A LOOK AT REDRY

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Lumber that is not adequately dry after leaving the kiln has typically been treated as a nuisance in most kiln drying operations. Since few mills are adequately equipped to remove wet lumber and rehandle it, its nuisance status is understood. As a result of this situation, it is common practice to dry the lumber low enough so that little or no redry is generated.

Let us look at the consequences of these drying procedures. While the redry problem is eliminated, we are simultaneously affecting the quality of the lumber. Lumber degrades in relationship to its loss of moisture so that as the moisture content is reduced, the amount of degrade increases. Extensive studies over the past several years within the Weyerhaeuser Company have shown that the rate of degrade for softwood dimension lumber is in the order of magnitude of 1 to 3 dollars per thousand board feet for every 1% of moisture lost in our normal drying range. That means that if a thousand board feet of dimension lumber were dried from 20 to 10% M.C., the value could be reduced 10 to 30 dollars. These numbers are based on lumber prices almost a year old. In today's higher priced market, the losses could be even greater.

Minimizing total costs including the indirect costs of degrade should be of concern to the kiln operator. With this magnitude of loss in value, are we perhaps fooling ourselves in drying an entire charge of lumber so that few or no pieces exceed the 19% moisture content limit?

Eventually the lumber must be dried below 19% M.C. in order to meet the grading rule specifications. If lumber all started out at a uniform moisture content and dried at a uniform rate, the maximum return could be achieved by drying it to just 19% M.C. Unfortunately, lumber neither starts at uniform conditions nor dries uniformly. Consequently, we are always faced with a range of moisture contents in our final product. A typical moisture content distribution after drying is shown in Figure 1. Given enough time, a very much tighter distribution could be achieved by allowing the lumber to equalize using a long equalizing kiln schedule. For dimension lumber, such an approach is impractical. The moisture content distribution is usually similar from run to run for a particular kiln and a set of conditions which includes the drying schedule, the species, the type of lumber, and the lumber stacking procedures. A significant change in any of these conditions can produce a change in the shape of the moisture distribution.

Since it is the upper part of the distribution above 19% M.C. that represents the redry material, it is important that we see how this changes as the lumber dries. By sampling moisture content from a good many units dried to various final average moisture contents, a curve of the type shown in Figure 2 can be generated. This particular curve represents data on Douglas-fir dimension of various widths dried at one

FIGURE 1

TYPICAL MOISTURE CONTENT DISTRIBUTION

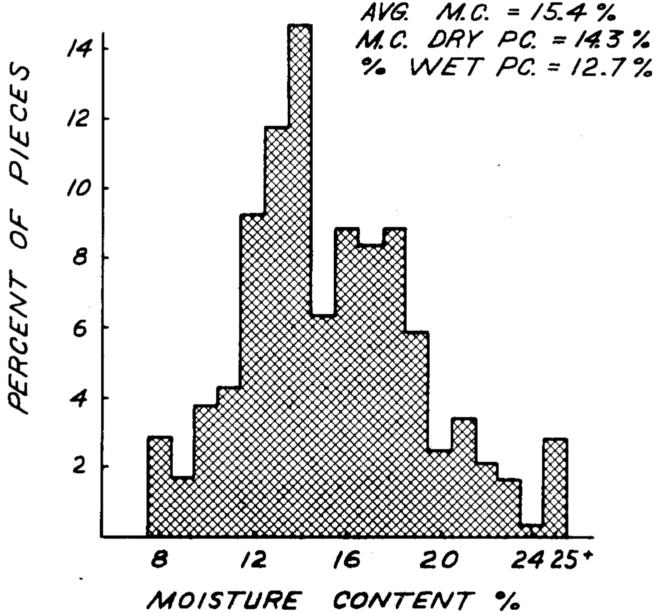
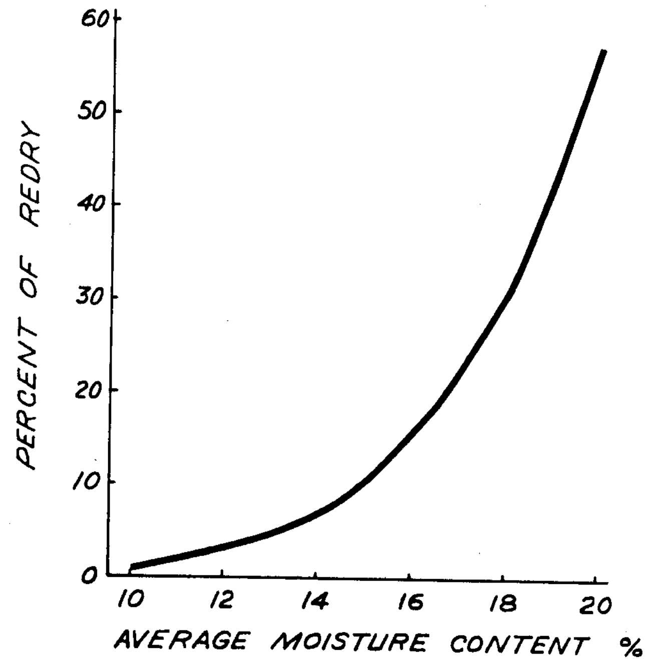


