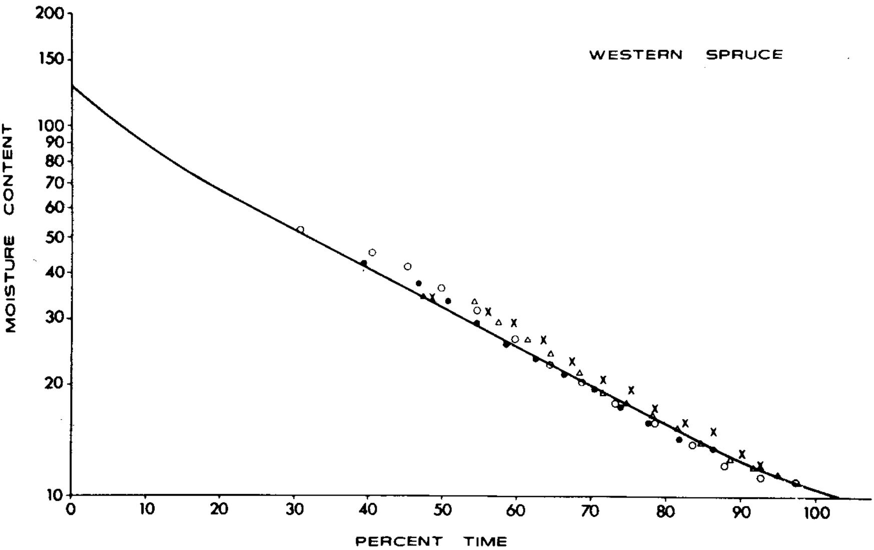


Figure 6. Relative drying rate for western spruce, four runs from 64 to 73 hours.

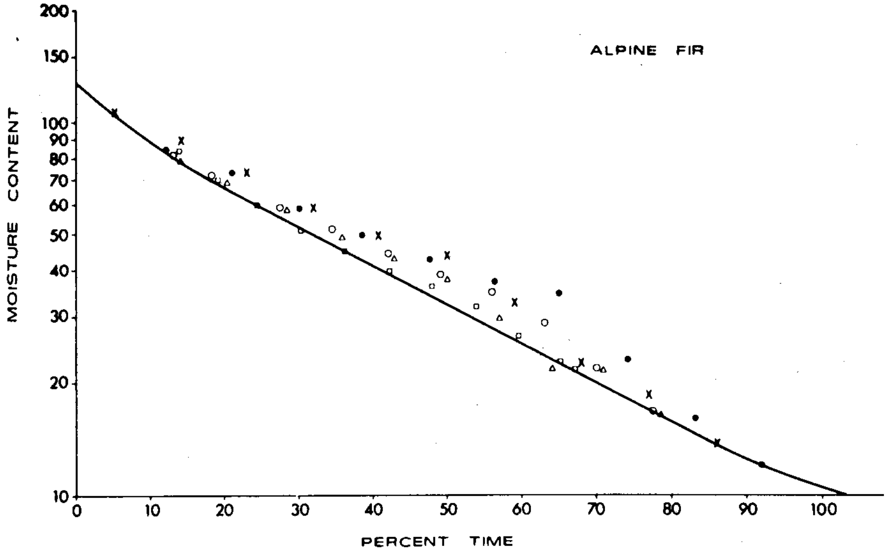


Figure 7. Relative drying rate for alpine fir, six runs from 46 to 117 hours (low-high schedule).

