

STICKER THICKNESS AND AIR VELOCITY

Kendall H. Bassett
Technical Center
Weyerhaeuser Company
Longview, Washington

In the kiln drying of lumber we depend on the circulation of air. Air transfers heat to the lumber and in turn removes water. The circulation in a kiln depends on the fan system and the paths available for air to pass through or around the loads of lumber. We often take the whole system for granted without considering in detail the factors that affect it. I would like to describe two experiments where we examined the air circulation through various size openings in the stacked load of lumber. These experiments were primarily concerned with different sticker thicknesses; however, the effect of somewhat larger openings was also determined.

The first experiment was originally undertaken to get data for design of a kiln using higher than normal air velocities. We needed to know the static pressure drops that would occur across loads of lumber stacked with various thickness stickers for a range of air velocities. This required a facility where sticker thickness and air velocity could readily be varied and static pressure and velocity easily measured. Our laboratory kiln was the answer. This facility takes a full 8 foot wide load, 8 feet long and approximately 3 feet high. Velocity can be varied over a wide range by means of a variable speed fan and a damper system.

The initial test was set up using 2 x 4's stacked with stickers of 1/2, 9/16, 5/8 and 3/4 inch thicknesses. Half the load included surfaced lumber with a single slot of each thickness and half used rough lumber with a slot of each thickness. Velocity readings were made on the leaving air side of each slot at various fan settings. Readings were taken with a hot wire velometer. A static pressure head was mounted in each plenum and the two heads connected across a magnehelic gauge to measure the static pressure drop across the load. Data were collected over a range of velocities from less than 200 fpm to over 1000 fpm.

After the first test we decided that sticker thicknesses varied over too limited a range and it would be interesting to find out the effects of larger openings. Thus the entire procedure was repeated with the addition of openings of 3/8" and 1 1/2" in thickness. In this case, only rough 2 x 4's were used for the test. A third test was finally made with the addition of a 3" opening.

Data from the three tests all follow the same pattern; however, the static pressure differences are not the same in each test for a given velocity and slot thickness. The complete cause of the static pressure variations was not determined. At the end of the final test the static pressure head in one of the plenums was moved about in the plenum. Static pressure differences between it and the fixed head in the opposite plenum varied from 0.13 to 0.19 inches. This variation could account for the test differences. Certainly the test data are of the correct order of magnitude. It is plain that if we are to get true static pressure drops the measuring techniques must be improved.

Because the pattern of readings from all three tests is similar I will use only the most comprehensive data from the third test. This is shown graphically in Figure 1. Each line in the figure represents readings taken at one fan setting. The static pressure differences are shown for reference. However, since the static pressure measurements are in doubt the figure might best be viewed as a family of curves associated with different velocity levels without regard to static pressure differences.

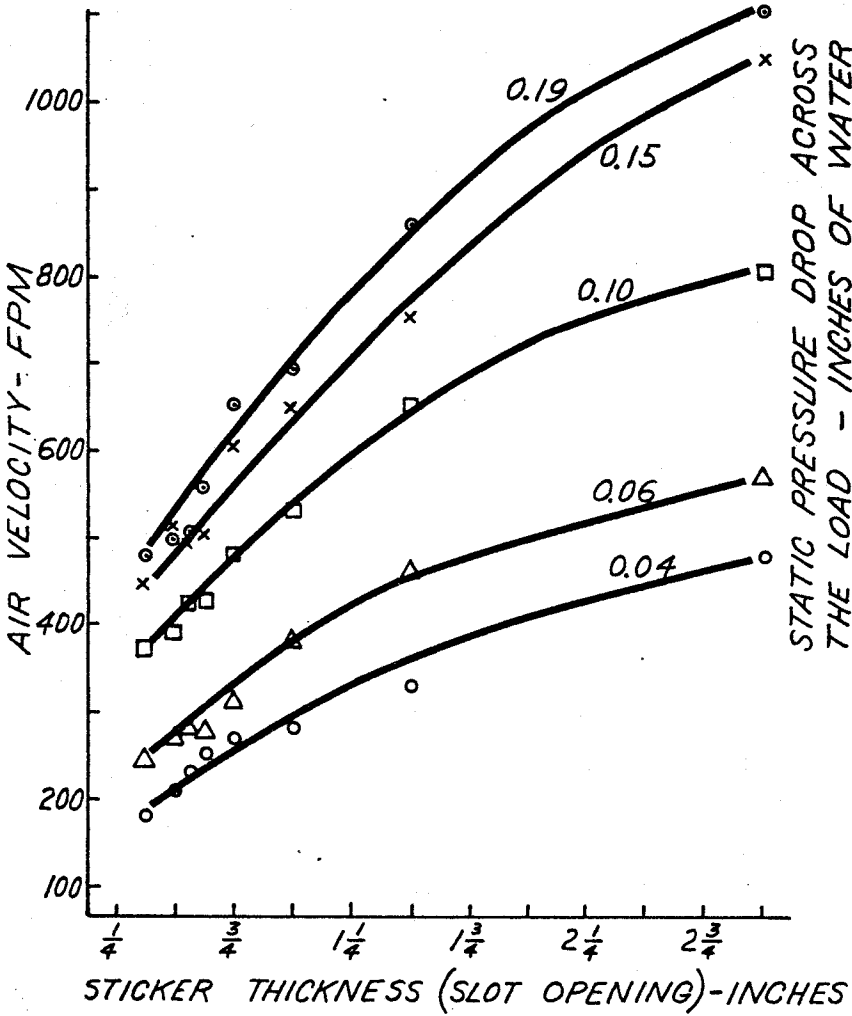
The only specific comment to be made about the first test concerns the results comparing smooth (planed) versus rough lumber. At the lower velocities there was no difference between the two. With increasing velocities above 200 fpm there was an increasingly greater flow through the planed load. At 1000 fpm the difference was about 15%. In other words, at 1000 fpm air velocity through the rough lumber, the velocity through the planed lumber was 1150 fpm.

