QUALITY CONTROL PROGRAMS FOR SOFTWOOD DIMENSION

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Softwood dimension drying is a fairly simple process: stack the lumber, put it on a cart, roll it into the kiln, close the door, turn on the fans, set the controls, and turn the air "on" to the instrument. In less than 24 hours for southern pine and less than three days for most other softwood species, the kiln is shut off and lumber pulled out. After cooling for three days, the lumber is unstacked, planed, graded, and trimmed. If we watch the grading operation, however, we fairly quickly see a fair number of warped pieces, pieces with end checks, and pieces that look "awfully dry."

Have you ever wondered "How bad is it? Is drying degrade really a problem in my operation? Is the competition doing better?" This article gives the details on two relatively simple QC programs designed by Virginia Tech for the softwood dimension industry. The purpose of these programs is to identify the magnitude of the problem (If it ain't broke, don't fix it!), to identify the likely cause and cure for the problem, and to permit an estimate of the cost benefit ratio of initiating any changes. After any changes are made, the new results can be measured to document the extent of the improvements, too.

There are three programs that Virginia Tech has developed. Anyone having further questions or needing assistance should feel free to contact the author.

QC PROGRAM #1

The first program involves measuring the final moisture content of a large number (perhaps as many as a thousand) of boards in a pack of lumber. This moisture content is measured with an electrical resistance, pin-type moisture meter. Readings are taken at least 2 feet from one end and are taken to the closest 1% MC. The lumber must not be hot. The needles should be driven to a depth of 1/5 of the thickness. (It has been shown that MC readings can be taken by driving the needles into the end grain of lumber that is still stacked. Although the ends may be several percent drier than the rest of the board, the MC trends can still be measured.) The location of each board (layers above the floor, distance from the edge, and location along the length is noted as well as the MC. If several packs are measured, the lumber size (2x4x16, 2x6x12, etc.) should be noted.

In order to provide as meaningful data as possible, the MC measurements should be taken as selectively as possible. For example, assume that a package of lumber is 24 2x4's wide, 22 layers high and is stacked in the kiln three packages high. There are 5 sets of packages on each track (each set being three high) for a total of 15 individual packages per track. In a two track kiln, there would be 30 packages of lumber. This is over 15,000

2x4's per kiln load! The measurement procedure suggested is that one set of three packages on one track is chosen for a thorough analysis. This means that every second board in a layer is measured for MC, but only every third layer is measured. This is 12 boards per layer and 7 layers per pack. With three packs, this means 252 measurements. Then in the rest of the kiln, sample every other board in one layer (in the center of the pack) in every pack.

After this data is collected, it then should be processed. Although a computer could do the job, it is just as easy to do it by hand. Because the data will show a lot of variation, it is necessary that we smooth out the variation by averaging.

First, calculate the individual average MC for each pack. This number will show if there are any large variations in kiln performance. An extreme case of variation is shown (Fig. 1) in a direct fired southern pine kiln in Virginia, where the heat on one side was defective (due to a broken vent in a hot air duct) making an obvious difference in MC from left to right, and also the plenum air space on the door side was too small (due to changing the package width from 6-feet to 7-feet after the kiln was constructed). Second, for the three special packs calculate the average MC for each layer. Make a graph of MC vs. location (height above the floor). Also calculate the average MC across the pack, averaging all the layers in a pack together. An example of this calculation is shown in Figures 2 and 3, again for a kiln in Virginia drying southern pine. Larry Culpepper of Kilnsight assisted in data collection. In this case, it is clear that there is a substantial gradient in MC from top to bottom, with the top being 4 percent drier. If we use some data from Weyerhaeuser that each percent MC that we over dry, we lose approximately $2.50/MBF, then all the top packs in the kiln (which is 1/3 of the kiln's production) will be worth $10/MBF less the lumber on the bottom. In this kiln the problem was in air flow distribution, being slightly higher near the roof than at the floor. Notice also the much lower MC at the 4x4.

The graph of MC across the width of the pile shows a typical gradient that is expected. The boards on the outside edge, because they have an edge exposed as well as both faces, will dry much faster and will therefore be at a lower MC than the rest of the load. Thicker stickers will reduce the internal gradient between the pieces, but won't affect the edge pieces.