FIGURE 2

PERCENT OF REDRY AS A FUNCTION OF AVERAGE MOISTURE CONTENT OF DOUGLAS-FIR DIMENSION



particular mill location. Statistical methods were used to derive a smooth curve from the sample data.

By removing the wet pieces from a moisture content distribution, the average moisture content of the remaining pieces will shift slightly lower. In order to determine the extent of degrade, it is necessary that we know the average moisture content of the dry pieces. The same sampling used to generate the percent of redry data can be used to determine the moisture content of the dry pieces. Figure 3 shows the relationship between the moisture content of the dry pieces compared to the average moisture content of the entire sample. This relationship is based on the same data as previously used. Again, statistical methods were applied to arrive at a smooth curve.

We have mentioned the magnitude of the indirect costs due to degrade; we must now look at the direct costs. Each mill has its own situation, but for the purposes of this example, let's assume a $5.70 cost for drying Douglas-fir dimension to an average of 15% moisture content. This should be a fairly realistic figure within the industry. By far the largest portion of this amount comes from stacking and handling and could include rough green storage, stacking, sticker costs, kiln loading and unloading, unstacking, and rough dry storage. These costs will remain constant regardless how long the lumber is dried, for they are a function of handling a certain number of board feet. Other costs such as direct kiln operating labor and maintenance, depreciation, taxes and insurance and energy will vary to some degree with the drying time, and thus with the final moisture content. For the purpose of our example, let us assume there is a 5¢ change in costs for each 1% of moisture content. This is a good approximation though the amount is probably not completely linear with moisture content.

All of the ingredients are now on hand to put together the total cost picture for drying dimension Douglas-fir. The costs at each moisture content from 10 to 20% are summarized in Table 1. Let us examine each step involved in arriving at a final total cost. Costs shown in the table are on a dollars per thousand board feet basis. Column A is the average moisture content to which the lumber is dried in the initial kiln run. It is the key on which the balance of the table is built. The moisture content of the dry pieces and the percent of wet pieces, or redry, columns B and C, are from the mill generated data shown in Figures 2 and 3. The data in columns A, B, and C are the basis for allotting the costs in the remainder of the table.

The direct drying costs are given in column D. They vary only 5¢ per % M. C. starting with the base of $5.70/MBF at 15% M. C. Column E shows the indirect costs attributable to degrade of the dry portion. It is based on a rather conservative degrade factor of $1.25/MBF per percent moisture content and is arbitrarily set up so that the material at the highest moisture content is assigned a degrade value of zero. Progressively higher amounts of degrade occur as a function of the lowering moisture content. To calculate the degrade value in column E, it is necessary to multiply the $1.25 times the change in moisture content of the dry pieces from the highest level where no degrade occurred, then finally times the percent of the pieces that are represented in the dry portion. This may be written:

$$\text{Degrade Loss} = 1.25\ (17.2 - \text{M.C.})(\%\ \text{Dry Portion} \div 100)$$

The percent of dry pieces may be determined by subtracting the percent of wet pieces from 100%.

