STEPS TOWARD REDUCTION OF DRYING DEGRADE

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The recent literature on the drying of western softwoods has been filled with papers on moisture content control. Many of these papers also involve degrade, because any item of great moisture content variability that is dried long enough to meet the new maximum moisture content standard ends up with a great deal of lumber under 10 percent moisture content. Below 10 percent, degrade is excessive (7).[2] The use of elevated and high-temperature drying schedules has accentuated the problems. The industry is determined to meet the moisture content specifications (14). The question is, "How do you go about this without the usual increase in degrade?" This is a very difficult problem. It involves not only differences between sapwood and heartwood, but extremely slow drying, defect-prone material infected by bacteria (2).

The problem of degrade has been outlined by Knauss (5), Kozlik (7) and Huber (3). Primary drying defects such as surface checking, ring separation, warp, and brown stain can result in major losses. Large final moisture content variability also is a degrading factor because the overdried wood is subject to planer splitting and knot dropout. If the wood is not dry enough, high moisture content itself is considered a degrade.

I am not an expert on degrade control. I shall, however, attempt to draw together several observations on what happens to softwoods as they dry and outline steps that can be taken to prevent primary drying defects and to meet maximum moisture content requirements without overdrying.

Prevention of Primary Drying Defects

Kimball and Lowery (4) found that surface checking resulted in degrade of about 3 percent of high-temperature-dried lodgepole pine studs. The comparable value for larch studs was 7-1/4 percent. At conventional temperatures, checking degrade was only 1/2 percent in the lodgepole pine and 3-1/2 percent in the larch. This was one "advantage" for conventional drying.

The way surface checking can come about was suggested in the study of moisture distributions and drying strains in ponderosa pine (8). I will not review this now, but can answer questions if anyone has serious checking problems.

Honeycombing, ring separation, and collapse may be grouped as degrade factors because they are all aggravated by use of excessive kiln temperatures on susceptible material. Although common with sinker redwood and western redcedar, with most species only a percentage of the wood is subject to these defects. At the present, the Forest Products Laboratory is leaning toward the conclusion that most, if not all, of this defect-prone wood has been bacterially infected. If the defect-prone boards make up only a very small percentage of the green lumber, they should be sorted out and given some special treatment. If they make up a larger

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[1] Maintained in cooperation with the University of Wisconsin, Madison, WI.

[2] Numbers in parenthesis refer to Literature Cited at the end of the report.

percentage, but not the majority of the stock, means should be found for selectively sorting out an appropriate percentage that should be dried by an intermediate kiln schedule. The bulk of the stock would be dried at an elevated or high temperature with considerable time saving and improved moisture uniformity.

My experience in drying softwoods subject to these defects was with eastern hemlock studs. Using a moisture content schedule, basing changes of kiln conditions on the moisture content of the wettest half of the kiln samples, drying time was 25 days. Analysis of the drying rates of the individual pieces indicated that a better segregation for uniform drying could be attained if the green studs were sorted on a weight basis rather than on an initial moisture content basis. The remaining test material was accordingly separated into a medium weight group, a high weight group, and a low weight group. These sorts then were dried separately without defects, except when partly predried heavy stock was dried on an elevated-temperature schedule. Similar material from the same source was dried by high-temperature processes at the Eastern Forest Products Laboratory, Ottawa, Canada. The results of this small-scale experiment were disastrous because excessive honeycombing and shake opening occurred.

The schedule ultimately recommended for medium weight stock took 11 days. The moisture contents of 95 percent of the pieces were under 20 percent (Figure 1). A similar moderate-temperature schedule taking only 8 days did not produce moisture uniformity.

It is interesting to note that shake in western larch studs was not aggravated by high-temperature drying (4).

On warp, Snodgrass noted some time ago that there was a great tendency for young growth Douglas-fir boards to twist (12). Knauss (5) said that warping caused more degrade than surface checking in upper grade ponderosa pine. The old standbys of sorting to length, good sticker alinement, and full support under every sticker are still major means of reducing warp. The sawing of lumber to uniform thickness is of great importance in this regard. Fortunately, there is a large-scale movement towards improvement in the sawing process today. If you haven't heard about SIP, the Sawmill Improvement Program, you should ask the forest utilization men in your state about it (13).

