SOME EFFECTS OF KILN CONFIGURATION, DRYING SCHEDULES AND WOOD SPECIES ON MOISTURE CONTENT DISTRIBUTION

Kendall H. Bassett
Weyerhaeuser Company
Technical Center
Longview, Washington

Introduction

Moisture content distributions are regularly used to describe the results of drying studies and in drying quality control. Often the distributions are taken for granted with little consideration for all of the things that can influence them. This paper is a look at a few of those influencing variables. It is the outgrowth of an accumulation of data from many different tests run over several years. The data were selected to illustrate various points and were not necessarily gathered with this in mind. All of the data shown are from production kilns. Much of it was gathered under matched test conditions.

As a start let us look at how moisture content distributions are shown. Probably the most common moisture content distribution is the bar graph histogram, Figure 1-A. The number of pieces or percent of total number of pieces is shown by a bar at each moisture content. It is easy to construct because it comes right off the moisture content tally sheet. Often the tally sheet itself represents a histogram. The biggest drawback from this kind of display is the difficulty of showing more than one distribution at a time.

A second way to show moisture distribution is to connect points representing number of pieces at each moisture content. The same data displayed in this way are shown in Figure 1-B. This has the advantage of being able to superimpose two distributions without confusion. For the purposes of this paper I shall go one step further and fit a smooth curve to the data. This is shown in Figure 1-C. Data displayed in this way is much nicer to look at since it smooths out some of the bumps. There is some justification for smoothing out bumps which are often due to metering prejudices. For example, there seems to be a prejudice for recording even moisture contents in preference to odd. Also, just below the cutoff limit for a certain specification there is often a bulge as the person metering tries to crowd everything possible under the limit. Finally there are naturally bulges at the maximum and minimum meter limit.

Note that each figure displays the average moisture content, the standard deviation and the number of observations. This practice will be used throughout for a point of reference. The standard deviation is a useful statistic indicating the distribution of observations around the average. Recall that plus or minus one standard deviation from the average includes about two-thirds of the observations. Two standard deviations around the average includes 95% of the observations and three standard deviations includes 99%.