The final graph to make is a histogram of all the MC values (Figure 4). This diagram will show the full range of final MC. Of course, there is nothing wrong, according to the grading rules, in having dry lumber, but this dry lumber requires energy to dry and is much more likely to have warp (especially crook). An indication of the amount of wet lumber is also given.

It is our aim in kiln drying (and the premise of this QC method), that much of the loss in quality in drying is due to overdrying much of the load. Of course we do this to avoid wet lumber that won't meet the grade. Research has shown, however, that a frequent cause of overdrying much of the load (or stated another way, a wide spread in final MC), is the variation in drying conditions brought out by the kiln equipment itself. This QC method is looking for those variations. Once found, adjustments in air velocity and heat (and occasionally humidity) can be made to produce more uniform drying.

QC PROGRAM #2

The second QC program is much more detailed than the first, but it also is much more powerful. Data collection and processing is more involved. This program collects information on various wood properties including sapwood percentage, amount of compression wood, thickness, grain pattern, pith location, and growth rate. These characteristics and properties are measured before the lumber is placed into the kiln. Also included is the location of each piece of lumber in the kiln.

After drying the moisture content of each test piece is measured with an electric resistance, pin-type moisture meter. Further, each piece is graded, "as is," and for those pieces that have drying degrade (such as splits or warp) that lowers their grade, the reason for the loss in grade and the potential grade are recorded. If the degraded piece can be upgraded by trimming, this is also noted. In summary, any piece that does not meet its potential grade (i.e., its green grade) is noted.

The data are then processed in a special manner called an analysis of variance. This requires a home computer such as an APPLE or IBM-PC or a larger unit. What this analysis does is relate the various properties or characteristics to those pieces of lumber that were degraded or required manufacturing. Important trends can be discerned.

The power of these measurements is best illustrated by example. Paul Bois of National Wood Drying Associates assisted in data collection. A summary of the results is given in Table 1. From these results, we can see that the percent of lumber in each grade is not dependent on variables such as thickness, or sapwood percentage (i.e., the percentage falldown is the same in both levels of the variable). On the other hand, there is a strong relationship between the loss of grade and compression wood, between loss of grade and final moisture content, and between loss of grade and grain pattern (Table 2). The relationship involving compression wood and final MC is not surprising. However, the relationship with grain pattern certainly has some implication to the headrig sawing process. Relationships between degrade and location in the kiln are also searched for.

In summary, this second program looks at the quality of drying. Where there is a loss of quality noted, various wood properties and drying characteristics are examined in order to find a relationship between the degrade and the property or characteristic. The likelihood of pieces with the property or characteristic having degrade is also given.

QC PROGRAM #3

How many times have you measured the moisture content (MC) of several pieces of lumber in a load to find out if the lumber's too wet, too dry, or just right? How many pieces should you measure? And when you measure several different MC's--for example, 17.1, 15.2, 15.0, 13.8, 13.7, 13.4, 13.4, 13.1, 13.0 and 10.9%--what do these values tell us about the average and the spread of the values for the rest of the pieces in the load? Can you estimate, based on the measurements above, how many pieces in the load are likely to be above 19% MC or how many are below 10% MC?

If you run kilns, you may wish to know if a particular pack is wetter than normal, meaning there are either problems with the kiln equipment or the load was pulled too early. You may wish to catch small errors or trends early before they become catastrophic. Or you may wish to optimize a kiln schedule.

The above questions can be answered and objectives can be met using a few carefully taken MC measurements and the computational techniques described below. Measurements for each pack in the kiln or just for each kiln load take only a few minutes, but the information that can be gained is tremendous. With increasing pressure from outside lumber suppliers, we have to be more quality conscious than ever. This QC technique will be a big help to monitoring and improving MC quality.

The QC technique uses four simple, calculations called statistical parameters. A detailed example of how these measurements are taken and how the results are interpreted will be given below; but first, how to calculate the statistical parameters will be discussed.

STATISTICAL PARAMETERS

From a given stack or load of lumber, 10 to 15 boards are sampled for MC. Generally, three to five MC measurements are taken on each board using an electrical resistance, pin-type moisture meter. (See the final section of this paper for additional measurement details.) This procedure results in 30 to 75 MC measurements per stack or load of lumber.