Some real benefits from high-temperature drying are reported for the reduction of warp. I will speak of two studies. In the one on lodgepole pine and larch studs (4), only 6 percent of the lodgepole pine studs dried by high temperature were degraded by warping, while 9 percent were degraded at conventional temperatures. For the western larch, the values were 4-1/4 and 7-1/4 percent, respectively. One reason why the studs dried at high temperature warped less than those dried by conventional temperatures was that the truckloads in the high-temperature kiln were three packages high while those in the conventional-temperature kiln were only two packages high. It was always my personal feeling that the beneficial effect was due to both restraint and high temperature.

A 1973 study on strength and warp in South African pine (15) shed some new light on this matter. The pine was plantation-grown patula and slash pine. The boards were 38 millimeters (1-1/2 in.) by 115 millimeters (4-1/2 in.) in size. The presence of pith in the piece was a major factor. The principal type of warp was twist. Twist was reduced considerably when the boards were dried under restraint at high temperatures. Without restraint, the temperature effect was absent. With

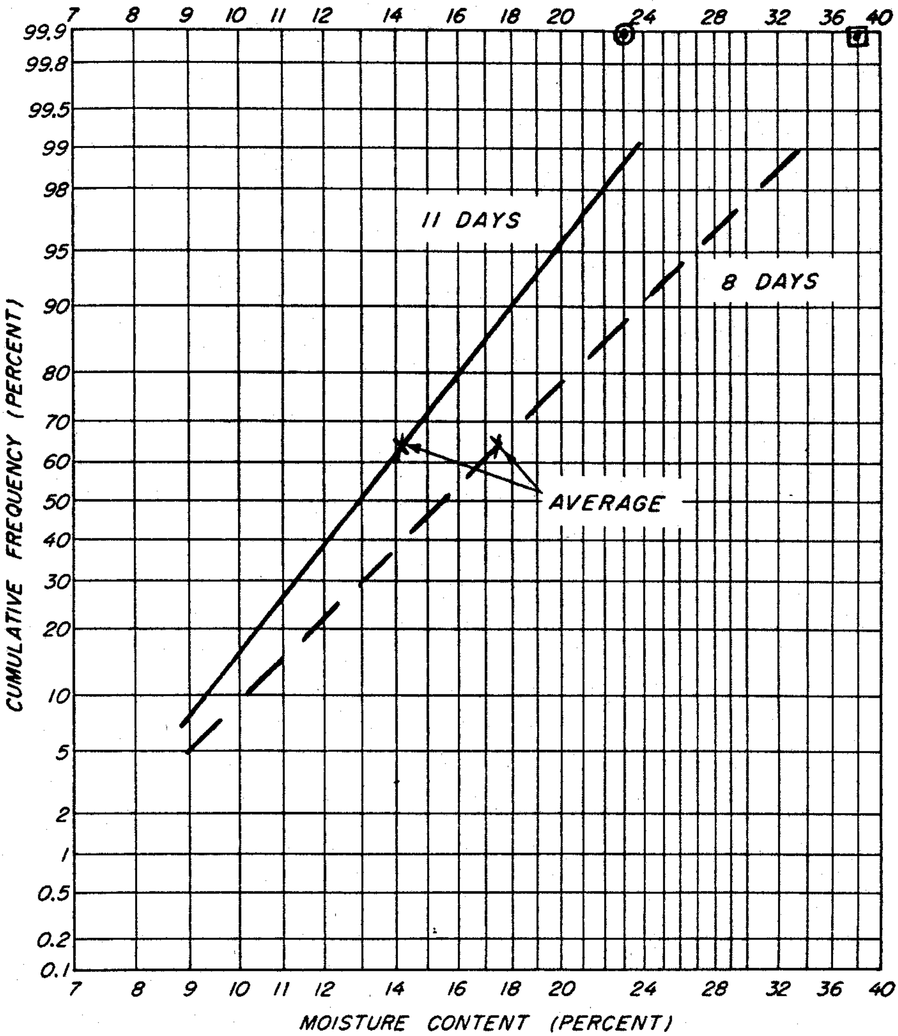

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Figure 1. Moisture content distribution, medium-weight eastern hemlock 2 by 4's dried by moderate temperature kiln schedules (9).