Now let us look at Figure 1 and see what we may learn. Suppose we have a load of lumber stacked with $1/2''$ sticks where we normally read an air velocity of 400 fpm. This very nearly corresponds to a point on the $0.10''$ static pressure drop curve. In the same load we have $3''$ bunks between top and bottom units. Following up the $0.10''$ curve we see that through a $3''$ opening velocity would be 800 fpm, twice the velocity through the $1/2''$ slots. The situation is, however, worse than that. The $3''$ openings is 6 times as large as the $1/2''$ opening so that we are losing not twice as much air but rather 12 times as much (twice the velocity and six times the thickness). This points up the extreme importance of good baffling. Air preferentially flows through large openings. All the air that is going through a large opening such as between loads or around the end or over the top is lost to effective drying.

Unfortunately from these data it is not possible to predict exactly what would happen if we were to change sticker thickness in an entire kiln charge. Suppose as in the first example we are using $1/2''$ sticks and getting a 400 fpm velocity and want to find out what would happen if we changed the entire kiln to $3/4''$ sticks. The curve says we would expect about a 475 fpm velocity through that size opening if the static pressure stayed constant. However, if we were to change the entire kiln load to thicker sticks we would have less resistance to flow and the static pressure difference would be less. Thus instead of 475 fpm we would expect something less. If we were to go the other way from $1/2$ to $3/8''$ stickers the curve says we might expect about a 370 fpm velocity. If the entire charge were changed we would up the resistance to flow causing a slightly higher static difference across the load. From this we would expect a velocity somewhat higher than the 370 fpm. The next experiment shows more closely what might actually happen in changing the sticker in a production kiln situation.

In this second experiment the specific objective was to determine the effects on drying of going to a thinner sticker thickness. The mill now uses a $9/16''$ thick wood sticker and wished to evaluate a $3/8''$ composition sticker. To do this a kiln charge was prepared where half the loads were stacked with $9/16''$ sticks and the other half with $3/8''$. For the test new wood stickers of each thickness were used. At this particular mill the production kilns are single track 104' which allowed 3 - 16' length loads of each type. 2 x 6 Douglas-fir was stacked by units, two units high and two units wide. The charge was very well stacked and the kiln well baffled. Before drying commenced a traverse of air velocity was made on the

FIGURE 1 - AIR VELOCITIES THROUGH AN 8 FOOT WIDE LOAD OF LUMBER STACKED WITH VARIOUS THICKNESS STICKERS



leaving air side at the center of each car. The charge was then dried following normal procedures. The time was a little bit long so that the entire charge ended up too dry. After drying and cooling the charge was unstacked. At unstacking the moisture content of each piece was metered.

A summary of the results of this test is shown in Table 1. It is quite apparent that there is a very real difference in the air velocity through the 3/8" and 9/16" slots. The difference in air velocity results in about a 2% moisture content difference for the comparable drying time. If the quantity of air through each slot is calculated it is found that there is about 80% more air passing through the 9/16" slots. With this difference in volume it is surprising that the moisture content difference is not greater than it is.