The first statistical parameter, the AVERAGE BOARD MOISTURE CONTENT (MC board), is the average MC for an individual board. With 10 boards, there would be 10 different values.

While the average moisture content tells us where the "middle" of the data are; we do not know anything about the "spread" of the data. For example, suppose we want a piece of lumber that has an 8% average moisture content. If the moisture content on one end is 14% and on the other end is 2%, the average board moisture content is 8 percent. However, the spread of the moisture content (2% to 14%) is well above typically acceptable limits. A way to measure the moisture content spread is by using a statistical parameter called the standard deviation.

In the measurement of the MC in a stack of lumber there are three standard deviations which are important. Each of these standard deviations are closely related. The first standard deviation, called the STANDARD DEVIATION WITHIN, measures the spread of the MC's within the individual boards.

The second standard deviation, called the VARIATION BETWEEN, measures the spread of MC's between the individual pieces in a sample; that is, the MC spread from piece to piece.

The third standard deviation, the TOTAL VARIATION, measures the total average spread of MC from all the readings.

INTERPRETING THE RESULTS

The limits of the statistical parameters for a typical softwood with a desired final moisture content of under 19 percent are shown in Table 3. The best way to use the calculated values of average MC and the three standard deviations is to compare the calculated values (See a sample calculation in Table 4) with the guideline values of Table 3.

When data are taken on a daily or periodic basis, graphs can be drawn for each value using the limits established by Table 3. Each sample represents a point on the graphs and gives an immediate pictorial indication of process performance.

If the overall AVERAGE MOISTURE CONTENT is out of range, the problem could be one of the following:

1) The kiln controls (wet- and dry-bulb temperatures) are not properly set.
2) The kiln circulation system is malfunctioning.
3) The moisture content values of the sample boards were not taken properly.

The standard DEVIATION WITHIN tells us how the moisture content within the group of boards chosen for a sample varies. A large value of the standard deviation within indicates one or several things may be wrong.

1) The values for the moisture content were not taken correctly.
2) The air velocity, temperature and/or relative humidity was not the same at both ends of the board during drying. Usually the air circulation around the board or boards was impaired on one end.
3) A large within standard deviation could also mean that one end of the board was much drier than the other before the kiln was started.
4) The baffles were not in place.
5) The stacking was not properly done. Make sure the stickers are parallel to each other and to the airflow and that the stickers are uniform in thickness.

A large value for the standard DEVIATION BETWEEN also indicates that something is wrong. Common causes of a large standard deviation between include:

1) The values for the moisture content were not taken correctly.
2) The air velocity, temperature or relative humidity conditions were not the same on both sides of the stack.
3) The lumber was not equalized for a long enough period.
4) The lumber was not properly stacked.
5) The fans were not reversed periodically.
6) The species are mixed.
7) Lumber thicknesses are mixed.

An out of range value for the TOTAL standard deviation is a global indicator of a kiln problem. Such a problem can include one or more items from the two lists above.

HOW TO SAMPLE THE STACK

The more accurately MC is measured, the more accurate and precise the conclusions will be.

If an electric resistance meter is used, try to read the meter to the closest 1/2% MC. With an electric meter, the needles are driven in 1/5 the thickness for rough lumber or 1/4 the thickness for planed lumber. The pins run along the length and are located mid-width on the lumber. Always apply the necessary species correction factors. Because the temperature corrections suggested for these meters have been shown to be questionable, only meter wood that is close to room temperature.

The most precise, although time consuming method to measure moisture content is the oven-drying method where a small section of wood is cut, weighed, dried, and reweighed. A microwave oven with a carousel and a low power setting can be used to obtain oven-dry MC in about 20 minutes or less. An oven at 215°F can be used, but oven-drying times may be as long as 24 hours.

The number of samples needed to estimate the average MC and the spread for a pack of lumber is, as a general rule, approximately 10. (More would be needed if there is an extreme variation of MC.) Avoid sampling from the top or bottom layers as frequently these layers are drier than the majority of the load. A randcm sample from within the pile is the best practice.

For each piece of lumber at least 2 and preferably 3 readings should be taken; one from each end (no closer than 2 feet from the end) and another near mid-length.