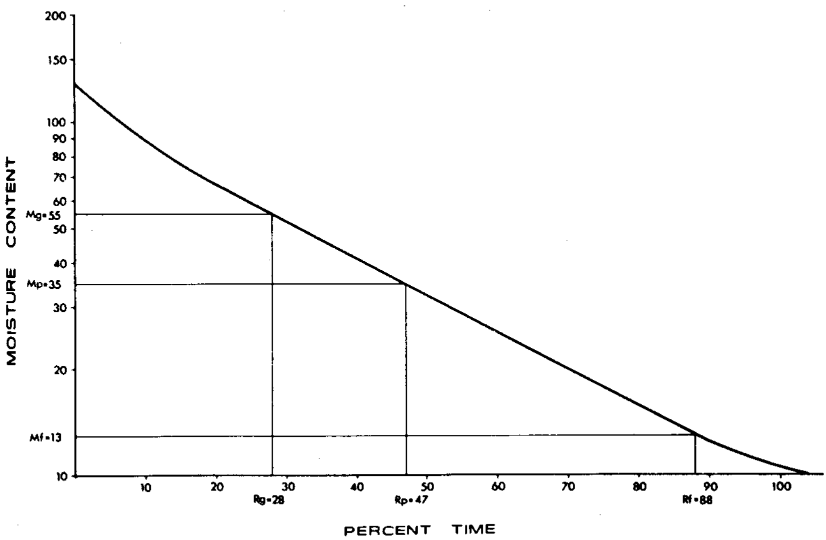


Figure 8. Use of drying-rate curve to calculate drying time reductions for partially air-dried lumber.

schedule should be entered if the mc of the partially air-dried material is known.

In using the information provided by the graphs, it is necessary to make some assumptions:

(1) Similar material has been dried from the green, or a less dry, condition and the schedule is satisfactory.
(2) The schedule gradually increases in severity to compensate for the normal reduction of drying rate as drying progresses.
(3) It is possible to enter the previously used schedule at dry- and wet-bulb temperatures corresponding to the mc of the lumber without inducing damage into the lumber.

The question then reduces itself to how much of the schedule can be discarded if we know:

(1) the mc of the green condition from which the lumber is normally dried ($M_g$);
(2) the mc of the p. a. d. lumber ($M_p$);
(3) the final mc desired ($M_f$);
(4) the duration of the schedule when drying from the green condition ($t_g$).

Find the percentage time on Figure 8 corresponding to the moisture contents $M_g$, $M_p$, and $M_f$. Call these percentage times $R_g$, $R_p$ and $R_f$. Then the number of hours $t_d$ to be discarded from the schedule is

$$t_d = \left(\frac{R_p - R_g}{R_f - R_g}\right) t_g$$

Example:

Two-inch spruce is 55% mc in the green condition and is dried to 13% mc by a "normal" schedule in 48 hours. After partially air drying the material, its mc is reduced to 35% mc. How many hours of the initial steps of the schedule should be discarded?

Original schedule = $t_g$ = 48 hr.

$M_g = 55$ $\qquad R_g = 28$

$M_p = 35$ $\qquad R_p = 47$

$M_f = 13$ $\qquad R_f = 88$

$$\text{Time reduced by } \left(\frac{R_p - R_g}{R_f - R_g}\right) tg =$$

$$\left(\frac{47 - 28}{88 - 28}\right) 48 = 15 \text{ hr.}$$

The schedule will therefore be the final 33 hours of the "green" schedule.

The weakness of this system is a knowledge of the initial mc of the partially air-dried material. Unless some reliable method (such as weighing of a sample load) is available, the figure obtained from a resistance moisture meter will be only an intelligent guess. Schedules should be expected to be modified accordingly.

The drying of partially air-dried lumber in a kiln without a supplementary source of humidity also introduces the problem of maintaining kiln humidity. Normally the high rate of evaporation of green material produces a high relative humidity. When drying partially air-dried lumber, this humidity will be much reduced at the start. Where the lumber is excessively dry, a preliminary soaking will increase kiln humidity without making excessive demands of energy.

## References


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Salamon, M. and S. McIntyre. 1971. How to dry lodgepole pine under the new lumber rules. Can. For. Ind. 91(12):39-41.

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## QUESTIONS AND ANSWERS

Q. I once had the opportunity north of Prince George to kiln dry quite a volume of pre air-dried lumber. I am assuming from your formula that the rate of drying from let's say 25 percent fibre saturation point to 15 percent has been established for green lumber. Therefore, in this formula we are assuming that the drying rate for partially air dried lumber would be the same from 25 to 15 percent.

A. That's correct.

Q. No, it isn't. I can assure you that it won't work in a gas kiln because the lumber in this particular case, again we are guessing the moisture content was around 25 percent since the lumber had case-hardened during the air drying process. In other words, it was slightly predamaged. So we had to reduce drastically the maximum drying temperature. We went from a normal 180 or 190 degrees at that particular moisture level down to 142 degrees and therefore, the drying rate was less than a kiln full of green lumber processed down to fibre saturation point. Other people have had similar experience where the lumber and conditions were different, and they follow your schedule. I admit your approach is perfectly possible but I'll just inject some warning.