FIGURE 1A - BAR GRAPH HISTOGRAM OF MOISTURE CONTENT DISTRIBUTION

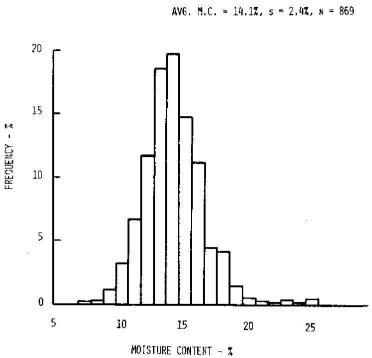


FIGURE 1B - CONNECTED POINT FREQUENCY DISTRIBUTION OF MOISTURE CONTENT

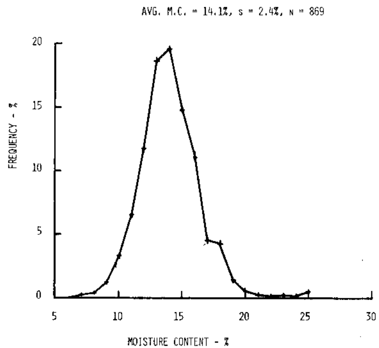


FIGURE 1C - SMOOTH CURVE FREQUENCY DISTRIBUTION OF MOISTURE CONTENT

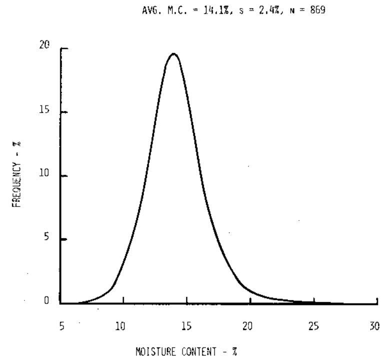


FIGURE 2 - MOISTURE CONTENT DISTRIBUTIONS OF DOUGLAS-FIR 2X8 DRIED TO THREE DIFFERENT MOISTURE CONTENTS

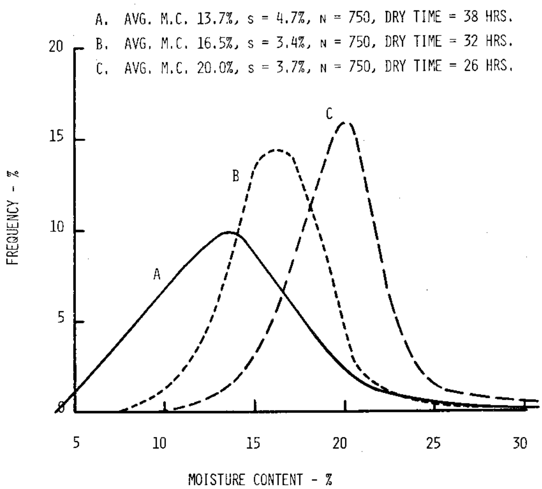
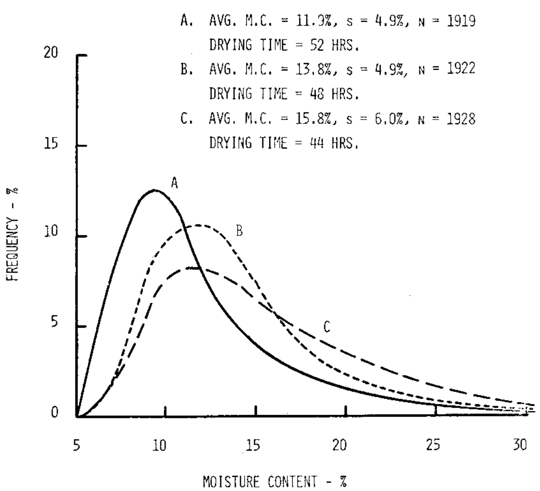


FIGURE 3 - MOISTURE CONTENT DISTRIBUTIONS OF HEMLOCK 2X4 DRIED TO THREE DIFFERENT MOISTURE CONTENTS



Species

Certainly, different species dry differently and end up with different moisture distributions. Many things influence this; variations in initial moisture content, variations in ability to give up moisture, the presence of different types of wood, for example, heart and sap, high density and low density, etc. Two examples will serve to show up some of the differences although a lot more could be said.

Figure 2 shows moisture distributions of Douglas-fir 2x8 dimension from old growth dried by an accelerated schedule. Matched stock was dried to three different final average moisture contents. The schedules differed only in their length of time. All three were run through the same kiln. It is characteristic of Douglas-fir that it goes from a tight distribution to a broader one as it gets dryer. It is also characteristically a quite symmetrical distribution.

Contrast the Douglas-fir to hemlock shown in Figure 3. These data are taken from hemlock small log 2x4's also dried by an accelerated schedule. Again the stock is matched and the different runs were dried in the same kiln for different lengths of time. Here the pattern is different. The moisture content is much broader and strongly skewed to the right. Quite characteristic of hemlock. These data also show lower moisture contents produce tighter moisture distributions. This is opposite to Douglas-fir. Other species undoubtedly have other patterns which need exploring.

Schedules

How lumber is dried can have a significant effect on what it will look like when it is finished. Figure 4 shows the results of two types of kiln schedules run on Douglas-fir 2x8 dimension. The first schedule is of a good conventional type without conditioning or equalizing. It was run in a good kiln. The second distribution is from a high temperature schedule run on matched stock for about half the length of time. It was run in the same kiln. Here we see that with the faster schedule there is a sacrifice in drying uniformity. The results here are of one test but have been amply verified by other testing. The length of the drying time does significantly affect the moisture distribution.

The above observations are valid because both schedules were run in the same equipment. A more typical comparison might be of an accelerated schedule run in a new, high temperature kiln compared to the old conventional schedule being used in older equipment.

Figure 5 shows such a comparison of matched 2x8 southern pine dimension. The conventional schedule was run in an old masonry kiln with poor circulation, poor heat and poor baffling. The high temperature schedule was run in a new kiln with better heat, circulation and baffling. Drying time was less than half as long for the high temperature schedule. In spite of the much faster drying time there has been no sacrifice in uniformity. The new equipment compensated for the inherent differences in schedule.

By definition equalizing is a part of a kiln schedule designed to "equalize" the moisture content. Dimension lumber schedules often do not include equalizing because of the extra time and costs required.

The costs are not recoverable in product value. Equalizing can, however, have a dramatic effect on the moisture content distribution.