Table 1. Analysis of various factors related to fall down (FD) in grade after drying and planing

ITEM	Drop in Grade
Growth rate	
- Fast	61%
- Slow	35
Sapwood amount	
- None	40
- 80 - 100%	43
Grain	
- Flat	31
- Quarter	55
Pith	
- Not close	36
- Bulls-eye	55
Thickness	
- Fat	36
- Thin	24
Compression wood	
- None	37
- Light	50

Table 2. Relationship of final grade to defect, MC, and compression wood

Final Grade	Percent of Pieces With				
	Fall-Down Caused By		Final MC of		No Compression Wood
	Bow & Crook	Twist	5-14%	15-18%	
1	6	0	57	23	61
2	71	21	65	21	55
3	63	27	72	15	47
4	66	11	76	11	39

Table 3. Limits for the average moisture content, variation within and between, and total variation for softwood lumber

Quantity	Acceptable Range (%)
Average moisture content	16-18
Variation within	0-0.80
Variation between	0-1.50
Total variation	0-1.60

Table 4. The typical results from the computer analysis of MC indicating the average MC and the ranges. Data: 16.0, 16.2/ 16.4, 16.6/ 16.6, 16.6/ 16.6, 16.8/ 16.9, 16.6/ 17.0, 17.0/ 17.0, 17.1/ 17.3, 17.5/ 17.5, 17.5/ 17.5, 17.8/ 18.0, 17.8

The results with 11 boards and 2 measurements per board are:

Average MC = 17.0%	Acceptable range = 16.0 to 18.0% MC
Variation within = 0.13	Acceptable range = 0 to 0.8
Variation between = 0.54	Acceptable range = 0 to 1.5
Total variation = 0.56	Acceptable range = 0 to 1.6

The 100% range is 15.3 to 18.7% MC.
The 95% range is 15.9 to 18.1% MC.
The 90% range is 16.1 to 17.9% MC.

The approximate number of readings over 19% MC is 0%
The approximate number of readings over 15% MC is 100%
The approximate number of readings over 10% MC is 100%
The approximate number of readings over 8% MC is 100%

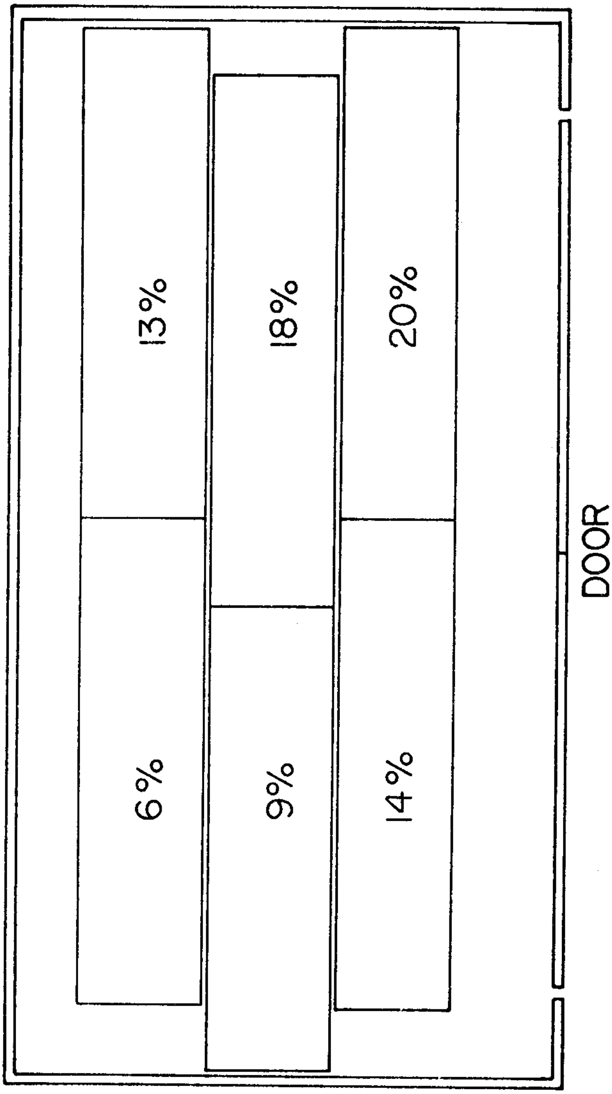

Figure 1. Distribution of final MC within a kiln with poor heat distribution and poor circulation (top view).