reduction of warp degrade as one of the major factors, the investigator found that drying efficiency was greatly improved by restraint and high temperature (Figure 2). The restrained boards were held down by a leverage system.

Finally, warp is greatly increased by overdrying. Snodgrass found that, in pieces likely to twist, there was a linear increase in twist as the lumber was dried from 16 to 6-1/2 percent.

Reduction of Manufacturing Defects

Knauss (5) found in the early 60's that planer or roller splitting may degrade from 4 to 10 percent of upper grade Douglas-fir and hemlock, and from 20 to 50 percent of 8-inch and wider ponderosa pine common. Kozlik (7) found this problem had become more acute in recent years. Younger aged timber yields boards with high ring angles on the outer edges. Kozlik stated that any moisture content below 10 percent resulted in excessive degrade from this factor.

Knot dropout is a defect that was very important in western softwood commons in the past. It possibly still is. Extensive studies by the Western Pine Association showed that overdrying was the principal cause. Knauss found that dropout could be kept within controllable limits at moisture content levels between 12 and 15 percent for ponderosa pine and between 15 and 18 percent for Douglas-fir and hemlock.

Undersize is a defect that should not be common now, but may become so as lumber becomes more precisely sawed and a closer shrinkage tolerance is sought. Kimball and Lowery (4) found that high-temperature drying gave considerably less undersize degrade than conventional-temperature drying for the lodgepole studs. This is one indicator that high-temperature drying may cause less shrinkage. The same did not apply to the western larch studs. Espenas (1), on the other hand, found that drying above 200°F. increased shrinkage in Douglas-fir and western hemlock. In any event, overdrying should be avoided.

Meeting Maximum Moisture Content Requirements Without Overdrying

As indicated above, both warping and manufacturing defects are greatly increased by drying softwood lumber to less than 10 percent moisture content. Yet as closer inspection procedures are being adopted by the consumer, the kiln operator is faced with having only a very little, if any, of his lumber over 19 percent. He must take steps to reduce moisture variability. These steps include improving kiln performance, controlling the moisture content of the stock entering the kiln, improving the drying operation, and greatly improving the kiln-run termination procedures.

Good kiln performance is a must. You cannot dry softwood lumber to a uniform moisture content in a kiln that does not have temperature uniformity throughout its length and air circulation uniformity through all loads. Temperature uniformity requires proper design of the heating system, its proper maintenance and operation, and uniformity of air flow over the coils. There are adequate guides (6, 11) for checking any kiln, including fan performance. The attainment of uniform air flow through the load involves both proper kiln loading and proper baffling. One general fault in baffling years ago was the lack of an adequate fan floor extending completely out to the sides of the loads. If such fan floors are not present, they should be considered. Another corrective measure is to have a