For the purposes of this example, \$5.50/MBF has been used as a direct cost of redrying. Most of the same operations as were carried out on the initial drying must also be carried out on the redried material. The only major difference is that shorter kiln residence times might be expected. \$5.50 should be a realistic number in relation to the initial direct drying costs. In order to keep all values on a per thousand board foot cost, we must multiply the \$5.50 times the percent of redry to arrive at the numbers in column F.

To determine the redrying degrade, it is necessary to decide upon a final average moisture content for the redry. In this example, let's assume this to be 16% M.C. To put the redry on the same degrade basis as used for the originally dried material, the 16% M.C. must be compared with the zero degrade level occurring at 17.2%. This means a 1.2% moisture content reduction. Applying the \$1.25/MBF per percent moisture content gives a total degrade value of \$1.50 per thousand for the redried material. To get the contribution of redry degrade shown in column G, we must now multiply the \$1.50 by the percent of lumber being redried. This can be written as:

$$\text{Redry Degrade Loss} = 1.25\,(17.2 - 16.0)(\%\ \text{Redry} \div 100)$$

Note that if we assume the same pattern of moisture distribution in the redried lumber as occurred in the original drying, there will be 15.3% that is still wet. Recall though that this is 15.3% of the redry and not the total. The 15.3% must be multiplied by the original wet percentage to determine the overall amount of wet stock. At an initial redry level of 30%, the final level of wets would be less than 5%.

One other calculable factor which contributes to the overall cost is that of underweight savings. Freight costs are normally collected for a standard shipping weight. If the lumber shipped weighs less than the quoted shipping weight, the shipper pockets the difference. As we dry to lower and lower moisture contents, the lumber becomes lighter and consequently the difference becomes greater and the amount of money larger. The effect on our overall cost picture is opposite to that of degrade. Before the underweight contribution can be determined, the shipping moisture content must be calculated for the entire thousand board feet, including the initially dried lumber as well as the redried material. The weighted average moisture content is obtained from the following equation:

$$\text{Combined Final Avg. M.C.} = \frac{(\text{M.C. dry pc.})(\%\ \text{dry pc.}) + (\text{M.C. redried Pc.})(\%\ \text{redry})}{100}$$

The final shipping moisture contents calculated from the above equation are shown in column H. Using these shipping moisture contents and assuming that we normally ship at 15% M.C., the underweight savings shown in column I have been calculated comparing the weight of the new shipping moisture contents with the base case at 15% M.C. A shipping rate of \$1.81/cwt (West Coast to Chicago) was used. The calculation takes into account changes in density both due to weight changes and shrinkage. At moisture contents below the normal 15%, we would be reducing the total cost of drying. Above 15%, we would be adding to

FIGURE 3

MOISTURE CONTENT OF THE DRY FRACTION OF A MOISTURE DISTRIBUTION AS A FUNCTION OF THE AVERAGE MOISTURE CONTENT FOR DOUGLAS-FIR DIMENSION