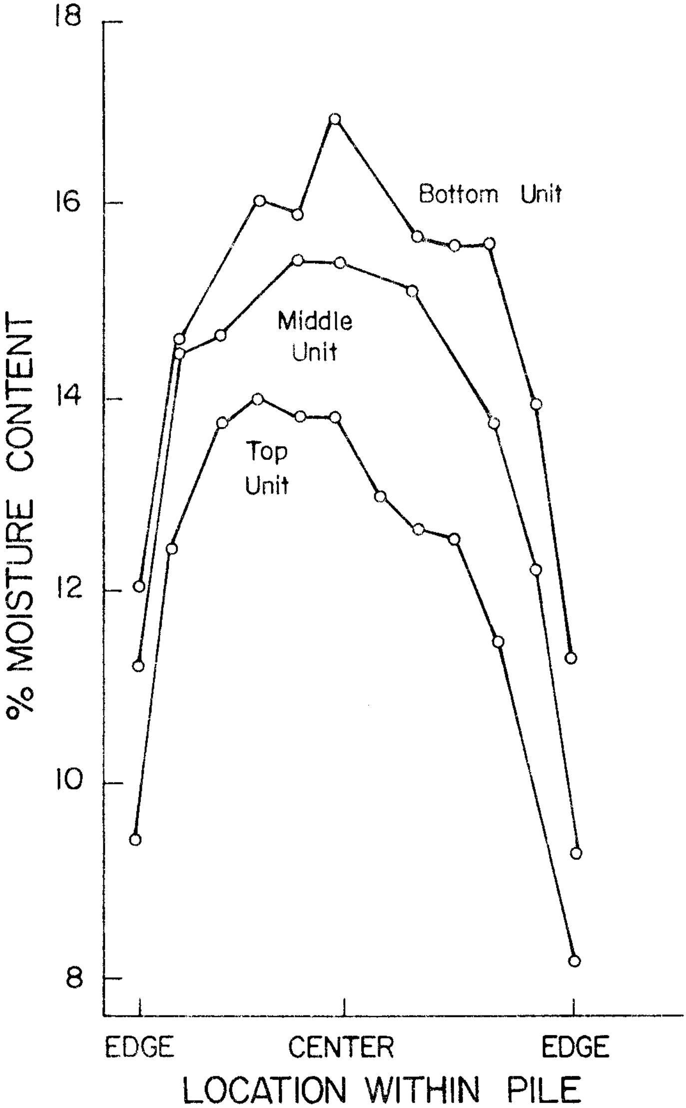

Figure 2. Distribution of final MC within a pile of lumber, for three different heights within the kiln.