FIGURE 4 - MOISTURE CONTENT DISTRIBUTIONS OF 2X8 DOUGLAS-FIR DRIED BY TWO TYPES OF KILN SCHEDULES IN THE SAME KILN

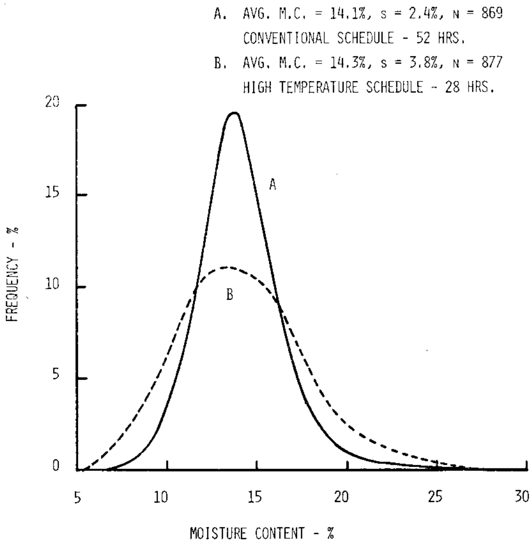


FIGURE 5 - MOISTURE CONTENT DISTRIBUTIONS OF 2X8 SOUTHERN PINE DRIED BY TWO TYPES OF KILN SCHEDULES IN DIFFERENT KILNS

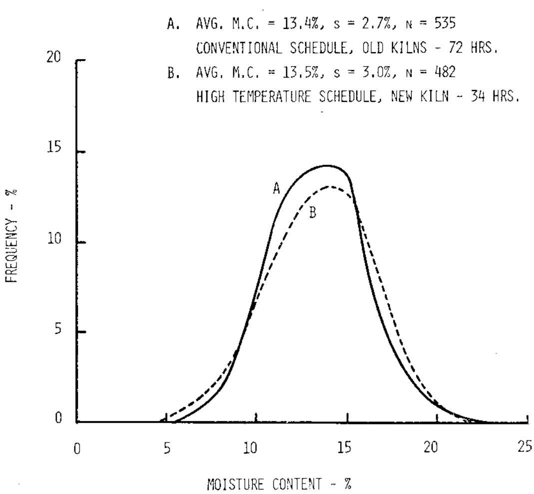


Figure 6, curve A represents distribution of 2x8 Douglas-fir dimension dried on a fairly slow CRT schedule without any conditioning. Looking back at Figure 2 we see that this is a fairly good distribution for the species and moisture content. Curve B shows a somewhat poorer distribution due to a faster schedule also without conditioning. Recall that at higher moisture content Douglas-fir has a tighter distribution and since B is higher average than A the difference in distribution would actually be more pronounced than is shown. Curve C was dried by exactly the same schedule as B but for 8 hours shorter time. It was then equalized at 11.5% EMC for 20 hours. A significantly tighter distribution is achieved. It is interesting to note that Schedule C and Schedule A are of equal total length. The combination of rapid drying followed by equalizing offers considerable potential for achieving tight moisture distributions in less total time than conventional schedules.

Equipment

We have already seen that good equipment does produce better moisture content uniformity. In part the differences in accelerated and slow schedules can also be attributed to equipment. Generally the accelerated schedules demand near maximum kiln output at all times. Any non-uniformities in heat distribution or air circulation will tend to be magnified by the accelerated schedule. By collecting the moisture content data by location in the kiln we can spot kiln problems.

Without extensive data the kiln operator knows that a really wet car can mean a steam leak or a fan out or a baffle missing, or some such malfunction. These things may be quite obvious. More detailed moisture content sampling of a kiln charge can show up problems that are not so obvious.

Figure 7 shows a reasonably good moisture content distribution for the particular kiln. The operator, however, noticed a consistent pattern of wet cars near the center of the kiln. Looking at these same data by kiln car we see the pattern shown in Figure 8. A repeated sampling of kiln cars showed this pattern to be consistent with each charge. A consistent pattern clearly indicates a kiln problem. If the problem could be corrected a better moisture content distribution should be achievable. The potential improvement is shown in Figure 9 where the four end cars and three center cars are separated into their component contributions to the total distribution. Either component is better than the combined. To determine the causes for the pattern of moisture content, additional data were gathered on the heating and air circulating systems. An analysis revealed that the problems were due to long runs of return bend heating pipe. The kiln is an older one recently converted to rapid CRT schedules without changes in the heating system. As originally used for long conventional schedules the heat demand was low enough so that the system was not being pushed. The new higher heat requirements are more demanding. The problem can be corrected by modification of the present heating system.