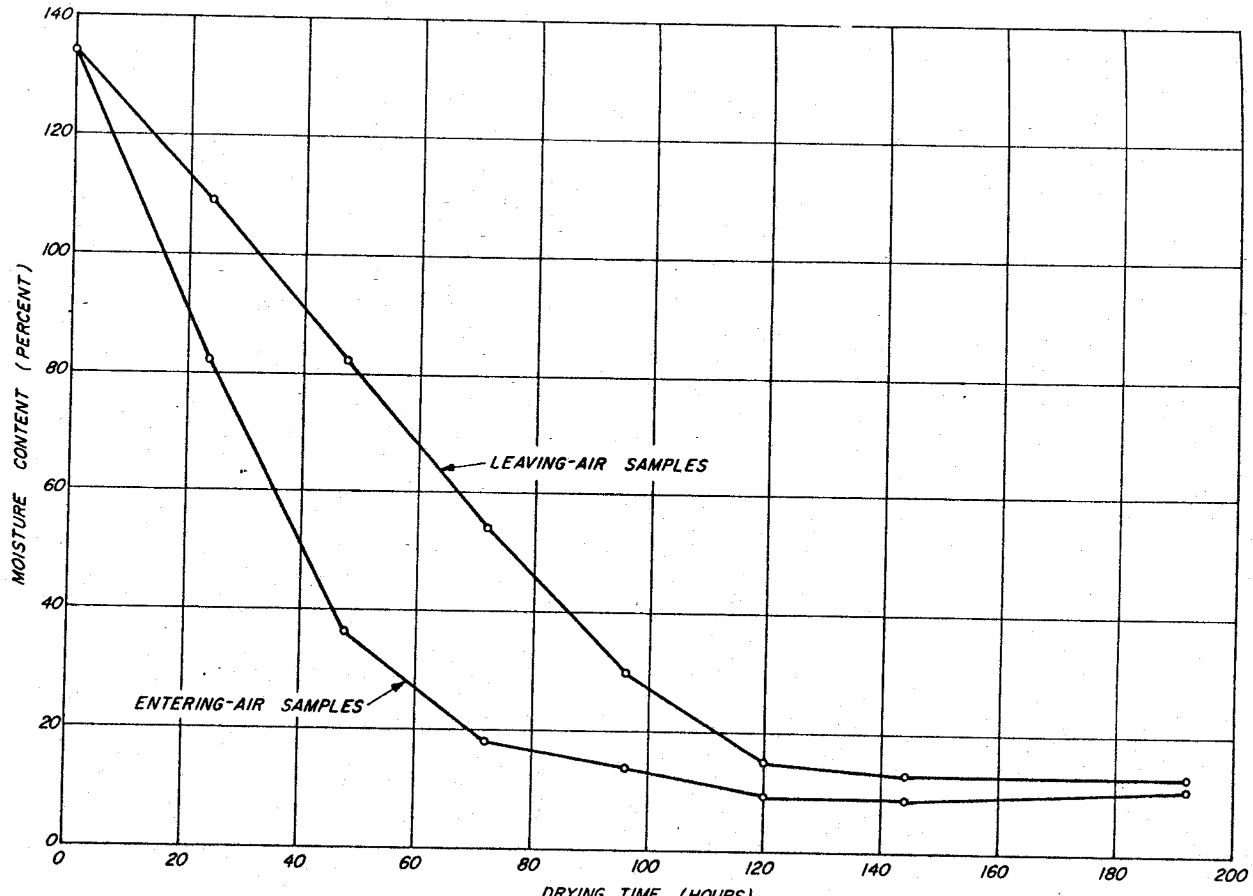

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Figure 2. Composite efficiency in drying plantation-grown South African pine 2 by 4's, as affected by restraint and temperature (15).

complete layer of full length boards in the top layer of each load. Complete baffling of the kilns so as to prevent air flow below and around the ends of the loads has not always been done. It probably would be desirable now. An increase in air velocity through the load would result in increased drying rate and provide the extra time needed for equalizing at the end of the run.

New developments in automatic kiln control should be helpful in getting better performance out of the dry kiln. These include the CRT process, weight-controlled automation (16), and commercial developments such as Kiln-Scan and Kiln-Mo-Trol. To properly function, these methods should provide some means of determining when the boards in the middle of a kiln truck catch up with the drying of the boards on the outside. The "leaving air" samples in a 4-foot-wide load of southern pine studs without reversal of air circulation (Figure 3) indicate what would happen in the middle of an 8-foot load with reversing circulation.