Both air velocity and moisture content measurements taken on the 3/8" stickered loads show higher standard deviations than those taken on the 9/16" stickered loads. The standard deviation is a statistical measure of the variation around the average which means that there was greater variation around the averages in the case of the 3/8" sticks. This can be shown very well graphically. Figure 2A shows the frequency distribution of air velocities. Note that the horizontal scale is reversed so that increasing velocity is from right to left rather than left to right. This is done so that the clear relationship of the distribution of air velocities and moisture contents can be seen. The moisture content distribution is shown in Figure 2B. The comparison of Figures 2A and B shows clearly the similarities. A wide variation in the air velocity produces a wide variation in moisture content and conversely a tight distribution in air velocities produces a tight distribution in moisture content. Other experience with Douglas-fir shows that the moisture content distribution becomes broader the lower the average moisture content. This means that if the 3/8" and 9/16" sticker loads were both compared at the same moisture content the difference in uniformity would probably be even greater than seen in this experiment.

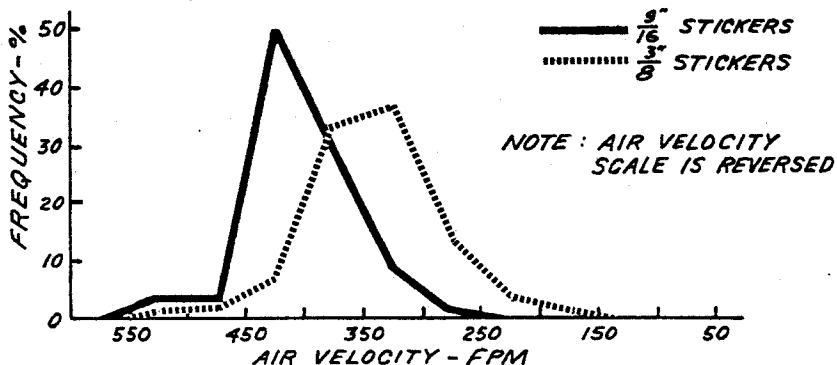
One of the oft proffered arguments for reducing sticker thickness is to increase kiln capacity. In this case there was a volume increase of 12% with the 3/8" stickers. This was, however, exactly offset by the estimated increase in time that would be required to dry to the same moisture content. The net result is no increase in overall kiln capacity. Because of the larger unit volumes there should be a slight advantage in handling costs associated with the thinner sticks.

The net effect on drying of reducing the sticker thickness from 9/16" to 3/8" appears to be poorer uniformity. It could be argued that by changing the entire kiln charge to 3/8" stickers the static pressure would increase and there would be a slightly higher velocity resulting in improved times. It also could be argued that the thin composition stickers might stay straighter than the normal wood sticks and thus improve air flow. On the other hand, it is probable that on a regular production basis the stacking would be less even than the test and larger gaps would result. The 3/8" sticks would be more sensitive to these variations. From a performance point of view the 3/8" stickers look like a large risk.

In summary, what these two experiments show us is the great sensitivity of air flow in a kiln to the size of openings within and between loads of lumber. Extraneous openings should be eliminated to obtain the maximum drying potential. Changes in sticker thickness should be approached with caution. They could result in unexpected and unacceptable changes in the moisture content distribution.

FIGURE 2 - AIR VELOCITY AND MOISTURE CONTENT DISTRIBUTION OF LOADS OF 2x6 DOUGLAS-FIR STACKED WITH $\frac{9}{16}$ AND $\frac{3}{8}$ INCH STICKERS

A. AIR VELOCITY DISTRIBUTION



B. MOISTURE CONTENT DISTRIBUTION

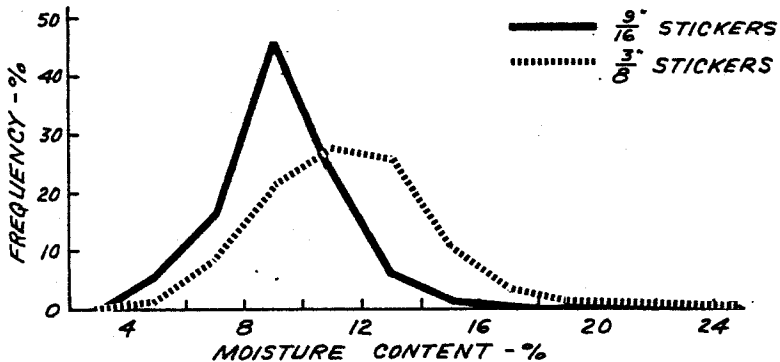


Table 1. Comparison of the Results of Loads of 16' 2 x 6 Douglas-fir Dried Using 9/16" and 3/8" Stickers.

| Property | Sticker Thickness | |
|--|-------------------|-------------|
| | 9/16" | 3/8" |
| Average air velocity-fpm | 400 | 340 |
| Standard deviation of air velocity-fpm | 43 | 57 |
| Average moisture content-% | 8.8 | 10.9 |
| Standard deviation of moisture content-% | 2.1 | 2.9 |
| Change in kiln capacity-% | --- | +12 |
| Change in drying time-% | --- | Approx. +12 |