In another case there was a frequent problem of wet boards in the bottom courses of lumber in each kiln car. The consistent repeat of this pattern again suggested a kiln problem. To elaborate the magnitude of the problem each kiln car was sampled by course number at the time it was unstacked. The overall data for the entire kiln charge are shown in Figure 10. The distribution is not too bad. If the wet lumber were

FIGURE 6 - MOISTURE CONTENT DISTRIBUTIONS OF 2X8 DOUGLAS-FIR DRIED BY THREE TYPES OF KILN SCHEDULES IN THE SAME KILN

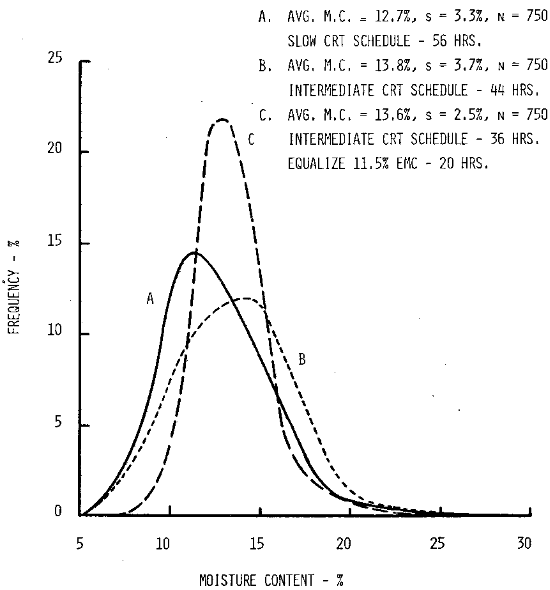


FIGURE 7 - MOISTURE CONTENT DISTRIBUTION OF 2X10 DOUGLAS-FIR DRIED BY AN ACCELERATED SCHEDULE - 54 HOURS

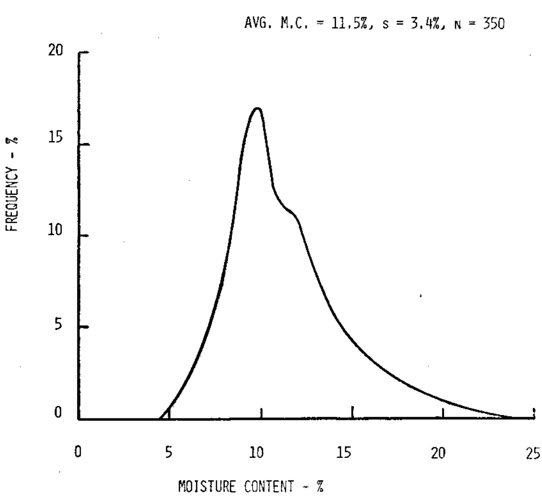


FIGURE 8 - AVERAGE MOISTURE CONTENT OF EACH KILN CAR IN A CHARGE OF 2X10 DOUGLAS-FIR

CAR 1 14' 9.7% M.C.
CAR 2 14' 11.6% M.C.
CAR 3 14' 12.9% M.C.
CAR 4 14' 15.2 % M.C.
CAR 5 12' 12.4% M.C.
CAR 6 12' 9.2% M.C.
CAR 7 12' 9.2% M.C.

FIGURE 9 - MOISTURE CONTENT DISTRIBUTION OF 2X10 DOUGLAS-FIR SHOWING DIFFERENCES DUE TO KILN CAR POSITION

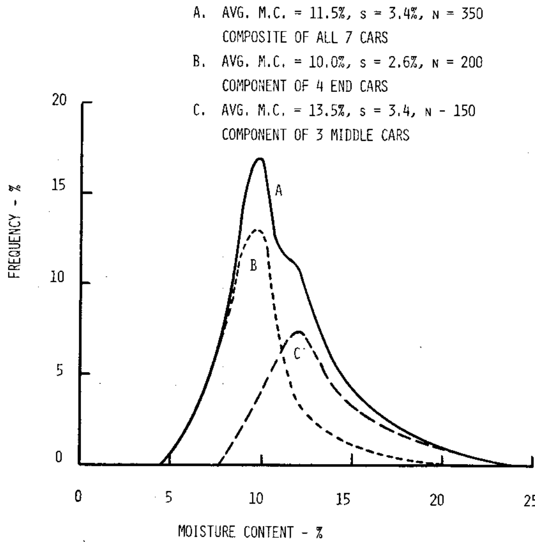


FIGURE 10 - MOISTURE CONTENT DISTRIBUTION OF 2X4 SOUTHERN PINE DRIED BY A CRT SCHEDULE - 28 HOURS

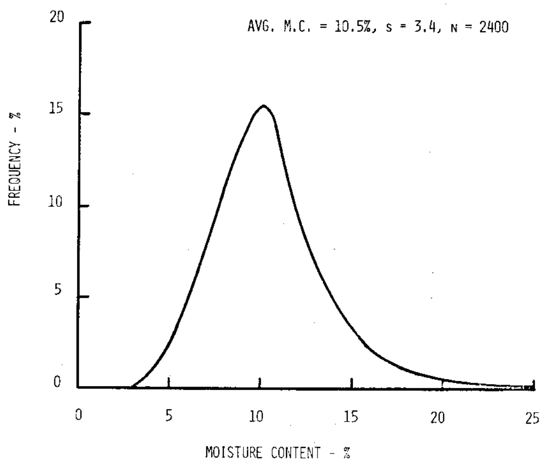


FIGURE 11 - AVERAGE MOISTURE CONTENT OF EACH TWO COURSES, TOP TO BOTTOM IN A KILN CHARGE OF 2x4 SOUTHERN PINE - 28 HOUR CRT SCHEDULE