The first and most obvious point in regard to control of moisture content of stock entering the kiln is the segregation of stock of different drying types within a species. Wherever volume and drying characteristics justify, sapwood should be separated from heartwood. The separation of extremely slow-drying, defect-prone material is especially important. We at the Forest Products Laboratory are attacking this problem from a number of angles. We are searching for automatic means compatible with the rapid lumber handling systems coming into use today. Meanwhile, a considerable amount of sorting can be done visually. In many cases it would be worthwhile to use extra manpower to do this job. The benefits available in the way of reduction of moisture variability and degrade are great.

Another important procedure that needs improvement is assessing the initial moisture content within any sort of lumber as it goes into the kiln. If a stickered charge sits on the yard during dry summer weather before going into the kiln, it is likely to come out with a much lower final moisture if a single time schedule is blindly followed. If the kiln operator had some means of assessing the moisture content of the lumber, and its drying characteristics, as it goes into the kiln, he could save considerable time and achieve greater final moisture uniformity safely.

The first thing the kiln operator can do to improve the drying operation is to select the proper type of schedule. Oberg (10) showed that better moisture uniformity was achieved by using a 132-hour schedule with equalizing than with a 96-hour non-equalizing schedule. One firm has recently solved a uniformity problem by going from a 3- to a 4-day schedule. While the longer schedule costs more, it may not be more expensive in the long run because of the reduction of degrade. The present demand for lumber is somewhat lower than it was a while back, giving the industry a chance to experiment with schedules to improve moisture uniformity. Personally, I believe there are many softwoods that can be dried with higher conventional or elevated temperatures if higher initial EMC's are used. The improved drying rate will save time for equalizing at the end.

It goes without saying that the kiln operator's attention to each charge is important in achieving moisture uniformity. There are clues given by the behavior of the wet- and dry-bulb pens that indicate kiln performance and how the lumber is drying. It is not possible to anticipate all variations at the start. The operator should learn to recognize variations on the chart, make judgments as to performance and drying behavior, and check

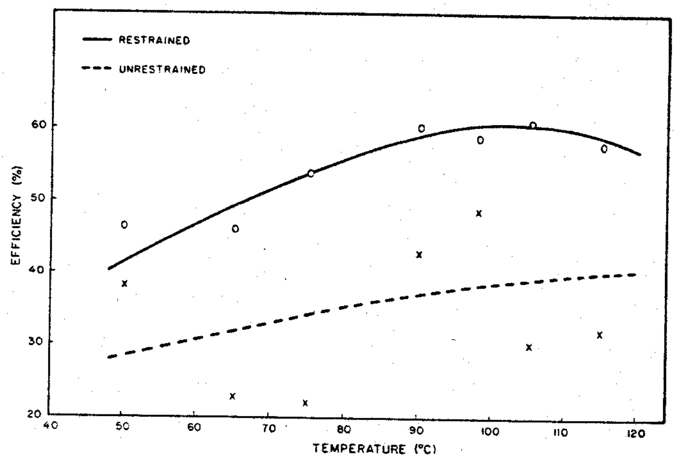

Figure 3. Drying curves, southern pine studs dried by a moderate temperature schedule in a 4-foot-wide load without fan reversal.

up on his judgments so as to develop an expertise that will supplement schedule pre-selection or automation.

Careful kiln run termination and equalizing are very important. One of the greatest steps that can be taken to improve moisture uniformity and avoid degrade from overdrying is to know when to stop the drying. Perhaps ultimately this can be done automatically. Meanwhile, the method of stopping the drying and cooling the kiln enough so that an operator can go in and make hot meter probe tests appears to be a step in the right direction. Here again the operator needs to develop his own expertise. If the operator's time in the kiln can be restricted to 1/2 hour or less, he should be able to enter the kiln when the wet-bulb temperature (within 6 ft. of the floor) has dropped to less than 130°F. If the charge is at too high a moisture content, the heat lost by the lumber and from the upper parts of the kiln should not be so great but that the kiln can be started up again with little lengthening of drying time. When the hot meter method is used, however, the operator should observe all safety precautions.