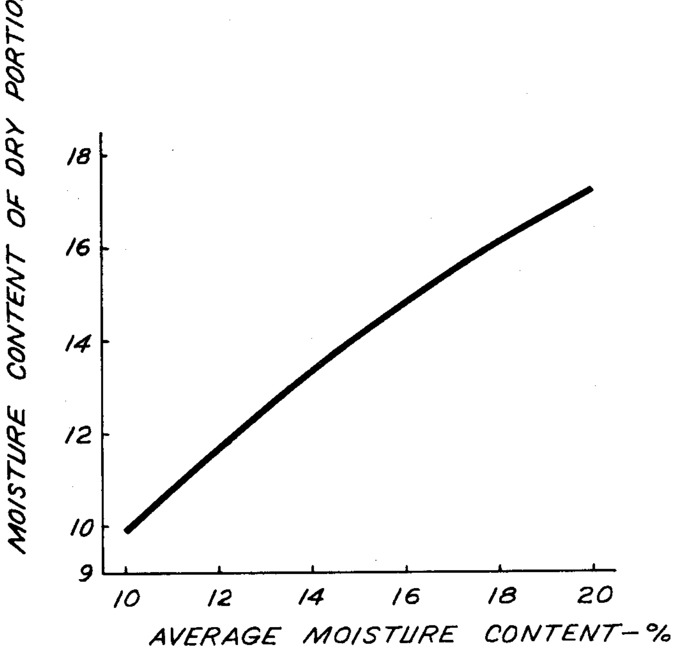
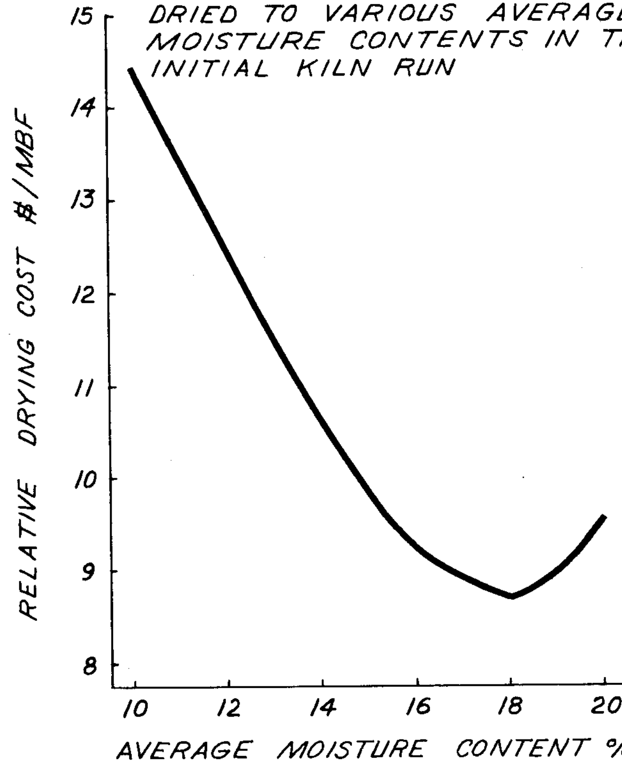


FIGURE 4

RELATIVE TOTAL DRYING COSTS FOR DOUGLAS-FIR DIMENSION DRIED TO VARIOUS AVERAGE MOISTURE CONTENTS IN THE INITIAL KILN RUN



the total cost. Though shipping underweights can contribute as much as \$0.50/MBF, they do not in any way change the ranking of the total costs.

The total relative drying cost is shown in column J. It is obtained by adding columns D, E, F, G, and I. The term "relative" is used because we have arbitrarily set the point of zero degrade at our highest moisture content level. We could just as easily have set our point of zero degrade at any other level and while the total relative drying costs would have been different in amount, the ranking of the totals in going from 10 to 20% M.C. in column A would have remained the same. The data from column J is shown graphically in Figure 4.

We now see clearly that in this example the minimum cost occurs at an initial dry moisture content of about 18% and a redry level in the neighborhood of 30%. If this level is only approached part way, there is still money to be made.

Beyond what has been demonstrated, there are still additional advantages for drying to higher final average moisture contents. Experience has shown that planer output can be increased at higher moisture levels. There is less likelihood of bad pieces breaking up in the planer causing slowdowns and good straight stock runs faster. Compare planing green lumber with planing dry. Higher moisture contents also mean that less shrinkage will take place. This in turn could reduce the original lumber target size requirements resulting in higher yields.