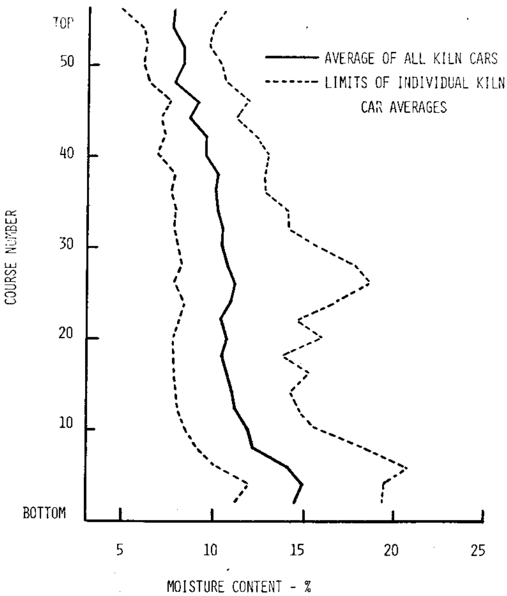
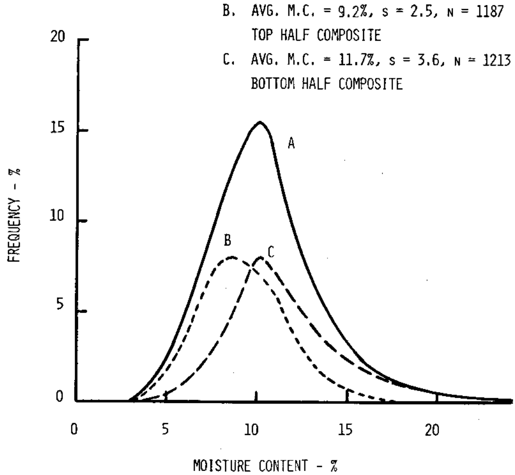


FIGURE 12 - MOISTURE CONTENT DISTRIBUTIONS OF 2X4 SOUTHERN PINE SHOWING DIFFERENCES DUE TO VERTICAL POSITION - 28 HOUR CRT SCHEDULE

A. AVG. M.C. =10.5%, s = 3.4, N = 2400
COMPOSITE OF ENTIRE KILN CHARGE

B. AVG. M.C. = 9.2%, s = 2.5, N = 1187
TOP HALF COMPOSITE

C. AVG. M.C. = 11.7%, s = 3.6, N = 1213
BOTTOM HALF COMPOSITE



scattered uniformly throughout an acceptable situation would exist. However, the concentration of wets at the bottom is not acceptable and more importantly suggests a kiln problem that should be subject to correction. In Figure 11 the same data are displayed by level in the kiln car. In this case each two courses from all kiln cars are averaged. Four boards were sampled per course. Now the distinct pattern of wet bottom layers can be seen. There is also more variation in the bottom layers. Note particularly the bulges at the bottom and in the middle shown by the dotted lines which represent the limits of individual kiln car averages. Figure 12 shows the top and bottom half distributions separately. The top half distribution would be particularly desirable.

This top to bottom uniformity problem is a vexing one which has not been completely solved. Some of the problem has been traced to the placement and baffling of the booster coils in this double track kiln. For example, the bulges in these data correspond to unbaffled gaps between booster coils. This and a number of other things have been corrected but the problem still persists to some extent. It is most certainly related to the booster coils and the heat distribution within these coils. A full solution remains to be found. The problem seems to be fairly widespread in high performance double track kilns. Perhaps we may be to the point of asking more from our kilns than present designs are capable of delivering. A fresh look at kiln design is suggested.

In summary, a number of things that affect moisture content distributions have been examined. They suggest that moisture content sampling and moisture content distributions are an important tool in examining the results of kiln drying and drying equipment. They must be used with an understanding of some of the basic factors that affect them. Differences in moisture content distributions must be viewed carefully to assure that the variable under study is the one causing the difference. By gathering moisture content data topically within a kiln much can be learned about kiln problems.