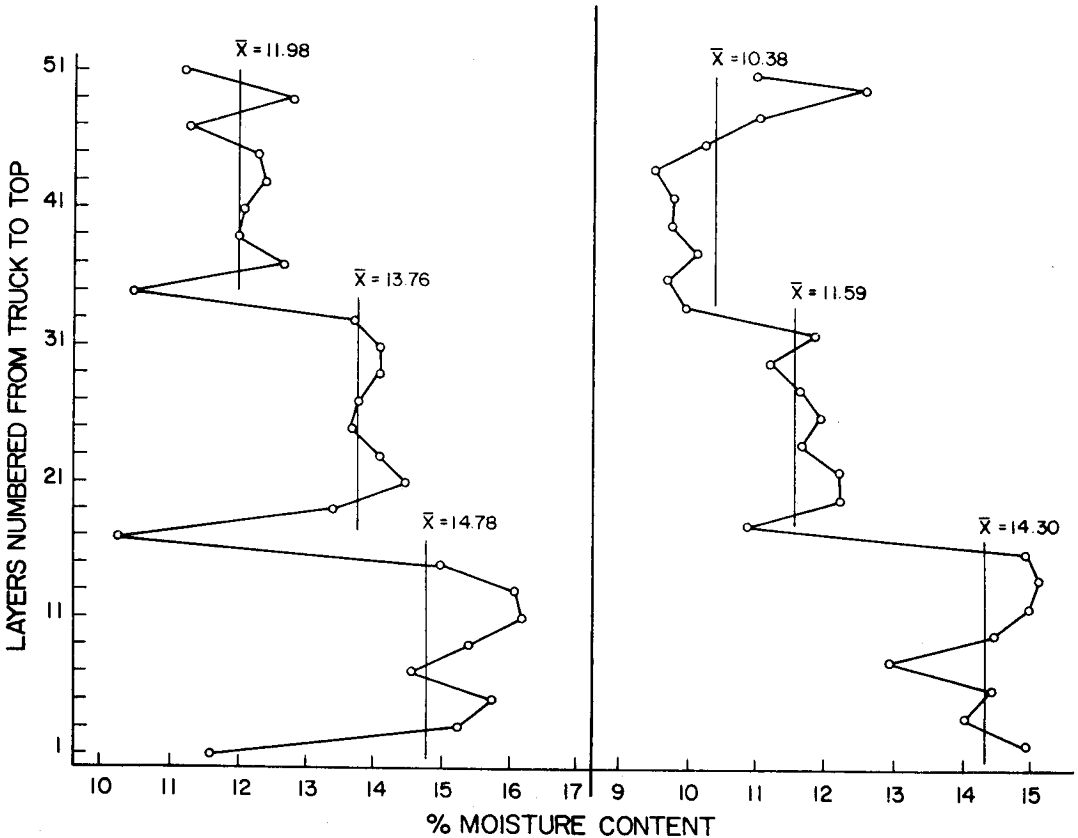

Figure 3. Distribution of final MC as a function of height within the kiln. The 4 x 4 bolsters were located at levels 17 and 35.

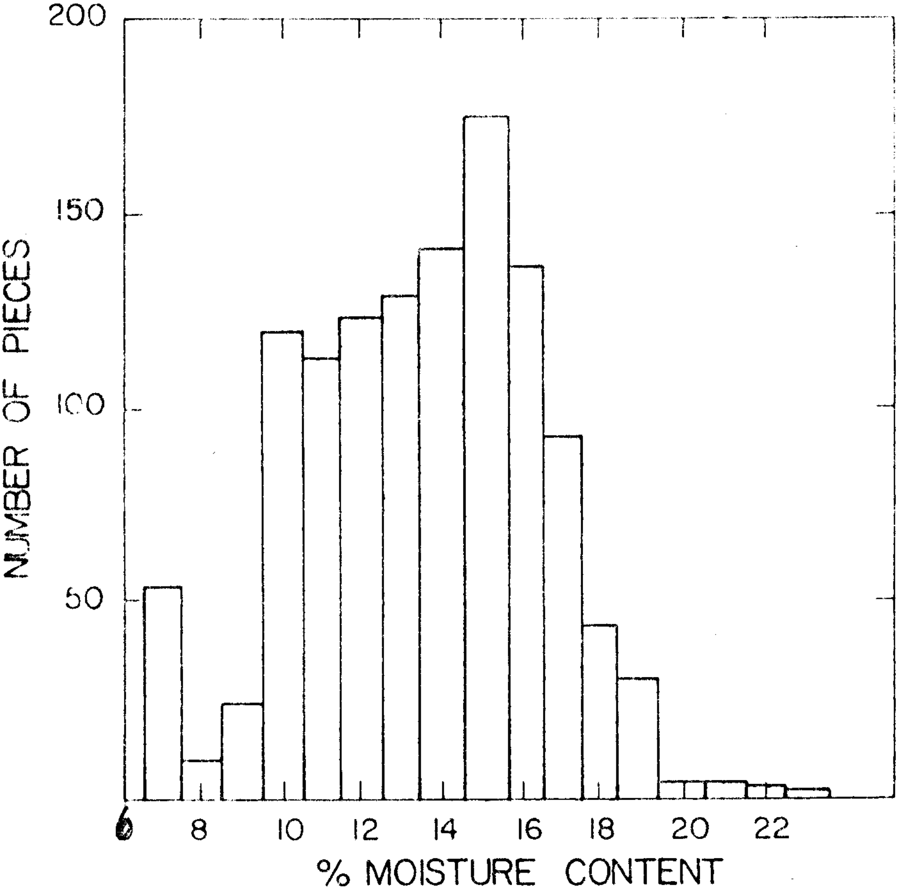

Figure 4. Distribution of final MC for an entire kiln load.