Another advantage inherent in accepting higher levels of redry is the opportunity to reduce total kiln residence time. This concept has already been used in a production situation to increase kiln output. That situation was reported by William Berry to this same group at its 1969 Annual Meeting.* A similar result can be demonstrated with the present example. Table 2 shows the drying time necessary to achieve the different initial average moisture contents and an estimate of the amount of time that would be required to redry the wet material generated at each moisture content. It is based on a conventional schedule. A total kiln time per thousand board feet is determined by adding the initial drying time and the percent of redry times the redry time. All of the numbers are shown to the nearest whole hour and include loading and unloading allowances. The minimum total drying time per thousand board feet is achieved at an initial dry average moisture content of between 17 and 18% and with a redry level between 20 and 30%. The reduced time means either we can operate at a higher production per kiln or, with new facilities, we can get by with fewer or smaller kilns and thus lower capital costs. The additional benefit derived from shorter total time has not really been figured into our total cost picture. It should emphasize further the benefits of higher redry levels.

In conclusion, it would be fair to say that there are some very real opportunities representing some large dollar returns to be achieved in accepting higher percentages of redry. Each particular situation would have to be examined to determine its optimum moisture content and level of redry. To take advantage of the potential, demands that we do some rethinking about our process. As already stated, most mills are presently ill equipped to handle redry. The segregation, handling, and actual redrying of redry needs to be studied in greater depth.

*William S. Berry, "An example of Operations Research in Dry Kilns", Proceedings Western Dry Kiln Clubs, 20th Annual Meeting, May 15-16, 1969. pp. 18-21.

The concept requires accurate kiln control, suggesting in-kiln moisture metering, particularly on accelerated schedules, and automatic metering and rejecting at the unstacker. The hardware for a total system is presently available but has not been put together as a system.

Table 1. Summary of Relative Drying Costs of Douglas Fir Dimension Dried to Various Average Moisture Contents.

A	B	C	D	E	F	G	H	I	J
Average Initial MC - %	M.C. Dry Portion %	Redry %	Direct Drying Cost $/MBF	Degrade Dry Portion $/MBF	Redry Cost $/MBF	Redry Degrade $/MBF	Combined Final Avg. MC - %	Underwt. Value $/MBF	Total Rel. Dry Cost $/MBF
10	9.9	1.0	5.95	9.03	.06	.02	10.0	-.58	14.48
11	10.8	1.7	5.90	7.86	.09	.03	10.9	-.48	13.40
12	11.7	2.8	5.85	6.68	.15	.04	11.8	-.37	12.35
13	12.5	4.5	5.80	5.61	.25	.07	12.6	-.29	11.44
14	13.3	6.9	5.75	4.54	.38	.10	13.5	-.18	10.59
15	14.1	10.4	5.70	3.47	.57	.16	14.3	-.09	9.81
16	14.8	15.3	5.65	2.54	.84	.23	14.9	-.02	9.24
17	15.4	21.8	5.60	1.76	1.20	.33	15.5	.05	8.94
18	16.1	30.6	5.55	0.95	1.68	.46	15.9	.10	8.74
19	16.7	42.1	5.50	0.36	2.32	.63	16.4	.15	8.96
20	17.2	57.0	5.45	0	3.14	.86	16.5	.17	9.62

Table 2. Summary of Drying Times for Douglas-Fir Dimension Dried to Various Average Moisture Contents.

Average MC - %	Kiln Time - hr.	Est. Redry Time - hr.	Redry Time Contribution hrs.	Total Kiln Time hrs/MBF
10	80	20	0.2	80
11	74	21	0.4	74
12	69	22	0.6	70
13	65	22	1.0	66
14	61	23	1.6	63
15	58	24	2.5	60
16	55	25	3.8	59
17	52	26	5.7	58
18	50	26	8.0	58
19	48	27	11.4	59
20	46	28	16.0	62