I believe equalizing is a must, even with properly sorted material. It is especially important if non-uniform material is entering the kiln. Equalizing is not such a bad word, for the last half of many of the conventional kiln schedules now used is either an equalizing or semi-equalizing condition. Many of the conventional and elevated schedules can be modified prior to equalizing by using larger wet-bulb depressions in the latter stages until the driest stock comes to 2 or 3 percent moisture content below the desired final minimum moisture content. This is different from our general recommendation for precision drying of hardwoods or lam stock. When this stage is reached, equalizing should start. To do equalizing, however, the dry-bulb temperature must be reduced to somewhere below 212° F. Depending on the tightness of the kiln, this might be anywhere from 160° to 210° F.

I would divide equalizing for dimension lumber into two parts: E-I and E-II. E-I stops drying of the driest boards while continuing rapid drying of wet boards. E-II raises surface moisture content of all boards, raises average moisture content of dry boards, and slightly lowers average moisture content of wet boards.

The E-I EMC should be set 2 or 3 percent below the desired final minimum moisture content. The wet-bulb temperature should be brought up to the desired value by use of steam spray alone, after the cooling down period. How long should the cooling down period be? Only your own experience can tell. Paul Bois[3] and I recently answered a telephone inquiry from Texas as to how to get uniformity of moisture content in 1 by 4 southern pine for boxspring framing. Neither of us had heard about the necessity of equalizing southern pine before, but this was a high-temperature operation at 230°F. We advised cooling the kiln, with doors open and fans running, to some temperature at which the operator could maintain a small wet-bulb depression. He should then equalize at this small depression until the wettest stock was sufficiently dried. The target moisture content was around 10 percent. Previous experience has taken some of the stock down to 3 or 4 percent, which was far too dry. A few

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weeks later we got a return call. Our suggestion had worked excellently. Before the operator used this procedure, kiln time was in the neighborhood of 26 hours. He changed the first drying period, at 230° F., to 20 hours. The kiln was then cooled 1-1/2 hours. Then a 10°F. wet-bulb depression at 185° F. dry bulb was established and held for 7-1/2 hours. This was really an E-II treatment. Total time became 29 to 30 hours.

Significant equalization within the driest boards of dimension lumber can be achieved in a 4- to 6-hour E-II period following the E-I treatment. The E-II treatment differs from conditioning used to completely remove drying stresses in shop lumber and hardwoods. E-II equalizing is designed to bring the surface moisture content of dimension lumber up to the desired minimum moisture content. Since the wood will be responding to the adsorption part of the hysteresis cycle, it is necessary to use a "book value" EMC about 1-1/2 percent higher than the desired minimum moisture content. For hemlock and Douglas-fir that have finished E-I equalizing at an EMC of 7 percent, the effect of an 11-1/2 percent book value EMC is as follows:

For boards at an average moisture content of	Average moisture content after conditioning will be
Pct.	Pct.
7	8-1/2
8	9-1/4
9	10
13	13-1/4
17	16-1/4
21	19-1/4

On the basis of the above, E-I equalizing should be continued until no stock is over 21 percent.

To do E-II equalizing, bring the wet-bulb pen up to the desired wet-bulb temperature with use of only the steam spray. The heating coils should be kept off. It may be necessary to use hand shutoff valves to make sure no steam is entering the coils and causing dry-bulb temperature override. After the wet-bulb pen is up to the set level, let the dry-bulb pen come up to its set level using a relatively small amount of radiation or a low steam pressure. For example, if E-I equalizing has been carried out at 185° F. (with a 23° F. wet-bulb depression), shut off the steam coils and set the wet-bulb indicator at 185° F., let the wet-bulb pen come up to this value. Then turn a small amount of radiation on and set the dry-bulb indicator at 194°F. E-II equalizing can be considered to have started when the wet-bulb pen reached 185° F. or when the actual depression became 9° F.

Conclusion

Many known procedures are helpful in reducing seasoning and seasoning-related degrade. A special modification of the old equalizing procedure appears to have great promise for reducing final moisture content variability and reducing degrade related to overdrying. To fully lick the problem, more developments are needed on methods of segregating wet, slow-drying material.

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